PRFLEX: PERFECTING THE RECYCLING SYSTEM FOR FLEXIBLE PLASTIC PACKAGING IN CANADA

PART 1 - DIAGNOSTICS

FINAL REPORT – DECEMBER 2023

NovAxia inc.

In collaboration with Lichens Recyclability, Crow’s Nest Environmental, JTL Squared Consulting & Policy Integrity

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The completion of this study and the publication of this report are the results of the collaboration, expertise, know-how, and field experience of experts from NovAxia Inc., Lichens Recyclability, Crow's Nest Environmental, JTL Squared Consulting, and Policy Integrity.

Our thanks go out to the members of the consortium, including the Canada Plastic Pact (CPP), Circular Material, Circular Plastic Taskforce (CPT), Éco Entreprises Québec (ÉEQ), the Chemistry Industry Association of Canada (CIAC), The Recycling Partnership, and Recycle BC.

A White Paper highlighting the key findings and recommendations of this study is also available here.

Sara-Emmanuelle Dubois
NovAxia Inc.
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All financial data presented in this report is expressed in Canadian dollars, except when indicated otherwise.

Glossary of Terms

AEPW	Alliance To End Plastic Waste
AI	Artificial intelligence
C&D	Construction and demolition
CIAC	Chemistry Industry Association of Canada
CM	Circular Materials
CPG	Consumer packaged goods
CPP	Canada Plastics Pact
ÉEQ	Éco Entreprises Québec
EPR	Extended Producer Responsibility
FPP	Flexible plastic packaging
GDR	Golden Design Rules for Plastics Packaging
ICI	Industrial, commercial and institutional
LDPE	Low-density polypropylene
LLDPE	Linear low-density polyethylene
MRF	Material recovery facility
NIR	Near infrared (spectroscopy)
PCR	Post-consumer resin
PE	Polyethylene
PET	Polyethylene Terephthalate
PP	Polypropylene
PRF	Plastic recycling facility
PRO	Producer responsibility organization
PVC	Polyvinyl chloride
RFEP	Reclaimer front-end process
rPE	Recycled PE
t	Tonne
TPY	Tonnes per year
WPC	Wood plastic composite

Key definitions

Aeraulic segregation: The process of separating material through an up-draft of air. Light pieces are removed with the up draft whereas heavier pieces fall with gravity.

Plastic Recycling Facility (PRF): "An industrial facility that accepts mixed plastic items from MRFs or generators, then conducts separation and contamination removal to create saleable grades of discrete plastic resins. A PRF might also conduct preliminary recycling operations such as size reduction to make plastic flake"[1].

Reclaimer: A commercial entity that accepts aggregated postconsumer and/or post-industrial plastic materials and performs a series of operations to allow them to return to commerce as useful raw materials or new finished items of commerce.[2]

Reclaimer front-end process (RFEP): Industrial process consisting of separating mixed post-consumer materials, according to the specifications required for the subsequent recycling stages, leading to the production of recyclates. This process is generally carried out by the reclaimer.

[1] The Association of Plastic Recyclers (2023), *Plastics Recycling Glossary*. Available at: https://plasticsrecycling.org/images/library/Plastics-Recycling-Glossary.pdf
[2] Idem

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1. Background

The PRFLEX project was launched in 2023 as a collaboration between the Canada Plastics Pact (CPP), Circular Materials, the Circular Plastics Taskforce (CPT), Éco Entreprises Québec (ÉEQ), the Chemistry Industry Association of Canada (CIAC), The Recycling Partnership, and Recycle BC. Its primary objective is to establish an effective, efficient collection and recycling system for all residential sector flexible plastics and films across Canada. Its two sub-objectives are to:

- determine effective sorting methods in Material Recovery Facilities (MRFs) and recycling facilities in the context of accepting all flexible plastic packaging (FPP) in curbside collection; and
- understand the ideal methods for separating the flow of flexible plastic packaging according to the needs of end markets and to enable greater amounts of recycled content from flexible plastic packaging in new packaging and other products.

Today, flexible plastic packaging is one of the most prevalent forms of packaging used for consumer goods due to its versatile applications across primary packaging (e.g., chip bag or standup pouch), secondary packaging (e.g., produce bag), transportation packaging (e.g., shipping bags for e-commerce or pallet wrap), and much more. As explained in the CPP *Pathways to Mono-Material Flexible Plastic Packaging* Guidance document, FPP is a preferred option for many reasons, such as its lightweight nature, high product-to-packaging ratio, ability to transport a substantial amount more of empty flexible packaging than what is possible with rigid packaging, and its resistance to shock[3].

While there is potential for FPP to be collected and recycled into new products or packaging, currently it is mostly disposed of at end-of-use due to several factors, including:

- Despite access rates for FPP varying from 13% to 32% overall in Canada[4], the inclusion of FPP in municipal collection programs can be limited to some materials or depot collection, which affects the opportunity for recovery.
- MRFs are not equipped to effectively separate FPP. This is unlikely to change in the near future as investments tend to be concentrated on the production of rigid plastic bales that are of higher financial value.
- The diversity in the FPP resin composition of multi-material FPP complicates the ability to separate the materials in MRFs and recycling facilities.
- The interest of recycling markets for sources of FPP of higher mono-polyethylene (PE) purity, mainly from institutional, commercial, or industrial (ICI) collection.

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[3] Canadian Plastics Pact (2023). Pathways to Mono-Material Plastic Packaging, Guidance Document – Version 1. Available at: https://plasticspact.ca/wp-content/uploads/2023/04/CPP_Pathways-to-Mono-Material-Flexible-Plastic-Packaging_-Guidance-Doc.pdf

[4] Circular Materials (2021). Access Report Study. Cited in Canada Plastics Pact "Advancing Circular Economy for FPP in Canada – 5-year roadmap. Available at: https://plasticspact.ca/wp-content/uploads/2023/09/Roadmap-Advancing-a-Circular-Economy-for-Flexible-Plastic-Packaging.pdf

These challenges highlight the need for measures to be implemented to improve recovery and recycling rates, such as the establishment of regulations for extended producer responsibility (EPR) with high-target goals (e.g., a recycling rate of 40% in Québec by 2027 or 25% in Ontario by 2026), and the development of new sorting techniques and technologies (e.g., artificial intelligence or AI, digital watermarking, etc.).

The recovery and recycling of FPP remains a challenge for the recycling industry, despite progressive annual growth of this packaging format. The challenge becomes more complex because there's a rise in FPP replacing other inflexible plastic or paper packaging, along with the introduction of new innovations and products. In short, the collection and processing infrastructure has not kept up with the pace of FPP packaging placed in the market.

2. Scope of the Study and Methodology

2.1. Contextualization of the project

The primary objective of the PRFLEX study is to assess the current recycling system to identify opportunities and barriers to improving the residential collection of FPP in Canada, enabling its effective recycling, and ultimately, increasing the integration of more recycled content in its manufacturing.

To this end, NovAxia was tasked with:

- Determining the percentage of FPP currently being collected and recycled, by format and resin types across Canadian provinces;
- Identifying the processing infrastructure gaps and needs, according to the collection method;
- Defining effective capture methods in MRFs, without impacting bale quality for other materials, including investigating new and innovative technologies for improved quality sortation, as well as identifying the optimal place in the value chain for these various technologies;
- Defining the effective sorting and cleaning methods and equipment at reclaimers, considering the various existing processes;
- Identifying the current and future needs of end markets (i.e., reclaimers) to enable effective separation of FPP.

This report provides analysis, as well as recommendations on possible next steps to improve current FPP recovery and recycling efforts across Canada, aiming to consolidate and validate the assumptions made and to promote the implementation of an optimized, efficient system that enables the achievement of FPP recycling targets.

2.2. Methodology

This project was carried out in three parts.

Part 1: Data collection

To determine Canada's current FPP flow, the project team updated the information provided in CPP's Foundational Research Study[5]. The updated data sources include new waste characterization results (e.g., Québec and Ontario province-wide characterization studies, and new characterization studies undertaken by municipal governments in British Columbia, Alberta, Saskatchewan, and Newfoundland and Labrador), as well as updated data provided by PROs on the amount of FPP collected by regulated provincial packaging recycling systems and sorted at MRFs[6].

[5] CPP (2021). Foundational Research and Study: Canadian Plastic Packaging Flows. Available at: https://plasticspact.ca/wp-content/uploads/2021/10/CPP-Foundational-Research-on-Canadian-Plastics-Packaging-Flows-May-2021-final.pdf
[6] Detailed approach is available in Appendix A

As in the baseline study, a recycling yield of between 50% and 75% was applied to estimated recycled quantities since there have been no major infrastructure changes that would justify adjustments. It should be noted that for some provinces, no new datapoints could be used, which limited the analysis of the evolution of FPP flow between 2019 and 2021.

The performance of FPP collection and separation by format and resin type is not possible with the above information since data sources and waste characterization usually don't provide that granularity of information for FPP. An evaluation of that granularity level was possible based on detailed multiple season characterization studies carried out on approximately thirty samples of garbage and recycling streams from curbside collection in Québec and Ontario[7][8].

It should be mentioned that the limited number of samples bring high variabilities in the results. Moreover, it remains impossible to identify composition of multi-material packaging and the different barriers used (e.g., aluminum, PVDC, and EVOH).

To overcome the above-mentioned limitations, other data sources (i.e., European data), were used to estimate this detailed composition.

Part 2: Optimization of capture rates

The tasks include for this phase included:

1. Determining:
    - the collection rate of FPP for each province and territory and estimate the increase in future collected rates; and
    - the recovery rate of FPP in MRFs.
2. Evaluating the potential impact of adding FPP as an accepted material stream on the quality of other bales generated at different types of MRFs.
3. Identifying the relevant equipment that would be needed to optimize the capture rate of FPP at different types of MRFs.
4. Providing recommendations on the next steps to improve the separation and capture of FPP at MRFs, including equipment to be tested and the pilot projects that would be needed to evaluate the related implementation costs.

Part 3: FPP Separation

The tasks include for this phase included:

1. Undertaking a preliminarily evaluation of the design of a FPP separation system and identifying its optimal positioning in the value chain, based on different input material composition scenarios and output material specifications, which includes attribute separation technologies, including digital watermarking and AI;

[7] Appendix A provides the methodology used by the audit firm.
[8] Characterization data from British-Columbia will also be presented in the final version of this report.

2. Identifying the specifications of current and potential end markets, in collaboration with the project partner's mechanical and chemical reclaimers for FPP;
3. Adapting the results of Step #1 and identifying the relevant equipment for separation of FPP and effective recycling for each partner reclaimer in the project; and
4. Recommending next steps, including the equipment to be tested, and evaluating the implementation costs.

3. Data Collection

3.1. FPP in the residential sector

3.1.1. FPP physical material flow

As shown in Table 1, it was estimated that 310,000 tonnes per year (TPY) of FPP are generated in Canada from the residential sector based on various characterization studies. The quantity collected and recycled (i.e., sent to end-market, taking reclaimer yield into account) in Canada remains low: only 34% of the FPP collected is sorted and sent to an end market, with only 4% of all FPP generated being recycled.

Table 1 Estimate of FPP generated, collected, sorted, and recycled in Canada

Residential FPP	Average	Confidence interval	Data reliability
Generated Average	310,714 TPY	270,000-349,000 TPY	Low-Medium[1]
Collected Average	52,186 TPY	46,000-59,000 TPY	Medium[2]
Sorted Average	18,038 TPY		Medium-High[3]
Recycled Average	11,244 TPY	9,000-13,000 TPY	Medium-High[3]
Sortation performance (vs. collected)	34%	31-39%	
Recycling performance (vs. generated)	4%	3-4%	
[1] Based on waste composition audits performed in the different provinces of Canada. Data should be taken with caution, as values obtained could be overestimated due to methodology (number of samples, potential integration of small ICI, and moisture level). See Appendix A for data limitations.			
[2] Based on waste characterization data and PROs annual report (where available)			
[3] Based on service providers data			

Compared to 2019, there appears to be little difference in quantities across Canada, given that the variation (-6%) might be comprised within a margin of error (Table 2). However, this also reflects the limited availability of uniform data. Results by province vary widely and for that reason this comparison should therefore be treated with caution. In some provinces, the low number of datapoints limit the analysis, and the confidence interval is high. In Québec, detailed characterization results offer insights: a significant reduction in carry-out bags (-88% generated) and other PE bags (-56% generated), but an increase in other bags, notably multi-materials (+18% generated)[9]. It is known that there is a significant 4.8% growth of FPP being generated globally, according to various market studies[10].

Thus, the decrease in flexible plastic packaging could be the result of the early implementation of regulations by the Government of Canada and local municipal on single-use plastic checkout bags. There could also be a movement to shift from unrecyclable flexible packaging to other types of packaging, including rigid packaging.

[9] Comparing characterization results from 2015-2017 and 2022

[10] Markets and Markets (2023). Flexible Packaging Market by Packaging Type, End-User Industry, Material and Region – Global Forecast to 2027 Link

Table 2 Change in average quantities generated quantities from 2019 to 2021, by province

Provinces	Variance 2019-2021 %
British Columbia	-22%
Alberta	+13%
Saskatchewan	+10%
Manitoba	-7%
Ontario	-14%
Québec	-12%
Atlantic Provinces	+17%
Total	**-6%**

Table 3 Change in average quantities collected between 2019 and 2021, by province

Provinces	2019 Collected Avg	2021 Collected Avg	Variance %
British Columbia	4,316	5,064	+15%
Alberta	7,192	7,228	+0.5%
Saskatchewan	837	580	-44%
Manitoba	1,066	1,094	+3%
Ontario	15,826	16,629	+5%
Québec	14,855	17,985	+17%
Atlantic Provinces	4,295	3,031	-40%
Total	**48,387**	**52,186**	**+7%**

British Columbia and Québec significantly increased the amount collected, while the Atlantic provinces and Manitoba saw a significant decrease. This can be explained by:

- The Recycle BC FPP collection program in British Columbia.
- An updated province-wide characterization study in Québec, noting that the previous study was undertaken in 2015-2017.
- New and robust data acquired from studies conducted for New Brunswick, which was completed to support its transition to EPR.

In terms of material sent to end-market, information gathered from several MRFs shows a 22% raise in quantity between 2019 (14,064 t) and 2021 (18,038 t); although, it varies widely from one province to another (
Table 4). Interviews with key operators revealed FPP bales today, when sent for recycling, are mainly shipped to overseas markets. However, most of the FPP generated today goes to landfill.

Table 4 Change in average quantities sorted between 2019 and 2021, by province

Provinces	Variance %
British Columbia	+75%
Alberta	-83%
Saskatchewan	N.A.
Manitoba	N.A.
Ontario	+9%
Québec	+78%
Atlantic Provinces	--93%
Total	**+22%**

3.2. Waste composition results

This section presents the results of waste characterization conducted on the garbage and recycling streams. This provides a more precise identification of FPP composition in terms of resins, format, and print coverage.

3.2.1. FPP resin composition

Thirty-one 5 kilograms samples[11] of flexible plastic disposed or placed in the blue bins from Ontario and Québec were sorted in ten different categories, based on the resin identification code and the audit firm. The aim of the characterization was to delve into a more detailed understanding of the composition, moving beyond a standard composition study. Because a significant quantity of uncoded plastic was present in the samples, a sub-sampling was performed using a resin identification device (Figure 1), supplemented by the audit firm's specialized knowledge.

Figure 1 - Resin identification device from ThermoScientific

Table 5 presents the results of the resin characterization for the garbage and recycling streams. The average composition of the recycling stream would theoretically represent actual inbound for MRFs (from the residential sector), while the average composition of the garbage stream represents the potential for improved collection.

Note: Results show considerable or broad variability in the 31 samples audited (i.e., showing heterogeneity between each other), because of the limited samples taken compared to the exhaustive category list. The results should be interpreted and used with caution.

[11] Samples were collected mainly in urban and peri-urban areas.

Table 5 Average proportion of each resin for FPP in the garbage and recycling streams

Categories	Avg % of FPP in garbage stream	Avg % of FPP in recycling stream
< 5 cm	0.2%	0.9%
MonoPE	38.1%	50.1%
MonoPP	1.9%	5.5%
MonoPVC	0.2%	0.3%
MonoPET	0.1%	0.3%
Degradable resins	0.8%	1.0%
Other FPP (multi-materials & unidentifiable flexible materials)	31.8%	26.5%
Non-PPP flexible (e.g., garbage bags)	27.0%	15.3%
Total	**100.0%**	**100.0%**

In both streams, “monoPE” and “Other FPP” comprise the majority of FPP generated in the residential sector. However, there is significant variability in FPP resin composition. While the monoPE proportion seems to be similar to other jurisdictions (between 40% and 50% of FPP generated), the proportion of monoPP differs. According to CEFLEX (a collaboration of over 180 European companies, associations and organizations representing the entire value chain of flexible packaging), 21% of all FPP supplied in the European market are PP,[12] compared to less than 5% in the above calculation. In France, CITEO estimates that 16% of supplied FPP are monoPP.[13] Industry knowledge also indicates growth of FPP made in monoPET (e.g., deli meat wraps), which was not observed in this characterization.

While the characterization of some product categories (e.g., pasta bags) was clear, it was more difficult to characterize others (e.g., candy wrappers, chip bags), which sometimes were identified as monoPP and other times as multi-materials. Further analysis should be performed to better define the exact composition of FPP supply on the market.

Figure 2 – Example of chip bags identification with a resin identification device

[12] CEFLEX. 2019. CEFLEX Scope bases on EU Market. Available at: https://ceflex.eu/flexible-packaging-in-europe/
[13] Discussion with CITEO, May 4th, 2023

Despite the above limitations, the characterization results and the tendency observed in the industry allows the project team to estimate that:

- Proportions of monoPE and monoPP are likely to grow in the future, due to the gradual implementation of the Golden Design Rules for Plastics Packaging (GDRs) or similar design guidelines.
- FPP in multi-materials will likely remain in the market in the coming years, especially for product requiring a high barrier, as outlined by CPP in the Guidance document "Pathways to mono-material FPP"[14]. The proportion of the total FPP supplied will likely decrease in time with the implementation of the GDRs.

Moreover, it should be noted that other mono-material FPP (e.g. PET) are emerging and could become more prevalent in the market in the coming years.

3.2.2. FPP size composition

Size is an important criterion for sortation, especially when designing sorting systems (e.g., to avoid overlapping of materials that reduces the performance of optical sorters). The project characterization included a size analysis of the products in three categories:

- <5 cm (2 inches)
- <A4/Letter Format
- >A4/Letter Format

Table 6 presents the results of the size characterization. In terms of size, less than 1% of FPP were <5 cm (2 in.), while the remaining is equally divided between under and over A4/Letter format size, as outlined in Table 6.

Table 6 Format composition of FPP

Format	Garbage Stream	Recycling Stream
<A4 Format	53%	45%
>A4 Format	47%	55%

3.2.3. FPP print coverage compostition

Print coverage is an important consideration for reclaimers (as end-markets make a distinction between clear and coloured product) and sorting technologies that may use the ink for watermarking products (e.g., optical sorter with a watermark detection module). Table 7 provides the results of the print coverage characterization.

Table 7 FPP print coverage composition.

Print coverage	Garbage stream	Recycling stream
0% (clear films)	34%	41%
Between 0% and 50%	14%	23%

[14] Available at : https://plasticspact.ca/wp-content/uploads/2023/04/CPP_Pathways-to-Mono-Material-Flexible-Plastic-Packaging_-Guidance-Doc.pdf

>50%	52%	36%

Overall, 60% or more of all FPP supplied in the residential sector are printed, with the majority of that having over 50% print coverage. The market offers a wide array of inks and colors, making it logistically and economically unfeasible to perform color separation of FPP in MRFs. The reasons behind this will be detailed in Section 5. However, if clear films were primarily made from one resin (i.e., PE), a sortation between clear and coloured film could be possible in a specialized facility.

3.3. FPP in the ICI sector

Interviews carried out with certain major ICI haulers indicate that collection dedicated solely to FPP is not widespread at present. The majority of FPP is collected in mixed mode (e.g., sandwich bales or mixed bales, mixed collection), which requires sorting into MRFs.

There is limited published characterization data available from the ICI sector. Moreover, characterization processes are not standardized, therefore comparisons between studies might be difficult. The data might also be biased by the fact that generators carrying out characterizations are generally those concerned with improving their performance. Finally, there are significant factors including size, legal status (e.g., not-for-profit, corporation), and access to municipal collection programs that affect characterization.

The project team used the results from the CPP BC ICI PPP Waste Flows Study[15] (hereafter, the BC Study) and reached out to several generators and FPP manufacturers to gain a better understanding of the exact composition of FPP generated and collected in the ICI sector.

3.3.1. Overall results

The BC Study analyzed 350 industry waste audits undertaken across Canada and compared the results to local government waste audits and information from BC waste service providers. The study found that three main sub-sectors contribute to 82% of all Packaging and Paper Products (PPP) disposed (Table 8).

Table 8 Main sub-sectors contribution to PPP disposal

Sub-sector	PPP Disposed (kg/FTE/year)	Sector contribution to PPP disposed in BC
Trade	339	40%
Manufacturing	194	9.2%
Food services	606	32%
Total for the 3 subsectors	**1139**	**82%**

[15] CPP. 2023. BC ICI PPP Waste Flows Study. Available at: https://plasticspact.ca/wp-content/uploads/2023/04/CPP_BC-ICI-Baseline-Report.pdf

The detailed results present high confidence intervals by category, thereby limiting the interpretation of results. Note that film represents the most prominent type of plastic packaging disposed of in trade and food services. Figures 3 to 5 illustrate some specific results available in the BC Study.

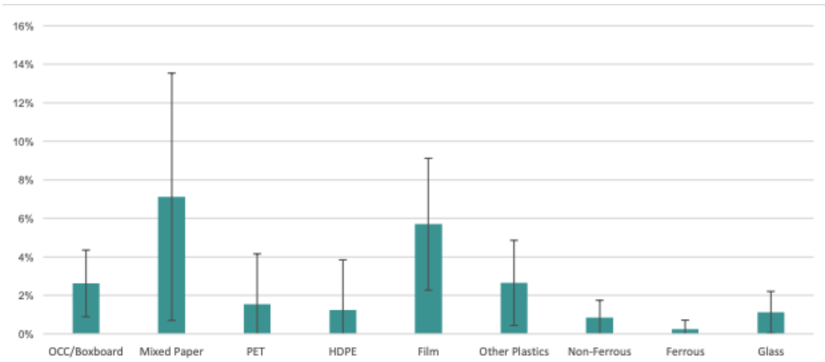


Figure 3 – Proportion of PPP in trade disposal stream[16]

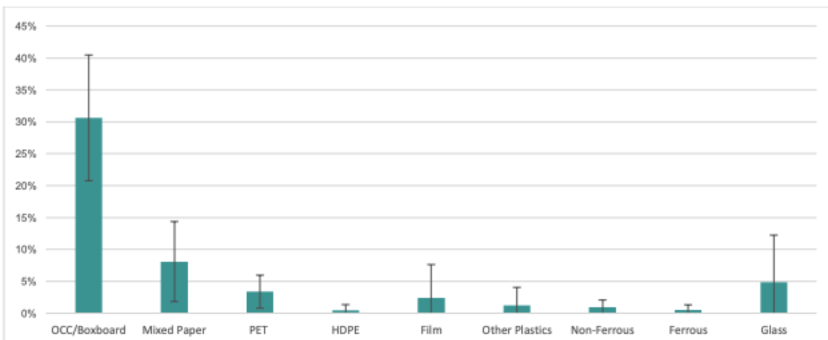


Figure 4 - Proportion of PPP in manufacturing disposal stream[17]

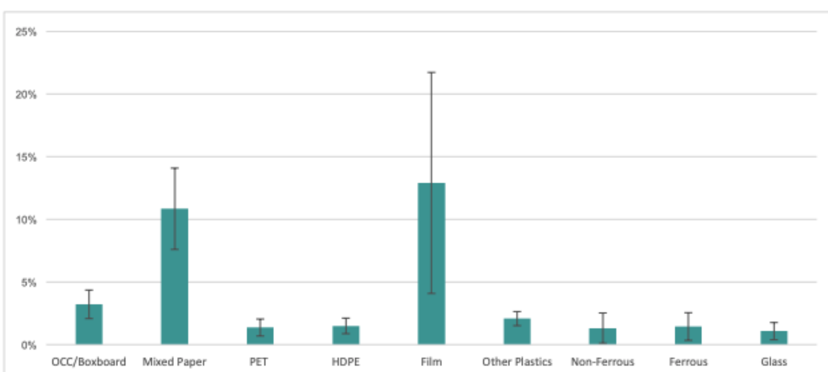


Figure 5 - Proportion of PPP in food services disposal stream[18]

[16] Figure from "BC ICI PPP Waste Flow Study", page 56. Available at: https://plasticspact.ca/wp-content/uploads/2023/04/CPP_BC-ICI-Baseline-Report.pdf
[17] Figure from "BC ICI PPP Waste Flow Study", page 68. Available at: https://plasticspact.ca/wp-content/uploads/2023/04/CPP_BC-ICI-Baseline-Report.pdf
[18] Figure from "BC ICI PPP Waste Flow Study", page 74. Available at: https://plasticspact.ca/wp-content/uploads/2023/04/CPP_BC-ICI-Baseline-Report.pdf

A similar study undertaken in Yukon revealed that the construction sector is another important contributor to generated FPP, representing 28% of all PPP disposed.[19]

It should be noted that extrapolating tonnage from BC and Yukon to the rest of Canada is out of scope for this project.

3.3.2. Sector specific results

3.3.2.1. Trade and manufacturing

Both the trade (e.g., retail, grocery stores and malls) and manufacturing sectors use a significant quantity of pallet wrap. According to data provided by two of the three main pallet wrap manufacturers in Canada, it is estimated that 88,000 tonnes of pallet wrap (LLDPE) are supplied to the Canadian market each year. However, because of international trade, it is reasonable to assume part of this tonnage is exported with the goods. Conversely, pallet wrap also enters the country through imported products. As a result, the exact proportion that is generated for management in Canada is difficult to measure, but the estimated 88,000 tonnes of pallet wraps appear to be a reasonable baseline.

Based on industry knowledge, one pallet wrap manufacturer estimates the recycling rate at 25%. Though confirming this performance is challenging, dedicated collection routes for this material exist within municipal programs (usually for small ICI and mixed with commingled materials from the residential sector) - separate from ICI establishments (mixed material collection at businesses, usually with OCC) - or through reverse logistic collection (usually through packaging distributors like Carrousel).

Apart from pallet wrap, other FPP is also generated, but are more specific to the activities within the two sectors.

- In the retail sector, shrink film (LDPE) used as secondary packaging and discarded at retailer locations, along with bladders used for fountain drinks, stand out as main contributors to FPP generation (Figure 6).
- In manufacturing, bladders (either mono-material and multi-layer), plastic liners (LDPE), and super sacks (PP) are also frequently used:
    - Bladders are primarily found in the manufacturing sector. Volume and composition vary from one facility to another.
    - Super sacks are made of PP. However, as reported by a study commissioned by Cleanfarms,[20] stitches, tie ropes and cord block are

Figure 6 - Secondary packaging shrink film (source: Pro Pac)

[19] Yukon Government. 2023. Yukon ICI PPP Waste Flow Study. Available at: https://yukon.ca/sites/yukon.ca/files/env/env-yukon-ici-ppp-report.pdf

[20] Kelleher Environmental. 2021. Bulk Bag Phase 1 Research. Non-public

usually made of nylon, polyester and sometimes HDPE. The study estimates that 16,000 TPY are used in Canada, of which 15%-20% is from the agricultural sector.

More discrete estimations of FPP generation and collection will require a dedicated study.

3.3.2.2. Food services

Data regarding the quantity of FPP generated in food services remains scarce. According to a waste audit company, during audits within the food industry, certain FPP items—either soiled or marked as non-recyclable—are occasionally categorized as residue within different sorting categories.

One key packaging distributor highlighted that with the shift from plastic to paper bags, a higher proportion of FPP within the food service industry is compostЕd of multi-materials, including lidding films, bulk goods, etc.

3.3.2.3. Construction

Most construction materials are shipped in FPP, which, according to some manufacturers, is usually PE resin. Figure 7 presents examples of FPP used in the construction industry.

Figure 7 Example of FPP used in the construction sector (source: Valipac)

One manufacturer estimates the construction market to be between 5,000 and 15,000 tonnes per year (TPY) in Canada. This number could not be verified with other sources.

Currently, construction FPP has minimal collection for recycling programs. Some FPP might end up in Construction and Demolition (C&D) MRFs, but sorting film is not a top priority in most of these facilities. Moreover, when blended with other products (on a construction site or in an MRF), FPP is often too contaminated for reclaimers. A major construction material retailer confirmed there is no recovery program of this material as of now because it is usually coloured and not accepted by its recycling service provider.

In Europe, the dedicated Producer Responsibility Organization (PRO) for industrial, commercial, and institutional (ICI) packaging, Valipac, has developed a specific program for FPP generated on construction sites. Specific bags can be purchased by contractors and Valipac takes charge of the collection and recycling. No performance data is available.

3.3.3. Other sector of interest

3.3.3.1. Agricultural

While the agricultural sector was out of scope for this study, it still generates a significant quantity of FPP, particularly with pallet wrap (Section 2.2.1. would include pallet wrap in the agricultural sector).

According to Cleanfarms, 1,300 TPY of agricultural LDPE packaging and 2,000 TPY of woven PP packaging are being generated in Canada.[21]

Agricultural plastic is also an important potential end-market for flexible PCR. For instance, the agricultural sector uses 30,000 TPY of LDPE for different products (e.g., silage wrap).

3.3.3.2. Health Care

The health care sector is not an important contributor of generated FPP, but the type of packaging is very specific as it includes a notable proportion of PVC, a resin that should not be mixed with others from a recycling perspective. Oxygen tubes and intravenous fluid bags are examples of PVC flexible plastic packaging. PVC FPP can represent 15% of all plastic generated in that sector, as outlined in the figure below[22].

[21] Cleanfarms. 2021. Agricultural Plastic Characterization and Management on Canadian Farms. Available at: https://cleanfarms.ca/wp-content/uploads/2021/08/Project-Building-a-Canada-Wide-Zero-Plastic-Waste-Strategy-for-Agriculture.pdf

[22] Santé Synergie Environnement. 2016. Récupération des plastiques hospitaliers. Available at: https://gmr.synergiesanteenvironnement.org/projets-pilotes/ (in French)

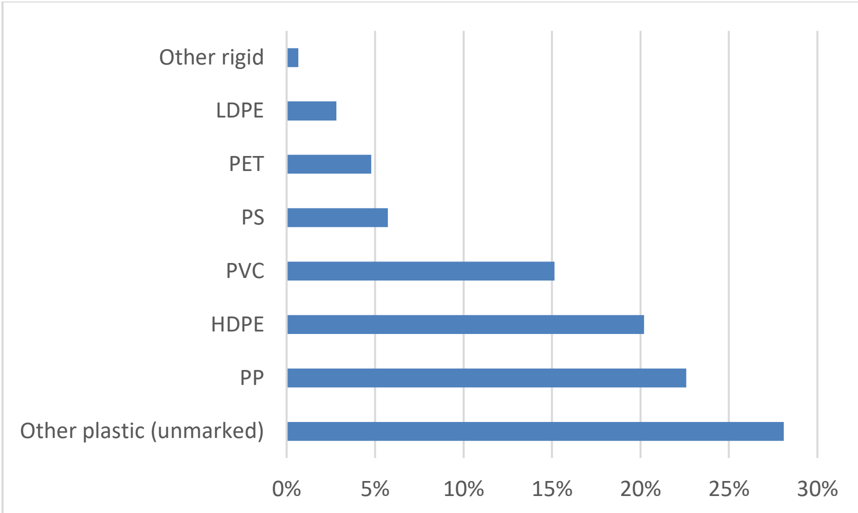


Figure 8 – Average proportion of plastic resins generated in three hospitals (source: SSE)

The Vinyl Institute of Canada has developed a specific collection program called Vinyl 123.[23]

3.4. Take aways on data collection

There is a significant variety of FPP on the market (resin type, structures, barriers, additives, etc.), which adds complexity to the recycling value chain.

There is a lack of reliable and granular data on FPP composition and volume, which hinders decision-making.

The ICI sector represents an untapped feedstock of high-quality and valuable FPP.

[23] Vinyl Institute. N.D. Vinyl 123. Available at: https://www.vinylinstituteofcanada.com/medical-pvc-recycling-pilot-program-pvc-123/

4. Best Practices in Capturing and Processing

European models were assessed to identify the success factors most likely to improve the performance of FPP recovery and recycling.

4.1. Fostplus (Belgium)

In 2021, Belgium added FPP to the accepted materials list (for residential and non-residential). In the same year, Belgium built five new identical greenfield MRFs to manage the expanded list of recyclables, with a design demonstrating the importance of isolating the FPP early in the sorting process.

To ensure the success of the approach, the organization responsible for Extended Producer Responsibility (EPR) on household packaging in Belgium, Fostplus, implemented the following measures:

- Three streams collection:
    - Glass - depot collection;
    - Paper and Paper packaging; and
    - Light-weight Packaging (LWP).
- Nine-year agreements with MRFs, which provides for longer amortization periods so investments can be made in a cost-effective manner.
- Production of two bale categories of FPP by the MRFs: bales of PE and bales of all other flexible packaging. This approach ensures greater capture of all FPP and garners better market value through the clean PE stream, without the need to identify each of the multitude of resin types and combinations in the feedstock.

The FPP sorting process, similar in the five Belgian MRFs, is as follows:

- opening of collection bags to release materials;
- screening of materials in a trommel screen to separate them according to their size;
- aeraulic segregation of a portion of the FPP from a conveyor;
- ferrous separation of the steel containers;
- after the removal of the first portion of carton and metal containers, an eddy current separates the aluminum containers, and then the two-dimensional materials are separated from the three-dimensional containers to join the air separated FPP;
- FPP is then sent to an optical sorter, where the PE is positively removed and residual FPP is sent to the bunker of other flexible plastic packaging; and
- the two categories of FPP are baled and sold to reclaimers that recycle the materials, according to their technical specifications for recycled content.

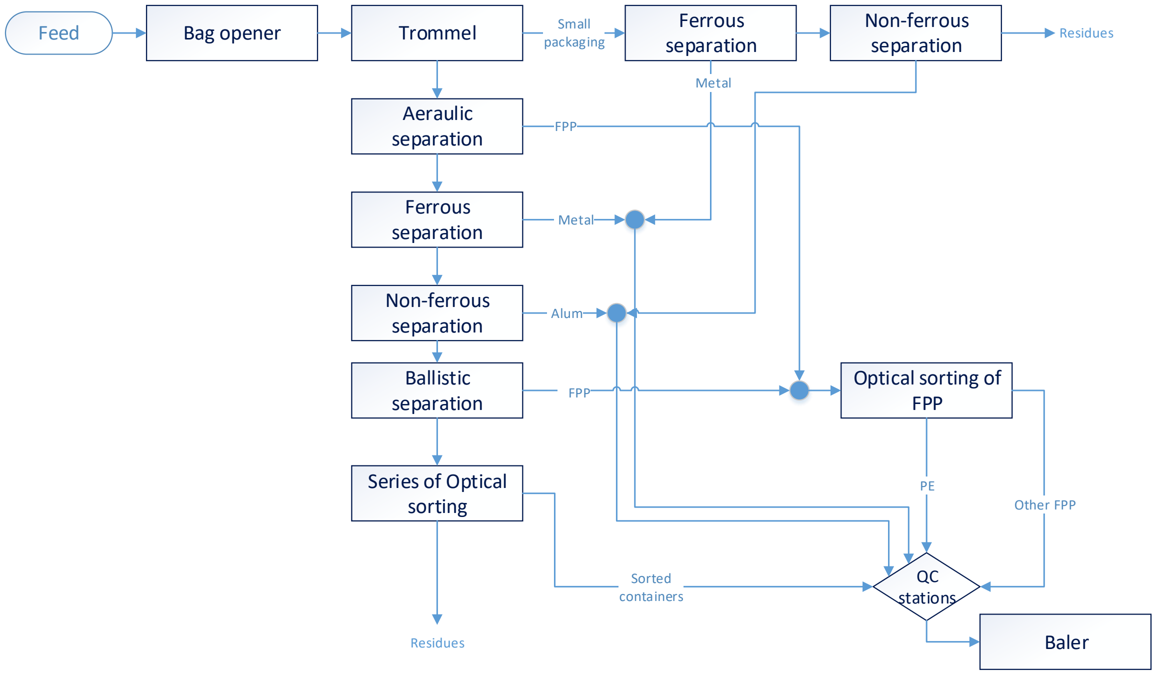


Figure 9 Sorting process, Fostplus

Bales of PE are sold to waste bag manufacturers across Europe, while bales of other FPP are sold to a Belgian durable goods manufacturer. Since chemical recycling (gasification/pyrolysis) is not considered 'recycling' and cannot be used to meet recycling targets, this avenue has not been explored for market development.

4.2. CITEO (France)

Since 2016, the organization responsible for EPR on household packaging in France, CITEO, has gradually increased the number and types of packaging and fibre to its curbside collection. FPP has been gradually integrated into what CITEO calls the "*FD20 development flow*", with the collection and sorting of LDPE film starting in 2019 (estimated at 130,000 TPY) then PP film in 2023 (estimated at 50,000 TPY). Only FPP primarily composed of PE or PP are accepted in the FPP development stream - currently excluding PVC, polyester, PS, biodegradables, and multi-material FPP. A national sorting labelling scheme is required by law in France; Triman signage and recovery instructions vary depending on the type of packaging (e.g. on the packaging, website)[24]. However, some grey areas remain, notably for multi-materials composed of 90% PE or PP base, but 10% other materials such as PET. While the initiative has just started, there is no indication on how successful the program is in terms of what is being collected and processed at MRFs.

[24] Ministère de la Transition écologique et de la Cohésion des territoires (2023). « *FAQ relative à la signalétique Triman et l'information précisant les modalités de tri* » (FAQ on Triman signage and recovery information). Available at: https://www.ecologie.gouv.fr/sites/default/files/FAQ%20Triman%20et%20frises.pdf (in French)

The collection system in France comprises of two streams:

- Glass, collected at depots or container parks, and;
- All other materials in a commingled stream.

The organization supports municipalities and operators in adapting a MRFs' processes to facilitate the handling of these new materials. CITEO requires French MRFs to produce a stream of FPP with a minimum content of 90% of films and bags composed of polyolefins (PE and PP base), with a tolerance of 3% for rigid PE and PP packaging. However, since each facility is responsible for the process design, the FPP sorting process is not harmonized. Most apply ballistic separation to sort two-dimensional packaging (paper, cardboard, and plastic films) from three-dimensional packaging (plastic and metal containers and rigid packaging). In some MRFs, the next step is a series of visual and near-infrared (NIR) optical sorters to separate the paper from the plastic in the 2D fraction, while other MRFs use air separation systems combined with NIR optical sorting.

With a recycling target of 52,000 TPY for PE and PP FPP, CITEO is deploying a system to establish new recycling channels for flexible plastics. CITEO states the success of this recycling sector is based on three essential conditions:

- a sufficient and guaranteed supply of packaging over time, as well as eco-design criteria in line with the technical capacity of reclaimers;
- efficient sorting and recycling technologies; and
- sufficient and sustainable outlets/markets.

The model developed by CITEO does not include any intermediate secondary sorting stage before recycling, since the reclaimers are responsible for preparing the FPP in a Reclaimer Front-End Process (RFEP), according to the defined specifications. Following a call for tenders for the recycling of polyethylene FPP from the development flow launched in 2022, CITEO distributed the quantities as follows:

- 50% is allocated to Machaon. In 2023, the company will initiate mechanical sorting of PE FPP at its plant in Chalons-en-Champagne, France, and then will add recycling by pyrolysis of the other films starting in 2025.
- 30% is allocated to Paprec-Total Energies partners. Paprec will be responsible for material preparation in Amiens, while Total Energie will perform chemical recycling of PE FPP by pyrolysis at its Grands-Puits plant starting 2024.
- 20% is allocated to Indaver, with the goal of preparing and chemically recycling PE FPP at its Belgian plant.

4.3. Other European case studies

Other European countries also have mechanisms in place for the collection and sorting of FPP, as reported in the "*State of Recycling Technologies for Flexible Plastic Packaging in Europe*"[25]:

- In Germany, the collection of FPP has been integrated into its EPR program (composed of 11 competing PROs) since 1991. The collection of FPP is combined with that of containers and packaging, with the exception of glass containers.

- In the Netherlands, the inclusion of FPP in the dedicated collection of containers and packaging took place in 2009. In the following years, the Netherlands expanded its integration to include additional categories. As of 2020, all FPP is accepted, except for multi-material laminated pouches. Similar to Germany, the Netherlands segregates glass and fiber into distinct streams. Both countries' facilities exclusively sort FPP in a format greater than A4, with sorting processes varying from one MRF to another.

[25] van Rossem, Chris, 2023. State of Recycling Technologies for Flexible Plastic Recycling in Europe. Kielce, Poland: EPRD Ltd.

5. Overview of the MRFs' Capacity to Capture FPP

5.1. Economic considerations

The main mission of a MRF is to separate mixed recyclable materials from collection, according to criteria established by end-markets. The MRF is dependent on the buyers of these materials, mostly secondary sorters or reclaimers. The nature of its activities and the intensification of sorting efforts are directly influenced by the stability of demand and by the price of a material (revenue versus operating cost). This is one of the reasons why, in the absence of a market and income for *"MRF film"* grade, FPP is considered low value by MRFs.

FPP price indices also reveal its low value in commodity markets. The lack of market for FPP, especially those from residential collection, and the obligation for some to dispose of them at very high cost or to send them to landfill, explains the negative average selling prices. Note the prices in Table 9 are for "*MRF film*" grade. For comparison, cleaner film, such as Grade A (commercial clear film >95% PE) are usually traded at least 10 times the value of low-grade film commodities, according to a price index (e.g., RecyclingMarkets.net[26]).

Table 9 Price indices for FPP sorted in Québec and Ontario, 2018 to 2022[27]

Source	2018 ($)	2019 ($)	2020 ($)	2021 ($)	2022 ($)
Québec (Recyc-Québec)[28]	-23	-14	-45	-24	-30
Ontario (CIF)[29]	15	3	-21	4	16

From this perspective, the management of FPP in most MRFs is similar to the approach for contaminants. The aim is to actively remove these materials from the flows in order to improve the quality of the bales of other sorted materials that will be marketed (e.g., mixed paper). Sorting is not focused on the production of FPP bales free of contamination, but rather on the implementation of various separation methods to ensure the production of FPP-free marketed materials.

To add to this, most Canadian MRFs are over a decade old. Consequently, their separation machinery isn't tailored to handle the present composition of incoming materials. As a result, their rudimentary design does not allow them to process increasing quantities of FPP.

[26] Available at: https://www.recyclingmarkets.net/
[27] Data from other provinces are not tracked by any organization or are considered confidential.
[28] RECYC-QUÉBEC (2023). Indice du prix des matières, Available at https://www.recyc-Québec.gouv.qc.ca/sites/default/files/documents/indice-prix-matieres-sommaire-1991-2022.pdf
[29] Continuous Improvement Fund (2023). Price Sheet. Available at https://thecif.ca/wp-content/uploads/2023/06/2023-May-CIF-Price-Sheet.pdf

Based on current configurations and infrastructure, it is difficult to imagine how any performance targets will be achieved in the coming years without modernization and new investments in capital-intensive equipment and technology. Industrial visits, as well as interviews carried out for this study, demonstrated an almost uniform inability across Canadian provinces to effectively sort FPP. The following sections explore the reasons behind the lack of consideration for FPP in MRFs and their major challenges.

5.2. MRFs' current process to capture FPP

Reaching high capture targets for FPP involves a combination of manual and automated sorting, which in turn introduces cost and efficiency pressures to operations. It is quite common to find FPP capture stations on many, if not most, sorting and quality control (QC) conveyors in a MRF. The processes and equipment introduced in Table 10 are among the most widespread in Canadian MRFs. These were identified following an in-depth evaluation conducted by the project team

Table 10 Canadian MRF's processes and equipment

Process / Equipment		Description	% of application in MRFs
Manual sort	Receiving	Large films are removed on tipping floors and sent to a bunker.	> 75%
	Pre-sort	Sorters positioned at picking stations will remove large FPP, empty or open bags, and free bagged material.	> 75%
	Quality control	Sorters positioned at QC stations to assess quality will remove any contaminants including FPP.	50-75%
Mechanical / automated sort	Bag opener	Located at the beginning of the sorting line, this equipment aims at separating bagged material with the help of claws or knifes before discharging it to a conveyor. Commonly used in facilities where curbside collection is managed with bags rather than carts.	0-25%
	Dimensional separation of material	Separation of fibre and containers based on size and shape using movement (elliptical inclination, ballistic separator), revolution (trommel screen, etc.) and screening (star screens). Commonly used to separate large items or to separate 2D and 3D material.	> 75%
	Optical separation	The optical sorter performs an automated separation of material based on their signature (NIR curve) as they pass on a belt at high speed and under an intense light source. Depending on the result of the detection, which is obtained when the material passes under the light source lenses, a command will be sent to certain ejection nozzles located on a strip positioned after the lenses. These nozzles send compressed air to the product(s) targeted by the optical sorter's programming to direct them to the correct chute (up ejection or down ejection).	50-75%; 25-50% on FPP separation

Process / Equipment		Description	% of application in MRFs
	AI-based separation	Technologies combining artificial intelligence and mechanical separation of FPP are now being introduced into MRFs. Although AI separation of FPP has not yet been implemented in a Canadian MRF, its installation on fibre QC lines to remove FPP could help to improve the purity of fibre bales.	<25%; 0% on FPP separation
	Air knife and wind sifter	Equipment designed to remove lightweight material from a stream. Based on the differences in particle shape and density, a light item can be lifted up in the air stream as the heavies are discharged at the bottom. Most commonly marketed equipment are zig zags and air knife separators, which are more utilized in Europe and could be explored in North America.	25-50%
Other peripheral	Film hoods and aeraulic conveyors	In the case of manual handpicked FPP, film hoods can help collect and convey the material to a bunker or directly to a baler. They are usually found at pre-sort and at some QC stations although in larger single stream facilities can be found throughout the system. Hoods can also be installed in the separation chamber of an optical sorter to separate film, over a piece of separation equipment or at the junction of two conveyors. Aeraulic (blowers) play a role in pushing material through a tube to its final storage location, reducing the need for handling. They are often installed at a QC conveyor outlet.	25-50%
	Baler	Material compaction equipment where a ram pushes the material against itself in a single direction to create a bale (single-RAM) or against a fixed wall to compress the bale from two sides (dual-RAM). The wires holding the bale are then added manually or automatically (auto-tie baler). In some cases, sorted FPP can also be sent to a stationary compactor, where material is compressed into a roll off container, optimizing its transportation.	>75%

5.2.1. Managing FPP in Single Stream MRFs

Since FPP can find its way into every material line, resulting in potentially high levels of contamination across multiple commodities, MRFs receiving materials collected in single stream require more sorting stations and equipment to capture FPP.

At pre-sort, bagged materials are often released, and employees remove the large FPP before they reach subsequent separators. Most of the FPP then progresses through separators, where materials are separated based on size and shape. Although a majority of FPP is directed to the 2D fibre stream, given their light weights and flat bodies, some bags are still drawn into the flow of containers, which forces operators to assign manual or automated sorters to several control stations.

Figure 10 shows a generic representation of the sorting process for single stream collection, with manual or automated sorting stations dedicated to the removal of FPP.

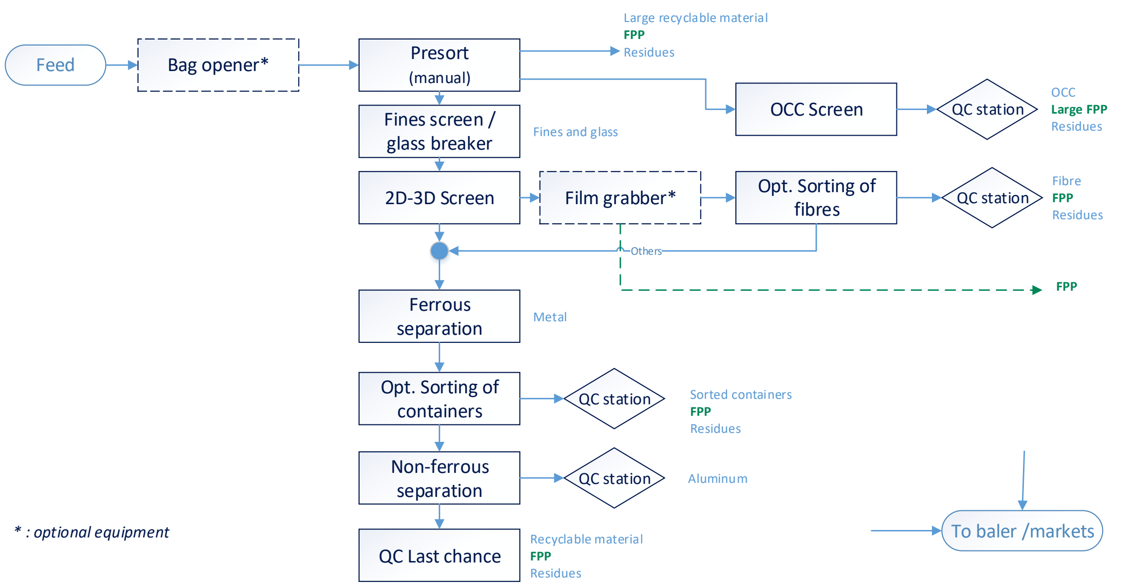


Figure 10 - Generic representation of a single stream MRF's process

Sorting FPP is among the most expensive activities in a single-stream MRF. Based on the financial information shared by operators on single stream MRF operations, the cost of sorting FPP varies from $488/tonne, in the case of a large capacity facility (>50,000 TPY), to $738/tonne, for a medium capacity facility (30,000 to 50,000 TPY), excluding costs or revenues related to the marketing, recovery, or disposal of these materials (Table 11). Despite these high costs, a high proportion of sorted FPP (37%)[30] does not find its way to the recycling markets.

[30] 6,322 t non recycled divided by 16,858 t sorted (Table 1)

Table 11 Cost/T to sort FPP in single-stream medium and large capacity MRFs

		Medium capacity MRF 30 000 TPY / 1 shift	Large capacity MRF 85 000 TPY / 2 shifts
Labor Cost			
	Sort and quality control	$344,385	$543,312
	Material Handling[31]	$48,057	$153,608
	Maintenance	$71,360	$270,592
	Administration	$16,905	$21,682
Operating expenses & amortization		$131,095	$157,386
Total cost for FPP sorting		$611,802	$1,146,581
Cost / tonne of FPP		**$738**	**$488**

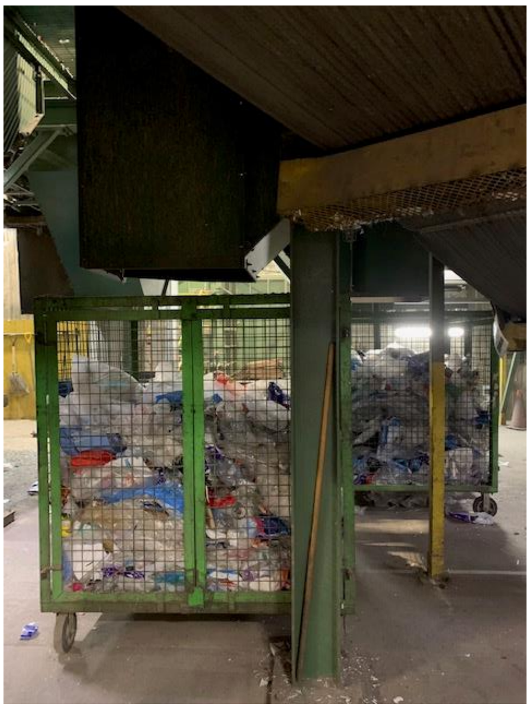


Figure 12 Storage equipment under sorting lines for manually removed FPP (Récup. Centre-du-Québec, Qc.). FPP was either sold to export or landfilled in 2022.

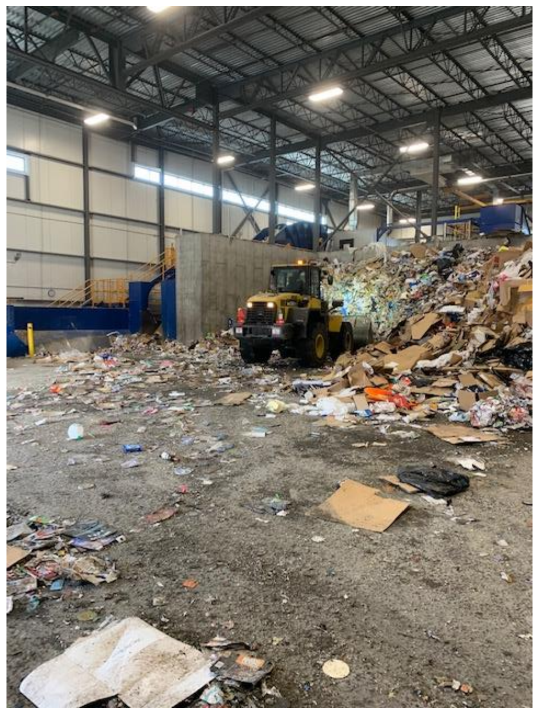


Figure 11 Tipping floor (Société Via, Qc.)

[31] Material handling refers to the handling of FPP, their transfer to the baling/packaging area, and their storage and loading into trailers.

Figure 14 FPP and other material rejected from 2D fibre line (Mazza Recycling, NJ)

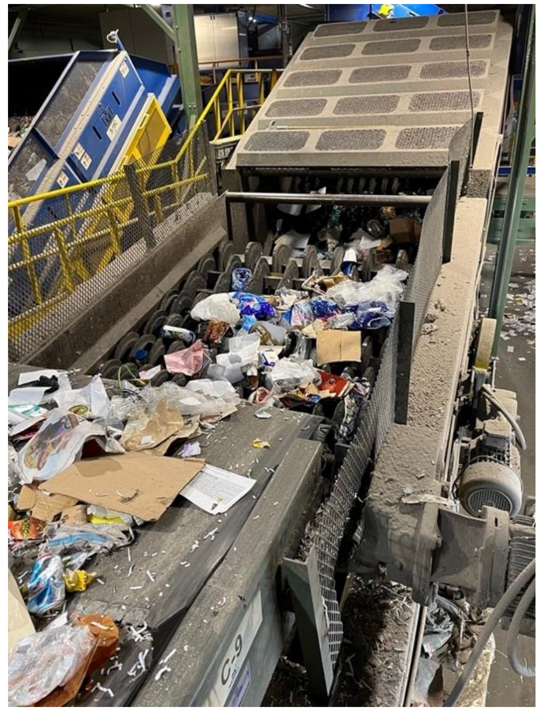


Figure 13 Material distribution on disc screen (Récup. Centre du Québec, Qc.)

5.2.2. Managing FPP in Dual Stream MRFs

Sorting FPP from dual stream collection is simpler since it bypasses the initial step of separating fiber from containers. For example, at a Vancouver, BC MRF (100,000 TPY), FPP is more prevalent in the Container stream, and its separation from rigid plastic is simplified. FPP is removed in the process flow after the trommel screen by a ballistic separator, then routed to a control conveyor where the small proportion of fibre present in the flow (<15%) can be removed. The low proportion of FPP found in the collected fibres requires an optical sorter and two quality sorters in order to remove them from the flow. In this specific case, the presence of a depot program for FPP also benefits the overall recovery rate for FPP. Based on a process review, the cost of sorting FPP is estimated by the project team to be under $300/tonne for both lines.

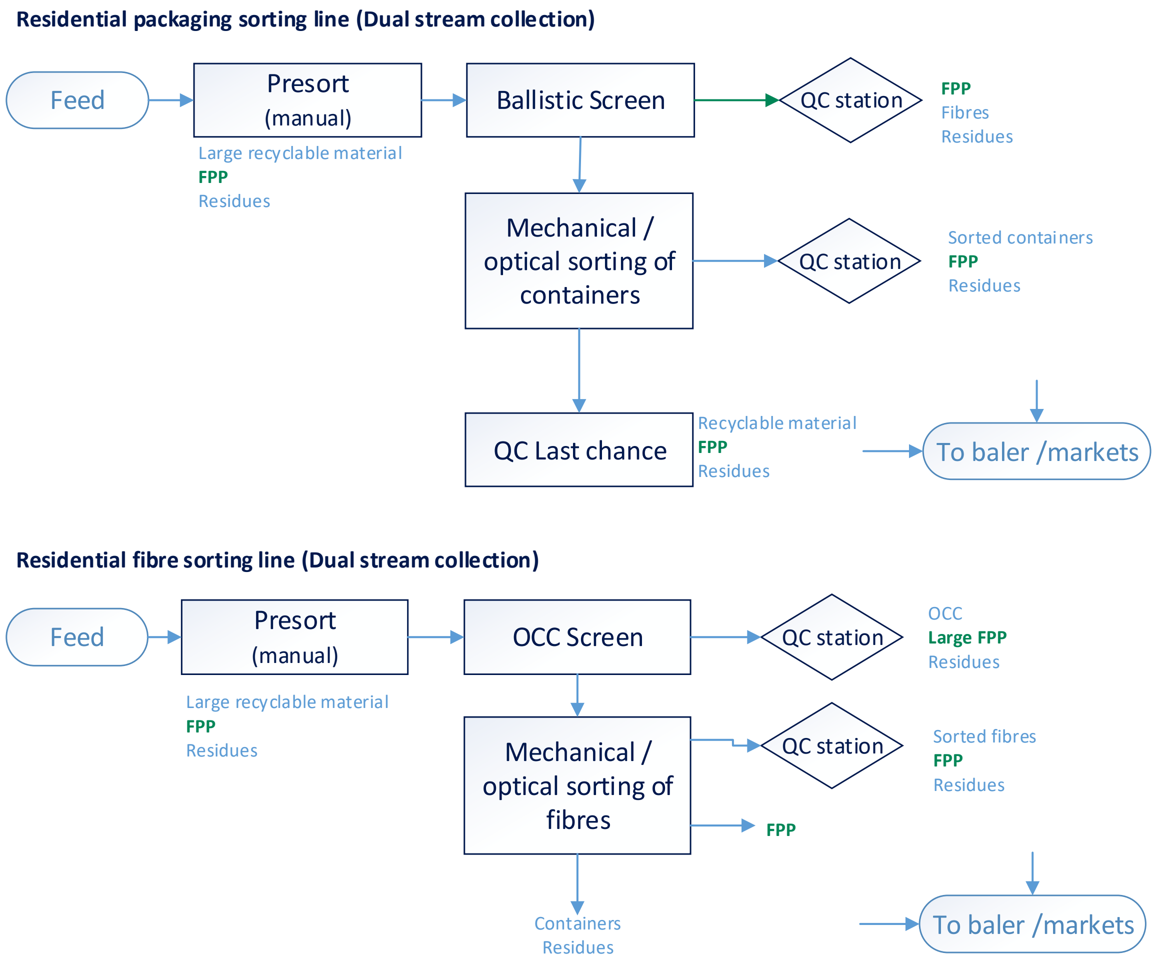


Figure 15 Dual stream sorting process of FPP

5.2.3. Managing FPP in ICI MRFs

Except for FPP collected in a dedicated stream, which, although not currently widespread, can be managed in a separate flow in a MRF (e.g., “push and bale”), the sorting of FPP from the ICI sector differs due to their generally larger size than what is found in the residential sector feedstock (e.g., protective envelopes for furniture, pallet wraps, supersacks). MRFs are typically designed to control the contamination of the prominent material, which is OCC. Moreover, in the absence of a market for FPP, no effort is currently being made to capture the smallest formats, which therefore end up in the residues.

In these MRFs, the large format FPP is removed on the ground or on the pre-sorting conveyor. A quality control station at the outlet of the OCC screen also allows the removal of FPP. Among surveyed operators, there's interest in certain FPP types separated from these positions, sorted as commodity Grade A or B. These specific FPP types hold significance for certain markets, leading to their isolation within a dedicated reserve.

Subsequently, any FPP that ends up mixed with commercial materials can be removed by an optical sorter or a hand sorter and is combined with the residues.

5.3. Potential Impacts of Accepting or Adding FPP

As described previously, FPP collection and its methods of sortation are not homogeneous across the country, since in regions where FPP collection is in place, the methods used can include curbside collection, depots, and dedicated programs. Based on the information shared by the facilities currently managing FPP, this section details the observed operational impacts and explores the potential effects on MRF’s operations if all FPP were to be collected with a high capture rate and sent to existing facilities.

In fact, as demonstrated in Section 3 of this report, reaching FPP collection targets would require a doubling of the quantities collected, as evidenced by the data presented in Table 12. While it is currently difficult to properly separate and manage FPP, doubling the collection quantities will create even greater challenges, given lack of capacity in the surveyed MRFs to sort FPP by resin.

Achieving the FPP collection targets as outlined in Table 12 would require a doubling of the current quantities collected (based on the numbers shared in Section 3). While it is currently difficult to properly separate and manage FPP, doubling the collection quantities will create even greater challenges given lack of capacity in the surveyed MRFs to sort FPP by resin.

Table 12 Estimation of collected FPP required to be collected to meet targets in Canada.

Category	Collected Avg (t)	Min Collected Avg (units)	Max Collected Avg (units)
Estimated tonnage and units of flexible plastic packaging collected by 2027 in Canada[32]	118,585	7,887,000,000	23,662,000,000

In terms of MRFs operations, the pressure and impacts will be observed on the sorting process, on the quality of marketed products, and on maintenance. The requirement for managing double the amount of FPP will limit the ability to produce high-quality materials and achieve higher capture rates unless significant investments are made.

As an indication, to sort the number of FPP units presented in Table 12, between 14 and 41 optical sorters fully dedicated to FPP would be required[33], representing an investment cost of $13.3 to $39 million dollars just for the acquisition of the equipment (excluding integration costs, commissioning, and peripheral equipment)[34].

5.3.1. On the sorting process

- Labour shortage

MRFs struggle to recruit employees and turnover rates are high. Despite the programs put in place by the operators, the attractiveness of MRF jobs remains low and absenteeism directly affects the reliability of sorting. As a result, contaminants are often not adequately removed, impacting the quality of the baled materials. The pandemic has also demonstrated that while curbside recycling remained an essential service to the population, the dependence on labour is an obstacle to the performance and reliability of most of the existing MRFs still using older processing technologies.

- Limited or no space available

The majority of MRFs interviewed highlighted constraints on their physical capacity for expansion. If new FPP sorting requirements were added or if new equipment proved necessary, they raised doubts about their capability to incorporate the necessary infrastructure to manage and sort FPP at full scale (e.g., new equipment, storing capacity, etc.).

[32] Based on an average calculation of different scenarios of collection rate results (25% and 50%) and a range packaging weight between 5 and 15 grams

[33] Based on the capacity of a 2.8 m optical sorter, fed at 4.5 m/s for 2000 h with a spreading factor of 20%, an ejection proportion of 60% of the stream and a rate of overall efficiency of the sorting line of 80% (Pellenc ST, 2023).

[34] Based on average prices provided by equipment vendors

- Investment required (transition)

Several MRFs mentioned that the regulatory changes announced in certain provinces and the resulting transition period represent an obstacle to innovation and process optimization. Although some MRFs are up to 20 years of age, some said they were waiting for contractual agreements and additional indications on targets and the marketing of materials before taking any further steps. Even with the advent of the new full EPR programs, the age and size of the existing network still calls into question the ability to adequately improve the infrastructure in a cost-effective manner to achieve the desired outcomes.

- Technological challenges

FPP, owing to its lightweight properties, poses considerable challenges for MRFs and equipment designers due to several key factors:

- It covers other material on conveyors and confounds recognition;
- Its distribution is difficult, often caused by turbulence and interference of heavier or larger objects;
- It tends to be contaminated by other material of similar density such as strings and twine, paper, etc., especially in presence of air classification and aeraulic transfer systems;
- It accumulates on the rotating components of equipment reducing their efficiency;
- It often contains other materials reducing sorting efficiency and the ability to capture all recyclables;
- It can contain organic matter, increasing the potential to contaminate other recyclables as well as FPP; and
- It involves a great deal of handling to produce a bale of FPP. A 750kg bale of FPP would contain between 75,000 and 225,000 single film units (assuming a weight of between 5g and 15g per unit).

Challenges are also denoted in the recognition and separation of heavily pigmented FPP (e.g., black, dark brown, dark green, etc.), FPP made from multiple resins, composite materials, metalized barriers, biodegradable plastic, and FPP with attachments (handles, enclosures, etc.) of a different resin or material, etc. Current AI might also find its limits with FPP of similar design made from different resins. Furthermore, as companies move from multi-materials, multi-laminated FPP to mono-material, multi-laminated FPP, typical camera-based AI systems would need a near infrared radiation (NIR) module added to ensure proper sortation to capture more PE.

5.3.2. On the quality of other bales, including mixed paper

According to the data collected from MRFs as part of the 2021 report on the management of residual materials in Québec by RECYC-QUÉBEC[35], fibre bales remain the most contaminated by FPP, especially in the case of mix paper (#54). Table 13 also shows that, on average, close to 19% of the incoming FPP is uncaptured and ends up in other marketed bales.

Table 13 Marketed material contamination by FPP, Québec (Recyc-Québec, 2021)

Bale	Total marketed product in 2021[36] (t)	Proportion of FPP/bale (%)	Est. weight of FPP in total marketed product (t)	Uncaptured inbound FPP (%)
Mix paper #54	175,500	1.4%	2,374.4	10.6%
Plastics #3-7	9,500	1.1%	102.6	0.5%
Boxboard	9,000	0,7%	63.4	0.3%
OCC	312,500	0.5%	1,411.8	6.3%
PET	27,000	0.4%	111.1	0.5%
Aluminum	1,000	0.3%	3.5	0.0%
Carton and aseptic	3,000	0.3%	9.8	0.0%
Steel can	19,000	0.3%	58.2	0.3%
HDPE	11,000	0.2%	27.2	0.1%
Deposit Al containers	5,000	0.0%	0.1	0.0%
Total	**572,500**		**4,162.2**	**18.5%**

Consequently, the value of bales is lowered, which compels the MRFs to focus their efforts on early separation and on allocating more manual sorting or control over the sorting lines to capture the maximum amount of FPP before it reaches the bunkers and the baling area. If not captured early, to meet stringent fibre end market specifications, MRFs are going to have to install optical sortation after fibres screens to remove the contaminants (i.e., FPP), adding complexity and cost to MRF operations. NIR optical sortation is being automatically integrated into fiber lines to guarantee that the bales adhere to specific standards. This trend isn't confined to new facilities; it's also prevalent in the revamping of existing MRFs, where incorporating NIR optical sortation has become a consistent theme.

[35] RECYC-QUÉBEC (2021) - Bilan 2021 de la gestion des matières résiduelles au Québec

[36] RECYC-QUÉBEC (2021) - Bilan 2021 de la gestion des matières résiduelles au Québec

5.3.3. On maintenance

The co-existence of FPP and MRF equipment puts a lot of pressure on the maintenance and cleaning teams. In terms of maintenance, the accumulation of bags in the mobile components of the equipment requires recurring interventions several times during each shift to maintain performance. Operators stated maintenance is planned at all breaks and shift changes to remove FPP in various screens throughout the facility. An excessive accumulation of materials in the components (shafts, bearings, conveyor rollers, etc.) can lead to blockages and breakages and cause unplanned shutdowns. Furthermore, the wrapped FPP also reduces the efficiency of the equipment, reducing capture rates and impacting product quality. Equipment, such as optical sorters and robots, that have fewer moving parts in contact with FPP do not require as much maintenance.

Figure 16 OCC screen with accumulated FPP

The cleaning of workspaces is strongly affected by the presence of FPP in MRFs. House cleaning might in some cases require the intervention of teams of five to ten staff, for which it is estimated that around 40% to 50% of their time is allocated to FPP recovery.

5.4. Optimization of capture rate in FPP bale production

In light of the findings set out above, and with the expected increase in the quantity of FPP in collection, it is essential to automate operations in MRFs with newer equipment that can effectively sort FPP to improve capture and diversion performance. The solutions recommended in this section must be considered as elements of an optimized global sorting system and not as single remedies since the issues, as has been demonstrated, are multiple.

5.4.1. Pre-sort

Whether it is a single or dual stream MRF, the quality of the pre-sort activity remains a critical element for performance, as well as for safety and maintenance. To reduce the pressure at the pre-sort station and to ease sortation of smaller FPP units, the addition of coarse separation equipment can be beneficial, making it possible to isolate large materials and to have a homogenous flow upstream of the sorting process. Unnecessary downtime can be avoided if FPP, especially large pieces, are removed from the material stream before the sorting process. In addition, large film is mainly made of PE, a sought-after material.

The process of an ICI MRF would also benefit from automating pre-sort by adding mechanical equipment, when physically possible, especially considering that these facilities receive substantial volumes of large FPP.

It should be noted though that most infeed systems are inground and cannot be moved to accommodate advanced sorting equipment ahead of the pre-sort, unless a project involving large-scale works is implied (construction of new pits, building expansion, etc.). If such work cannot be realized, then the option of manual sortation in the pre-sort, followed by a more robust sortation system immediately post-pre-sort, should be considered.

A review of mechanical pre-sort equipment is presented in Appendix C.

5.4.2. Sorting

In a single stream MRF
Unanimously, vendors admitted that a workable solution for FPP capture in a single stream MRF does not currently exist. The discussions made it possible to identify two main schools of thought on the sorting of FPP:

- The *early-catch process*: Experts are currently looking into the development of a sorting strategy aimed at removing FPP from the start of the line and preventing FPP from dispersing throughout the flows. To do this, they are considering, among other things, the removal of traditional mechanical separation equipment after pre-sort, such as disc separators in favor of vision equipment in which the detection is based on the image and the signature rather than on the shape and the dimension.
- The *catch-all process*: Other process experts favour the grouping of lower value materials (which includes FPP) in a series of flows towards the end of the process. These vendors and designers are of the opinion that it is wise to initially focus sorting efforts on value-added materials, ensuring that contaminants and low-value materials are removed from as many capture points as possible (mechanically, optically, etc.). Some even mention that the maximization of the numbers of capture points should be a priority to reduce the aggressiveness of certain processes and thereby the potential loss of good materials. Secondly, positive sorting on the last conveyors of material, such as specific categories of plastics, combining optical, robotic, and even aeraulic sorting, would make it possible to capture a large quantity of FPP. On the other hand, this approach might not alleviate the maintenance and quality control issues with having to manage FPP at so many points in the system.

The following diagrams present a very generic model of the early-catch and catch-all process strategies for single stream, based on information shared by vendors:

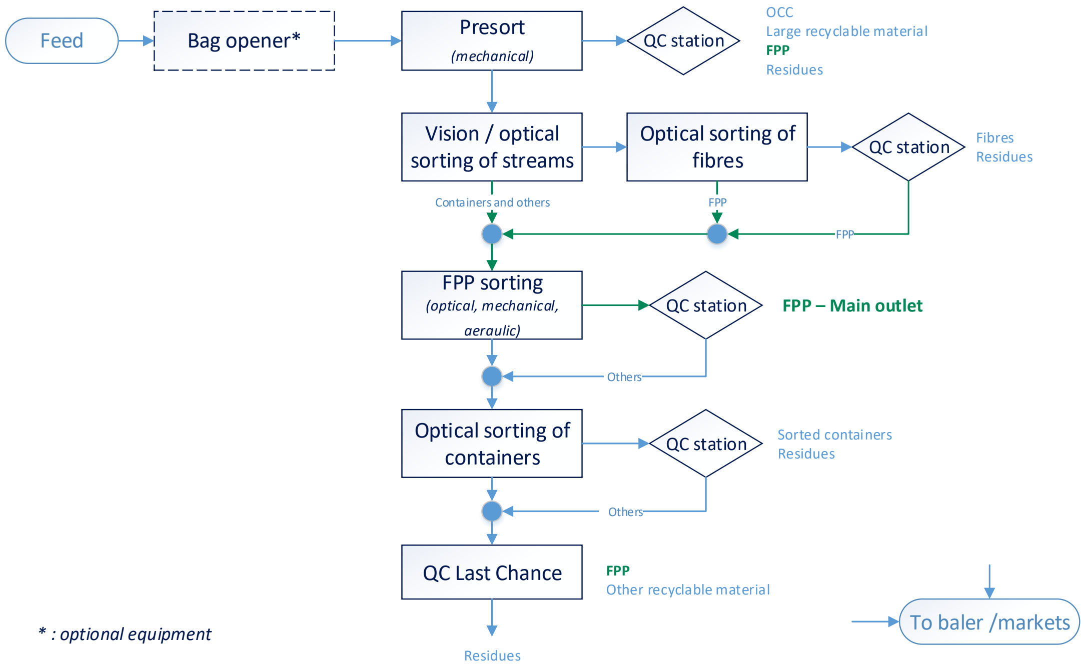


Figure 17 Generic model of an early-catch process strategy in a single stream MRF

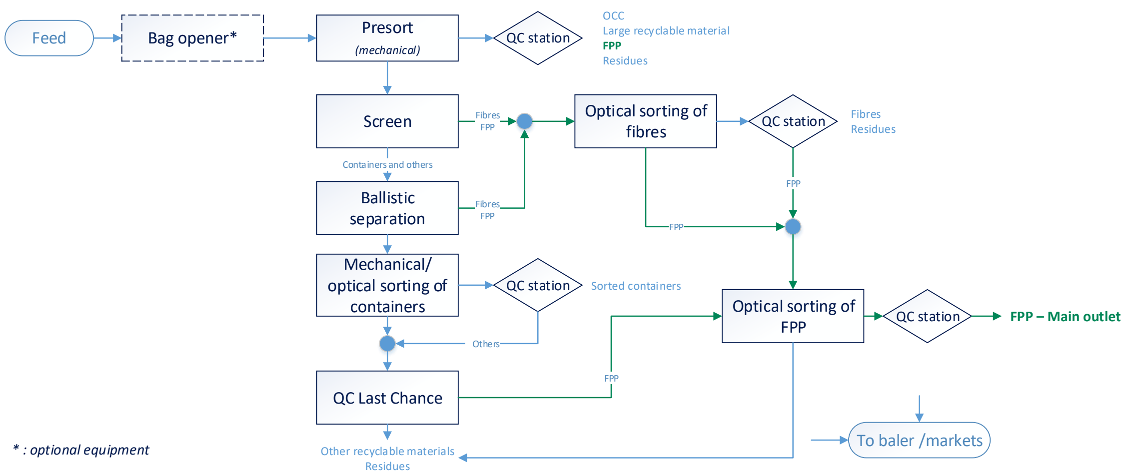


Figure 18 Generic model of a catch-all process strategy for a single stream MRF

It is clear that the full application of these processes is only possible within the framework of the construction of a new MRF (greenfield project). For an existing MRF, the catch-all process strategy appears to be a more reasonable solution, as demonstrated within the framework of the Materials Recovery for the Future (MRFF) project[37], but only in the context where the physical space is available and assuming the other equipment and processes are functioning properly. In this specific case, once capture points have been designed to collect and gather a maximum quantity of FPP traveling on the conveyors, a final optical sorter can be installed to clean any contaminant from the FPP. The investment required to implement this final cleaning step of FPP (speed conveyor, optical sorter, outlets, and chutes, but excluding the capture points on the line as they might vary greatly) ranges from $1.6M to $2.2M per facility, based on the prices shared by the vendors. The cost of a brownfield installation varies depending on the existing footprint of the equipment and available space in the facility. It's important to note that numerous factors need consideration before extending the price extrapolation to all facilities in Canada. Furthermore, certain MRFs might not be suitable for such an upgrade. This situation could justify either designing and implementing new infrastructure or establishing a separate collection system for FPP.

A review of mechanical sorting equipment is presented in Appendix C.

In a dual-stream MRF

Capturing FPP in a dual-stream MRF reduces the need for additional adjustments, as the process is already efficiently operational when collected through the container stream. Once on the sorting line, FPP is separated from containers by equipment, such as a ballistic separator. Then, an optical sorter or a robot could be installed as a quality control station to automate the removal of contaminants, such as the remaining fibres disposed by mistake by residents in the container stream. Because the optical sorter could positively sort contaminants and not FPP (as it is the case in single-stream facilities), it becomes much more efficient to produce a cleaner FPP bale. Where MRFs do not have mechanical separators, adding in the equipment might be more difficult and costly, but newer ballistic separators are available with smaller footprints, which means it might be easier to install the necessary equipment to more efficiently capture FPP.

In an ICI MRF

Again, while the construction of a new MRF paves the way for various designs and a sorting strategy that suits the operator's objectives, the catch-all process strategy appears to be a more reasonable solution in the case of a brownfield ICI facility. To maximize the capture of FPP that passes through the OCC separator, the addition of separation equipment (optical sorter, ballistic separator, or an air-knife separator) on the residue line is the most convenient.

[37] Graff, Susan (2023) MRFF final Project Report. Available at: https://www.materialsrecoveryforthefuture.com/wp-content/uploads/2023-MRFF-Pilot-Report-Feb-23_02-FINAL.pdf

5.5. The operational and financial impacts of the collection mode

Single and dual streams

The distribution of single and dual stream collection systems across Canada varies from province to province. According to data shared by Circular Materials, the collection by region is as outlined in Table 13. According to this data from 2021, one-third of the Canadian population was serviced by a dual or multi-stream recycling system ,[38] while the remainder combined their recyclables into a single stream.

Table 14 Population served as percentage of total served (2021)

Province	Collection type			Collection Frequency			Collection Containers		
	Single %	Dual %	Multi %	Weekly %	Biweekly %	Monthly %	Carts %	Boxes %	Bag %
British Columbia	43%	0%	57%	52%	48%	0%	40%	59%	1%
Alberta	94%	1%	5%	89%	11%	0%	52%	3%	45%
Saskatchewan	92%	2%	6%	8%	92%	0%	92%	0%	7%
Manitoba	100%	0%	0%	97%	3%	0%	65%	34%	1%
Ontario	55%	44%	1%	47%	53%	0%	36%	63%	1%
Quebec	100%	0%	0%	41%	59%	0%	100%	0%	0%
New Brunswick	63%	37%	0%	0%	92%	8%	23%	44%	33%
Nova Scotia	4%	96%	0%	52%	48%	0%	0%	0%	100%
Prince Edward Island	0%	100%	0%	0%	0%	100%	0%	0%	100%
Newfoundland and Labrador	33%	67%	0%	38%	62%	0%	0%	0%	100%
Canada	**69%**	**22%**	**9%**	**50%**	**49%**	**1%**	**54%**	**36%**	**11%**

A cost analysis comparing the two systems in Ontario for the same year demonstrates that the dual-stream collection and sorting system appears cheaper (between 12.1% and 13.3%[39] less), while recovering higher tonnages than single stream (6.1% more material per household)[40]. Several reasons could explain these differences; however, the results indicate that dual-stream systems might not necessarily be significantly more expensive than single-stream ones. It's important to note that other factors, like educational aspects, were beyond the study's scope and merit separate investigation.

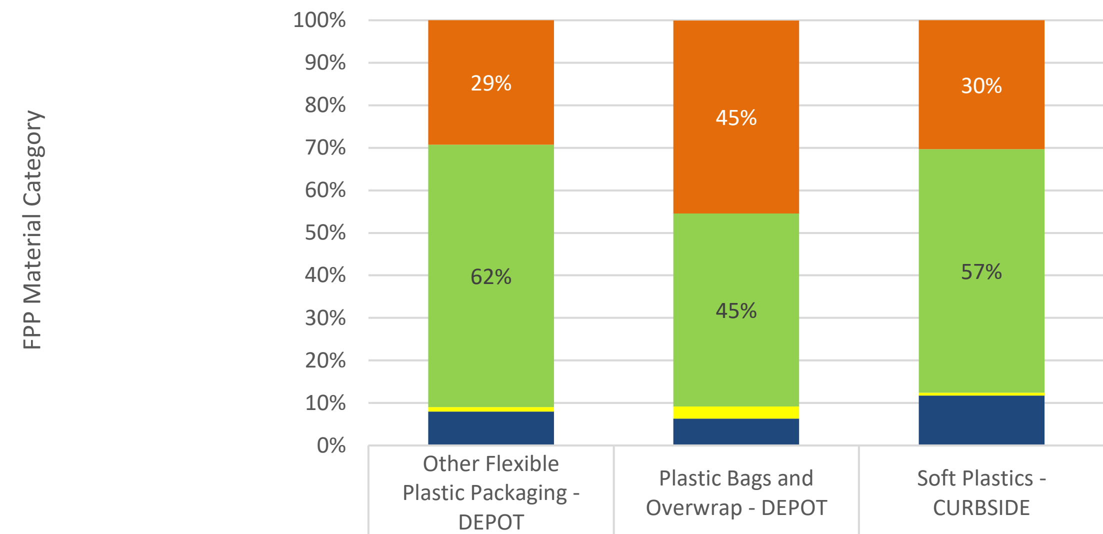
Table 15 Cost analysis of SS and DS system for the province of Ontario, 2021 (Source: Crow's Nest Environmental Inc.)

Collection system	Collection cost $/T	Depot/transfer cost $/T	Processing $/T	Total Cost $/T	Kg/Household
Single stream	$274	$31	$266	$571	131.80
Dual stream	$300	$34	$168	$502	139.9
Delta (%)	**9.28%**	**9.11%**	**-36.59%**	**-12.07%**	**6.15%**

[38] In British Columbia, the population can also dispose of some recyclables in depots.
[39] 13.3% less when excluding depots
[40] Data source: 2021 Resource Productivity and Recovery Authority annual data call

Depots

A pilot project led by Recycle BC over a six-month period (January to June 2022) showed that FPP collected in the province's depots had a quality rate similar to the FPP collected curbside (91% to 92% versus 87%, Figure 19), according to the list of accepted material for this pilot project, demonstrating that both systems can work effectively and be complementary[41].



	Other Flexible Plastic Packaging - DEPOT	Plastic Bags and Overwrap - DEPOT	Soft Plastics - CURBSIDE
Plastic Bags and Overwrap	29%	45%	30%
Other Flexible Plastic Packaging	62%	45%	57%
Not-Accepted Flexible Plastics	1%	3%	1%
Non-Flexible Plastics (Other)	8%	6%	12%

Figure 19 - Flexible Plastic Study - Composition of Stream (2022) – Source: Recycle BC

British Columbians can drop their FPP at one of 304 sites:

- Principal depots (224): approved depots from which in-scope FPP is picked up by the designated post-collection service provider.
- Satellite depots (47): approved depot from which contractor transports in-scope FPP to a designated Principal depot for pick-up by the designated post-collection service provider.
- Return-to-retail locations (53): for the purposes of the contracts, a return to retail is the equivalent of a satellite depot.

In 2018, Recycle BC expanded its collection efforts by including FPP (flexible polypropylene) alongside the PE mono-material films it had been gathering since the program launched in 2014. These materials were collected as two separate streams, with the PE mono-material film being recycled while the FPP was collected with the intention of providing Merlin Plastics, their plastics end market, enough material to perform

[41] Recycle BC (Feb 2023) Flexible plastics Pilot Study - A Comparison of Curbside to Depot Flexible Plastics Collection

research and development for a recycling solution. Up until the end of 2021, the FPP was being turned into an engineered fuel, at which point Merlin Plastics had successfully developed a recycling solution. The proprietary process they developed also used PE mono-material films as part of the same process. Starting in 2023, Recycle BC made the decision to collect these two streams together in a new stream called "Flexible Plastics."

The data shared by Recycle BC also demonstrated that between 2018 and 2022, between 58% and 68% of the FPP collected were in depots (Figure 20). It also shows a trend in the evolution of the categories collected, with the expansion of the list of accepted products, consistent with the trend observed with the marketing of FPP.

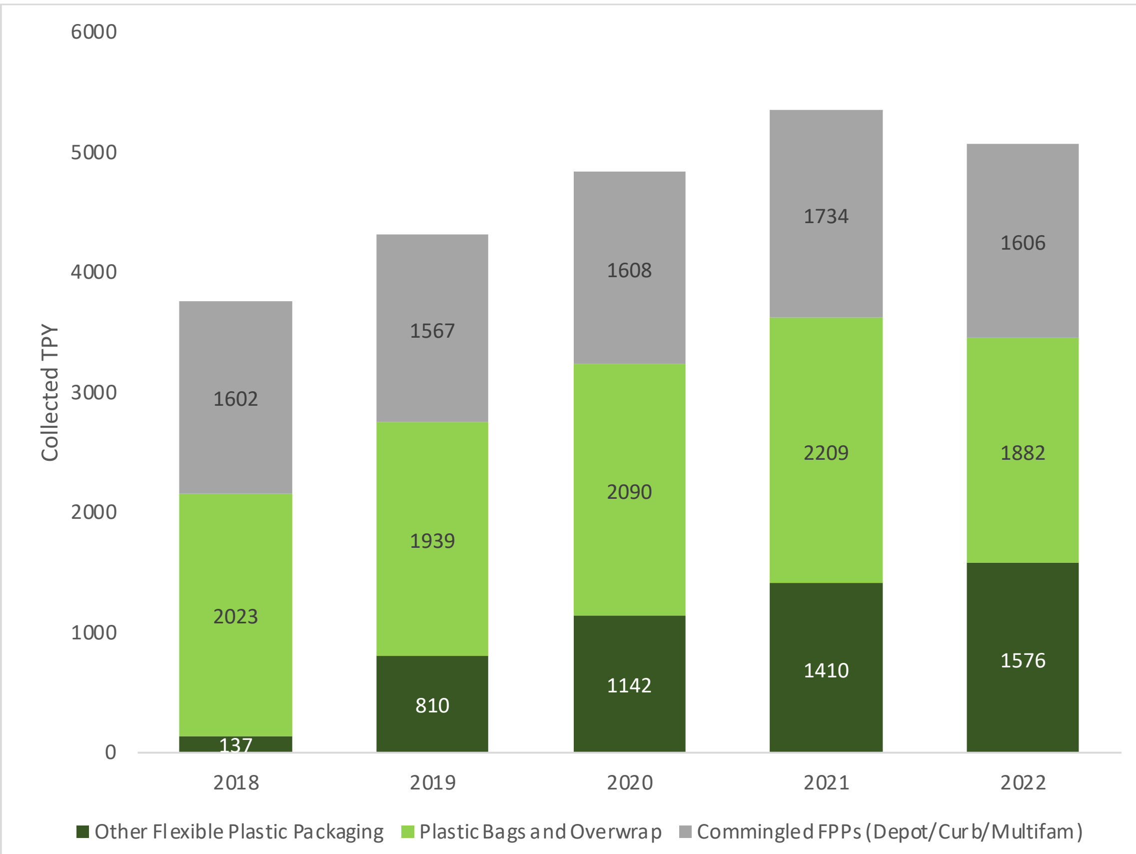


Figure 20 - Collected TPY of FPP in Recycle BC program from 2018 to 2022 (Source: Recycle BC)

Table 16 Evolution of FPP collection in B.C., 2018-2022[42]

	2018		2019		2020		2021		2022	
	T	%	T	%	T	%	T	%	T	%
Depot Other Flexible Plastic Packaging	137	4%	810	19%	1142	24%	1410	26%	1576	31%
Depot Plastic Bags and Overwrap	2023	54%	1939	45%	2090	43%	2209	41%	1882	37%
Commingled FPP (Depot /Curb/ Multifamily)	1602	43%	1567	36%	1608	33%	1734	32%	1606	32%
Total	**3762**		**4316**		**4840**		**5353**		**5064**	

5.6. Take aways from MRFs' capacity to capture FPP

Without accepting all FPP in the curbside collection systems, it will be challenging to reach the ambitious voluntary and regulatory performance targets.

A dual-stream collection model is better for sorting FPP, both technically and economically.

Technologies and procedures exist to efficiently process FPP in a single-stream collection model but implementing them in existing MRFs is not always possible due to operational constraints.

Loose FPP represents one of the most challenging and costly materials to sort for existing single-stream collection MRFs.

[42] Information provided by RECYCLE BC

6. Overview of the Recycling Capacity of the FPP Stream

The discussions with key stakeholders in the reverse supply chain highlighted the impact of Material Recovery Facilities (MRFs) in quality sorting and the role of packaging design for recyclability by brand owners. The availability of post-consumer resins (PCR) directly correlates with the product nature, reflecting how companies prioritize packaging design and manufacturing. This prioritization involves creating homogeneous properties, such as monostructures, and avoiding components that impede recovery and recycling processes.

6.1. Preliminary observations on separation capacity

Field observations revealed that reclaimers lack the capability to efficiently separate FPP based on resin types or other distinguishing attributes on a large scale. The surveyed reclaimers are only equipped with optical and flotation separation equipment, which highlights the limits to current market outlets for FPP to maximize recovery for recycling.

Numerous meetings and site visits conducted with reclaimers have revealed specific problematic contaminants. Among the factors identified as direct irritants affecting recycling efficiency, certain ones have emerged as particularly challenging, including:

- Multi-layer plastic packaging made of different resins or with incompatible barrier layers (metalized, nylon, PVDC, etc.).
- PVC, including in labels (on FPP or bottle labels that end up in the FPP stream) and inks.
- Additives that impact the recycling process, such as degradable additives,
- Paper, glass, and metal (free or attached to FPP packaging) as these materials directly affect the yield.

Consequently, secondary sorting is needed to remove contaminants that separate FPP according to the properties of the manufactured materials to be produced, and to potentially isolate certain packaging according to its attributes. Even with today's limitations, reclaimers have shown a very strong interest in implementing these new capabilities, where there are feedstock guarantees for periods of time (minimum of ten years). This guaranteed time would allow reclaimers to effectively monetize the necessary equipment.

6.2. Current and potential end market specifications

6.2.1. Current reclaimers landscape

In Canada, there are currently three major reclaimers that process post-consumer plastic film. While the facilities of Merlin Plastics (BC) and EFS-Plastics (ON and PA) can recycle significant volumes, Modix (QC) is limited in capacity, both in terms of the quantity and quality of post-consumer plastic film received. Merlin Plastics and EFS-Plastics process both rigid and flexible, while Modix only processes flexible plastic. It is estimated that these three reclaimers can currently process less than 30,000 TPY of FPP.

The volumes they process from curbside collection remain marginal compared to the volume from ICI sources (e.g., pallet wrap, bags for deposit containers, etc.). Moreover, other reclaimers, including Polykar (QC), Fraser Plastics (BC), Rundle Eco Services (AB), Paverreco (QC) and Trex (VA), also process feedstock from ICI sources. Some chemical recycling facilities also process FPP (among other feedstock). In Canada, Enerkem in Edmonton (AB) is the only one in operation at a commercial stage.

Except for Merlin Plastics (BC) and EFS Plastics (ON), there is no optical sorting of incoming feedstock. Consequently, the separation is undertaken using a conventional way by flotation tank, which does not allow adequate separation of PP, PET, or multi-materials packaging from PE film.

No chemical recycler in Canada processes a dedicated stream of FPP. However, some multi-material FPP can be sent to this type of facility, particularly in the United States, mainly to produce fuel. In Canada, only the Enerkem facility in Edmonton accepts FPP, although other industrial projects are being developed.

Recyclers interviewed confirm the potential for increased processing capacity as markets grow. This is driven by recycled content commitments and obligations, if investments are made to separate the FPP in MRFs, leaving the specific resin sortation to the reclaimers.
To reach 30% recycled content by 2027[43], an increased capacity of 70,000 TPY would be required based on the generated data presented above.

6.2.2. Resin types

The recycling market focuses on PE materials. Garbage bags, durable products, Wood-Plastic Composites (WPC), and construction material are the primary products from recycled PE.

[43] As stated by Objective #3 of CPP 5-year roadmap for Advancing Circular Economy for FPP in Canada (https://plasticspact.ca/wp-content/uploads/2023/09/Roadmap-Advancing-a-Circular-Economy-for-Flexible-Plastic-Packaging.pdf)

The manufacture of durable products or WPC makes it possible to process resins other than PE, in particular multi-material FPP. Quantities are however controlled and limited according to usage. Moreover, there is a market size limit since the sale of products, such as park benches, is also limited.

Currently, chemical recyclers mainly seek a supply of polyolefins (PE and PP) with a limited tolerance to PVC/PVDC (1%) and other barriers such as PET, EVOH, nylon (5%)[44], thereby limiting the ability to process multi-materials FPP.

Finally, there is currently no recycling outlet dedicated to the treatment of monoPP packaging exclusively, apart from the Pure Cycle Technology facility in the U.S.

6.3. Conditions for the development of recycling capacity

For a successful development of a flexible plastics processing sector, beyond the quality of the bales, two main elements must exist:

- Provide reclaimers with supply guarantees as an incentive for them to invest in infrastructure; and
- Increased demand for recycled plastic.

6.3.1. Supply guarantees

The reclaimers unanimously share a common observation: beyond the quality of the FPP stream and financial incentives, they require a stable and substantial supply of materials to achieve economies of scale.

After analyzing and engaging in discussions across different jurisdictions and interviewing various reclaimers, it was confirmed that a minimum quantity of approximately 40,000 to 50,000 TPY of incoming material, which can consist of flexible and/or rigid plastics, represents the minimum quantity necessary to ensure the viability of a recycling facility with a front-end process. This has been validated by Canadian reclaimers and project designers, and is also supported by recent developments in Europe[45], such as:

- Machaon recycling facility in France (50,000 TPY); and
- ValueFlex oversorting and recycling project (55 000 TPY).

Supply contracts therefore become key to achieving this tonnage. In France and Belgium, contracts of three to nine years are planned for various reclaimers. This is also a method implemented between private players. For example, the agreement between Waste Management and Dow Chemicals illustrates how a major collector and MRF operator can enable the investment of a chemical recycling plant[46].

[44] Alliance to End Plastic Waste. 2022. Feedstock Quality Guidelines for Pyrolysis Plastic Waste. Available at: https://endplasticwaste.org/en/our-stories/feedstock-for-pyrolysis

[45] Those projects do not necessarily include multi-materials packaging

[46] Resource Recycling (2023) *WM and Republic move forward on major plastic plans. Available at:* https://resource-recycling.com/recycling/2023/03/27/wm-and-republic-move-forward-on-major-plastic-plans/

The development of EPR on a Canadian scale and producers taking ownership of materials presents a promising opportunity to ensure supply guarantees. This assurance becomes instrumental in stabilizing investments, which allows reclaimers to begin implementation. Collaborative partnerships between stewardship agencies might also create additional opportunities.

6.4. Producers' commitments

Much like supply guarantees, post-consumer resin (PCR) supply commitments from producers will be required to ensure the stability of the system, particularly in the sectors identified above.

For example, the MBOLD project in the United States brings together a reclaimer (MyPlas, MN), a manufacturer (Chapter Next Generation (CNG)), and several producers, including General Mills, Target, and Cargill, to produce and use up to 40,000 TPY of recycled plastic in packaging[47]. CNG has outlined three primary outputs resulting from this collaboration: industrial films, consumer-grade films (such as e-commerce mailers and lawn & garden bags), and food-grade film[48] (to be developed at a later stage). The project commenced in spring 2023.

6.5. Potential end-markets

The commitment of producers to generate more "easily recyclable" FPP (i.e., PE and PP mono-material packaging) and move away from the multi-material structures with limited recycling opportunities, along with upcoming federal requirements for recycled content, are key elements to the future development of FPP recycling facilities and will strengthen markets. Currently, there's a demand for incorporating recycled content into different kinds of FPP. However, the limitations in sorting and mechanically recycling flexible plastics hinder meeting this demand. Furthermore, the production of transparent PCR from a mixed collection feedstock is impossible without the use of de-inking technologies. Achieving food-contact application further complicates the process because mechanical recycling requires source control of the materials used. This control is vital to limit the quantity of non-food materials into the recycling process.

For transparent and food applications involving post-consumer FPP, mechanical recycling cannot meet the requirements at present, and the establishment of a chemical recycling plant able to achieve this will require seven to ten years to develop. Examples in Europe (e.g., Total/Plastic Energy) and in the United States (e.g., Nexus) demonstrate that outcome can be achieved with chemical recycling technologies. If mechanical recycling is to be the focus, at least over the next few years, AI and/or digital watermarking will be

[47] MBOLD. 2023. Growing Innovation in Food & Agriculture. Available at: https://www.mbold.org/

[48] Scott Hammer. 2023. Presentation during Plastic Recycling Conference: "CNG is North America's Leading Independent Producer of Highly Engineered Sustainable Films. March 2023

needed to create 95% food-grade bales as feedstock and to maximize the opportunity for recycled content food-grade flexible PE or PP.

However, there are several markets that could be developed to help increase the demand for mechanically recycled plastic. According to the information shared by the reclaimers, a period of six months to one year is necessary to develop the quality of a resin for a given product for a given manufacturer. This reinforces the need for supply guarantees, necessary for product development.

6.5.1. Mechanically recycled potential end-markets

According to the reclaimers interviewed, it is possible to achieve the specifications of several markets by integrating efficient sorting of the different resins used in FPP (PE, PP, and multi-materials) and by using sources of materials from ICI collection (including agricultural plastics) in which homogeneity is more guaranteed. Nevertheless, the resin produced will be coloured.

Several markets for coloured resin could be developed, or where warranted, reclaimers could add colour sortation of film flake to make films of different colours. However, this would require increased investment and guaranteed supply chain end markets to justify these additional investments.

Agricultural film

According to Cleanfarms, around 30,000 TPY of LDPE film are used throughout Canada for various applications, such as mulch film, grain bags, and bale bags[49]. The plastic film manufacturers in that sector (e.g., Berry Global, ON and Poly Ag, AB) confirmed they are working on various initiatives to increase the recycled content used. While these companies can use agricultural film, it is also feasible to use FPP from curbside collection. <u>Potential recycled content</u>: 15-30% (4,500-9,000 TPY).

Construction films

One manufacturer supplying the construction sector estimates there is a high potential to use PCR, since colour is less of a concern. Among others, asphalt shingles, insulation products, and various rolls are using LDPE packaging. Some discussions have already been initiated with reclaimers to figure out how to integrate PCR in some of those products.
<u>Potential recycled-content</u>: 15%-30% (1,500-3,000 TPY).

Heavy-duty bags and sacks

Because the thickness of the product allows for more impurities than thin FPP, heavy-duty bags and sacks are identified as a potential growing demand for end-markets. Moreover, some of them are co-extruded when manufactured, and the inside liner is usually black, allowing the use of coloured PCR. Conversations are underway for products

[49] Cleanfarms. 2021. Agricultural Plastic Characterization and Management on Canadian Farms. Available at : https://cleanfarms.ca/wp-content/uploads/2021/08/Project-Building-a-Canada-Wide-Zero-Plastic-Waste-Strategy-for-Agriculture.pdf

like mulch bags or sand-filtration media. Similarly, e-commerce mailers could be another market sector to target.
Potential recycled content: 30% (market size unknown but considered significant).

Drainpipe
Drainpipe production has a long history of integrated PCR content. Companies like Soleno (QC), ADS (US), and Maxi-Drain (QC) have been using HDPE jugs for many years now. ADS itself is recognized as the biggest North American reclaimer in terms of volume; it has reported using around 230,000 tonnes of HDPE and PP in 2021[50]. The above companies are exploring the use of LDPE FPP and have expressed willingness to explore further.
Potential recycled content: 5% (15,000 TPY)

Sandwich layer in multi-layer plastic products
rPE film has the potential to grow in other FPP applications, such as in multi-layer pouches in which it is used as a "sandwich" layer to prevent the potential migration of contaminants into food. According to research piloted by CPT, there is currently nothing preventing PCR from being used as a sandwich layer in pouches, as long as the inner layer's thickness—adjacent to the product or acting as the barrier layer—is adequate to prevent any migration of contaminants. The report includes a recommendation to "undertake a project to define specific thicknesses of the functional barrier layers in multi-layers rigid and flexible food packaging, to help converters and consumer packaged goods (CPGs) safely use PCR in such structures (create library of typical multi-layers structures)."
Potential recycled content: unknown, market volume to be determined.

Specific markets for monoPP flexible

As identified in the data section, between 8% and 20% of the incoming feedstock could be composed of monoPP packaging, or PP with barrier layers. Reclaimers suggest that due to the comparable thermo-mechanical properties, using recycled PP (rPP) in both flexible and rigid PP applications is a feasible option. The challenge lies with the presence of barriers and additives that could be detrimental to recycling. As there are no guidelines for recyclability in North America for flexible PP, some information was gathered on the RecyClass Online Tool. Barriers like AlOx and SiOx are accepted, but metalized are considered medium-compatibility and PVC is considered incompatible.

The project team has undertaken an analysis to identify the capacity of actual sorting equipment to separate the different types of PP, but further tests would be required to adopt the European rules in a Canadian context. For instance, metalized films are likely to be considered incompatible, according to the recycler.

[50] PMM. 2022. ADS sets ambitious recycling goals. Available at: https://www.plasticsmachinerymanufacturing.com/recycling/article/21269185/ads-sets-ambitious-recycling-goals

Lower grade end-markets

According to various recyclers, producing PCR for film application offers more stability in turbulent economic conditions due to its higher value. However, even if associated with low-value market, other end-markets should be considered to address and enhance volume to be collected and recycled.

Other durable goods

During the research, the project team met several manufacturers that are using rLDPE in a range of products. Other examples, besides Wood Plastic Composite (WPC) like those from companies such as Trex, include:

- Premier Tech, which is using rLDPE in its septic tank production; and
- Paverreco, which is producing tiles and pavement using crushed glass and FPP.

Potential recycled content: unknown

Figure 21 - Pave produced by the company Paverreco using rLDPE

Asphalt

Recent research has opened avenues for utilizing recycled PE as a polymer additive in asphalt binders. Asphalt is a mix of aggregates and bitumen produced from petrochemicals. rPE has been tested to replace part of the bitumen to act as the binding agent. In the U.S., the NEMO (New End-Market Opportunities) for the Film Asphalt Project has assessed the performance and chemical characterization of asphalt binders using rPE[51]. A pilot project is underway in a parking lot using around 0.5 tonnes of LDPE bags. A specific project in Gaspésie (eastern QC), with the technical support of three academic research departments, is looking at how to use FPP sorted at a MRF and transformed in a facility nearby to produce a bitumen alternative. Research protocols intend on tracking the performance of the bitumen alternative input over the next years to document its resilience and stiffness.

Potential recycled content: TBD

The market for asphalt is a good example of a solution applied to MRFs located in regions that are far away from traditional markets. The environmental footprint caused by transport provides a strong incentive for the development of local recycling capacity on a small scale. Other applications that have or could be applied in remote areas include small scale pyrolysis units (e.g., Sustane Technologies Inc., Chester, NS) or concrete production. This avenue is being promoted by companies such as the Center for Regenerative Design & Collaboration (CRDC) with the production of RESIN8, and PLAEX Building Systems Inc.

[51] PLASTICS. 2020. Plastics and lyondellbasell collaborate on first paving project using recycled plastic. Available at : https://www.plasticsindustry.org/category/tags/new-end-market-opportunities-nemo-film-asphalt-project

6.6. Chemically recycled potential end-markets

As we see an increase in new projects, it is important to clarify the role of chemical recycling and how it complements mechanical recycling.

It is important to recognize that chemical recycling can play a key role in FPP recycling, particularly in the production of food-grade and/or transparent recycled resins, which represents a substantial portion of the current FPP supplied on the market. The capacity of producing food-grade and/or transparent recycled resins will be critical to reach recycled content targets from producers or governments. However, currently their specifications are more or less similar to mechanical recyclers. Regardless of the recycling approach, the common problematic contaminants remain consistent, including PVC, PET, metallized barriers, and fibers. Gasification recycling technologies are more tolerant of the contaminants accepted in the process, while expanding the specification scope is already being analyzed by major chemical recyclers using pyrolysis. Realistically both pyrolysis and gasification still need a mechanical sorting front-end to remove contaminants and create a feedstock of consistent quality prior to any chemical treatment, as mechanical recyclers require. Neither chemical nor mechanical can take materials from the backdoor of a MRF without any front-end process.

It is possible that chemical recyclers and mechanical recyclers will compete for the supply of raw materials, especially since the volumes needed to justify the investments are generally high. For instance, recent announcements include the following production capacities for chemical recycling:

- Encina (PA): 450,000 TPY;
- Brightmark (IN): 400,000 TPY;
- Enerkem (QC): 200,000 TPY; and
- Nova Chemicals / Plastics Energy (ON): 66,000 TPY.

Economics is an important decision-making factor. Currently, mechanical recycling is less expensive than chemical recycling and is proven capable of producing high-quality recyclates. That means chemical recyclers might, unless economic factors change, be left having to manage lower grade plastics. This might encourage chemical recyclers to target fuel-based end products that currently hold a higher market value compared to PE and PP production.

Chemical recycling can be very complementary to mechanical recycling. Its ability to produce recycled resins suitable for food contact and transparent resins means it is well positioned to manage a stream of multi-material FPP.

As an example, CITEO (France) recently published a call for tenders for the recycling of PE and PP FPP for which it is responsible for end-of-life management. The three selected projects all involve a chemical recycling dimension (cf section 4.2).

In Canada, known chemical recycling opportunities for flexibles are in three provinces:

- Edmonton, Alberta: Nova Chemicals, in partnership with Enerkem (in operation).
- Varennes, Québec: Enerkem (scheduled for 2025).
- Sarnia, Ontario: Nova Chemicals, in collaboration with Plastics Energy (under feasibility study); and
- Sarnia, Ontario: Imperial Oil (under evaluation).

6.7. Infrastructure gap

Based on the above, four main infrastructure gaps have been identified and should be given priority to raise the potential capacity for FPP recycling.

Limited capacity for secondary sortation

The primary infrastructure gap identified lies in the insufficient capacity of reclaimers to effectively sort and prepare materials for recycling, aligning with the needs of the end-markets. The only real reclaimer front-end process (RFEP) in Canada for FPP is located at Merlin facility in BC, which produces pellets composed of a blend of PE and PP (with compatibilizers), and it has the potential to grow significantly. Similar RFEP should be implemented at least in Ontario, Québec, and potentially Alberta. This strategic move will significantly enhance the recycling end-market, fostering its growth and effectiveness across these provinces.

Limited (to non-existent) capacity to produce food-grade and/or transparent rPE

Even if sorted through a RFEP, colour sortation rarely occurs given the composition of inbound material. Several pathways have been identified:

- Define specific thicknesses of the functional barrier layers in multi-layer rigid and flexible food packaging to help converters and CPGs safely use PCR in such structures. Design packaging in a way to avoid unwanted contaminant for food-grade production.
- Use deinking technologies (after RFEP but before washing); and
- Develop a chemical recycling process.

No capacity to recycle Flexible PP

No reclaimer currently processes flexible PP as a dedicated stream (i.e., not mixed with PE). However, the material could potentially be recycled either through mechanical or chemical recycling processes, as the end-markets seem to exist already.

Limited (to non-existent) capacity to recycle multi-material products

Except for a few low-value markets, there is insufficient capacity to process the wide variety of multi-material available in the market. While some can be diluted with PE film recycling with the help of a compatibilizer, this has not been demonstrated with much greater quantities. It also remains difficult to separate those from mono-materials. The commitment of producers to produce more “easily recyclable” (i.e., PE and PP monostructure pouches and moving away from the multi-material structures and PVC/PVDC barriers) is the best pathway for recyclability, as well as chemical recycling should their scope specification expand.

6.8. Take aways from the Recycling Capacity of the FPP Stream

There are only a few FPP reclaimers in Canada and their capacity to process large volumes and non-PE FPP are limited.

End markets for FPP collected through curbside collection systems remain limited, especially for hard-to-recycle materials.

7. Recommendations

7.1. Findings and Recommendations

Finding 1: There is a significant variety of FPP on the market (resin types, structures, barriers, additives, etc.), which adds complexity to the recycling value chain.

Recommendation: Aim for better harmonization of FPP through the implementation of design for recyclability measures following established industry guidelines.

As a priority, brand owners should be made aware of the impacts of marketing FPP that is not designed for recycling through Canada's existing recycling infrastructure and technology. It becomes impossible for reclaimers to supply PCR to companies and enable them to meet their recycled content targets if they receive materials that are difficult to process. Brand owners should also be made responsible for the design choices they make, and measures should be implemented to promote "designed to be recycled FPP" and support those who still must make efforts to achieve this objective. The promotion of the Canadian Guidance for Golden Design Rule #6 for Plastic Packaging ("Increase Recycling Value in Flexible Consumer Packaging")[52] and the APR Design Guide[53] could serve as a solid foundation for launching a movement aimed at designing for recyclability.

An approval mechanism in the form of a committee or an exchange platform should be put in place to establish a dialogue between brand owners and reclaimers. The latter would inform FPP designers about specific technical constraints in recycling targeted products. This information would guide designers towards alternative approaches or modifications. Conversely, it could also help in adapting packaging to align with existing facilities, avoiding substantial capital investments for new film manufacturing and filling lines. As packaging plays many roles, the implementation of a platform that highlights advances in FPP design could guide CPG manufacturers to change their packaging.

For example, the CPP has a microsite dedicated to the Golden Design Rules for Plastics Packaging and aims to expand its educational resources. This includes showcasing companies implementing innovative packaging solutions to assist CPGs in transitioning toward recyclable formats and adopting mono-material structures[54]. By creating packaging that can be recycled, which includes being sold to end markets, design for recyclability will help brand owners meet their goals for recyclability.

Finally, if EPR fees were to look at setting fees for multi-material structures at a much higher price point in comparison to mono-material structures, there might be enough of a financial incentive to evaluate alternatives (i.e., level the cost playing field for the initial

[52] CPP (2023) The Golden Design Rules for Plastic Packaging. Available at: https://goldendesignrules.plasticspact.ca/
[53] APR (2023) PE Film Design Guidance. Available at: https://plasticsrecycling.org/pe-film-design-guidance
[54] CPP (2023) Pathways to Mono-material Flexible Plastic Packaging. Available at: https://plasticspact.ca/wp-content/uploads/2023/04/CPP_Pathways-to-Mono-Material-Flexible-Plastic-Packaging_-Guidance-Doc.pdf

package). Financial support to brand owners who will integrate design for recyclability into their design and production process is essential if we want to create a real balance in the value chain.

Finding 2: There is a lack of reliable and granular data on FPP composition and volume, which hinders decision-making.

Recommendation: Through regulatory reporting and waste studies, improve the understanding of FPP composition and market.

The report underscored the absence of comprehensive data regarding the composition of FPP flow. It is difficult to precisely know the quantities of packaging considered as mono-material or multi-materials. It is also challenging to estimate which types of packaging have problematic barriers or what proportion of the market is made up of different multi-material packaging structures.

This lack of information is a major obstacle to guiding investment at both MRFs and reclaimers. While some packaging may be compatible with existing channels, others are not, and their complex separation can compromise overall recycling capacity.

It would therefore be useful to develop knowledge and data on FPP placed on the market, particularly through the contribution of producers to their PROs. To this end, PROs could request that FPP be classified in several more precise categories.

A harmonized way of measuring what is collected, sorted, and recycled should also be developed across Canada. This way, various stakeholders (governments, PROs, municipalities) could agree on a common characterization methodology, which should include a component enabling the identification of different resins.

Finding 3: Without accepting all FPP in the curbside collection systems, it will be very difficult to reach the ambitious voluntary and regulatory performance targets.

Recommendation: Accept all FPP in curbside collection and make MRFs responsible for capturing FPP, and not for separating FPP by resin or type.

The report demonstrated the major efforts required to achieve the various recycling targets imposed by current regulations. This begins with a significant increase in the collection rate, which seems to be achievable by focusing on the curbside collection of FPP.

One pivotal finding in this study underscores the considerable challenge MRFs face in effectively capturing FPP. Testimonials gathered from operators and reclaimers reveal that while efforts are concentrated on enhancing capture rates, it doesn't assure the purity of FPP bales, as the focus has been on improving the quality of marketed materials like fibers, as demonstrated by recent characterizations.

Given the current state of sorting technologies utilized by MRF operators, alongside the level of plant automation and available space, coupled with the impending performance targets set in specific jurisdictions, it's evident that today's MRFs fall short in capturing the maximum amount of FPP, let alone produce separate bales of FPP with varying resin compositions.

MRFs generally share a unanimous belief that they lack the capacity to produce distinct bales of flexible PE, PP, or other materials as per the specifications outlined by the reclaimers. This belief finds validation from end markets, substantiated by instances where MRF operators attempted to generate bales of different resins. Observations from industrial visits conducted across multiple facilities during the spring further confirmed and supported this finding.

It is therefore recommended that MRFs be required to focus on maximizing capture of mixed bales of FPP or bales combining rigid plastics with FPP (e.g., bale of plastics #2-7 or #3-7 including FPP), which can be managed by some end markets in Canada. MRFs need to focus on removing the contaminants deemed problematic by the buyers, namely fibres, metal, and glass.

The responsibility for separating resins should lie with reclaimers. Their task will involve demonstrating the flexibility required to accept bales of different plastic compositions and preparing the material according to their technical processes and the evolving market demand. This could possibly include packaging applications in the future. Discussions with end markets state that they, under proper market conditions, will have both the flexibility and capabilities to produce high-grade mixed FPP bales and maximize recovery.

Finding 4: The ICI sector represents an untapped feedstock of high-quality and valuable FPP.

Recommendation 4: Set up dedicated collection of FPP in ICI.

The advantages of having the volumes of FPP generated by ICI have been demonstrated in this report. The FPP collected are of better quality, primarily consisting of PE. The FPP can also be sorted at the source, meaning less contamination, and the materials are readily available in large quantities. It also reduces the impact of certain impurities of curbside FPP, and thus increases the potential for mechanical recycling of the latter.

However, the study shows that managing FPP in a mixed collection or in ICI MRFs does not guarantee that recyclers have access to this value-added source. Therefore, the main issue for ICI FPP recycling is to collect material, thus the establishment of collection programs dedicated to ICI FPP is important. The programs must be adapted to the generators' context in terms of service terms (frequency, storage method, etc.) and allow them to benefit from financial support to amortize the implementation costs when needed.

While in Québec this responsibility will fall under the PRO (Éco Entreprises Québec), other organizations could be leading the initiative in other provinces.

Finding 5: A dual-stream collection model is better for sorting FPP, both technically and economically.

Recommendation: Where not already implemented, evaluate the feasibility of dual-stream collection.

Through facility visits and experience, it has been noted that FPP can be managed more efficiently in a dual-stream MRF. Its preliminary segregation from fibre during collection simplifies the sorting process since both fibre and FPP share common mechanical properties, which complicates sorting operations in single-stream MRFs. Once mixed with the containers and packaging, the task of withdrawing them can be done with mechanical, optical or aeraulic operations, as their mechanical properties differ from containers and packaging.

It is therefore recommended that the opportunity of setting up or converting to dual-stream collection be seriously considered to increase collection rates and simplify sorting for provinces still operating under a single-stream system.

While some provinces are already engaged in the process of transitioning to a dual-stream collection system, an economic assessment is needed, including the cost involved in converting to a full dual-stream collection and sorting system in other provinces. This evaluation will gauge the extent of the transition in the different provinces, with a detailed plan of the transition mechanism based on the current capacity of the MRFs and future infrastructures that might be added.

Finding 6: Technologies and procedures exist to efficiently process FPP in a single-stream collection model, but implementing them in existing MRFs is not always possible due to operational constraints.

Recommendation: When dual stream is not suitable, evaluate the feasibility of building new single-stream MRFs designed to sort FPP more efficiently.

If the conversion from single to dual stream collection is not a possibility, then a viable pathway must be identified to reduce the pressure on MRFs caused by the need to sort high quantities of FPP. As demonstrated previously, the current capacity of MRFs does not allow for adequately capturing the new quantity of FPP that will eventually be collected. In addition, the estimated investment required to adapt the MRFs would be too high and not garner a desired outcome due to limitations within the existing infrastructure.

Creating new, purpose-built MRFs designed to effectively handle FPP is a preferred strategy. These specialized facilities would align with performance targets, mitigating the risk of contaminating existing commodities being produced. This considers the following parameters:

- the lack of updated equipment;
- the age of many facilities; and
- the anticipated increasing volumes of FPP inbound in the next few years.

One viable approach to consider is establishing agreements with existing MRFs for a longer-term commitment to construct a new facility. This new infrastructure would be purposefully designed and optimized to efficiently capture FPP while ensuring adherence to reclaimer specifications for other materials being sold. This approach could also avoid pushback from the existing players who would have to retire existing plants, as they would have new long-term contracts. This would also be an excellent opportunity to draw up specifications for the construction of new MRFs that would focus on choosing the best, most efficient technologies for top performance.

Ideally, a new network of state-of-the-art MRFs would be built to ensure that the quantity of FPP captured is maximized, the quality of the FPP bales reduces recycling costs downstream, and that the overall commodity quality in general is improved.

Finding 7: Loose FPP represents one of the most challenging and costly materials to sort for existing single-stream collection MRFs.

Recommendation: If building a new single-stream MRF is not feasible, implement solutions for reducing loose FPP, such as depots and bag-in-bag collection programs.

As stated in Recommendation 5, the current sorting infrastructure is not designed nor prepared to receive larger quantities of loose FPP. To see immediate results, there is a need to reduce pressure on single-stream MRFs by implementing alternative collection programs, such as:

• Use of depots and return-to-retail: Although this recommendation applies more to single stream, it can also prove beneficial in the context of a dual stream, as observed in Recycle BC's program. For example, depots in commercial areas and eco-centres can become FPP collection points, as well as retailers who will accept this material on behalf of a stewardship agency.

• Use a dedicated bag-in-bag collection program: To reduce pressures on single-stream MRFs, it will be important to encourage households to bundle FPP in one clear package. Throughout the years, this collection method has demonstrated its effectiveness in streamlining collection processes, reducing the workload for sorters and maintenance teams, and rendering their tasks more manageable. Experiences from pilot projects and specific bag-in-bag programs in certain Canadian regions, such as the Hefty Bag Program and Calgary's recent MRF commissioning, reveal that sustaining such initiatives demands ongoing and consistent support to citizens. It's essential to highlight that these programs demonstrate efficiency through consistent and transparent communication, coupled with the provision of collection bags to citizens at no cost. Improving the documentation of bag usage for efficiency is necessary. Additionally, exploring alternatives to single-use bags, like placing FPP within the largest bag residents aim to recycle, could offer a viable solution.

Finding 8: There are only a few FPP reclaimers in Canada and their capacity to process large volumes and non-PE FPP are limited.

Recommendation: Develop new capacities for FPP separation at reclaimers and implement emerging sorting and recycling technologies.

Regardless of the option(s) selected and applied across the country to boost recovery and ensure its growth (dual-stream collection, depots, etc.), the proposal to promote the production of bales of mixed FPP or, where the infrastructure in the MRF is not capable of separating FPP, mixed rigid and flexible plastics is the most prudent approach to follow. However, this method hinges on the establishment of a recycling plant network dedicated to managing mixed FPP.

Traditionally, the secondary sorting of FPP can generally be ensured by two alternatives: the RFEP and the PRF, both dedicated to the separation and preparation of materials, but whose processes and business models are governed differently. The field assessment and interviews conducted with reclaimers in the spring of 2023 demonstrates the technological expertise as well as a knowledge of processes and customer specific requirements that justify the establishment of dedicated plants for each reclaimer, or RFEP. Introducing a PRF as an intermediary step wouldn't provide any added benefits. Reclaimers have explicitly stated their necessity to conduct independent sorting and cleaning to meet their feedstock specifications. This additional step would only increase costs without offering any noticeable advantages in product value before reaching the downstream reclaimer.

Sorting FPP in a dedicated RFEP also appears to be the most economical option and allows for more significant investment in advanced technologies. As an example, the investment required for the integration of AI and NIR material recognition might prove more judicious in a few dedicated installations for sorting FPP, rather than if it were required to be installed in each of the 75 or more MRFs throughout the country. The same would apply if/where digital watermarking was widely adopted for use in packaging, thanks to image recognition that allows for the detection of FPP by attributes. For example, the results of a CPT pilot project, in collaboration with Digimarc and Pellenc ST, in 2022 proved a sorting efficiency of >95% to separate mono-material from multi-material packaging[55], which is consistent to the development of the Holy Grail project in Europe.

Implementing a structured RFEP network is the optimal option for FPP separation. This network must at least rely on the modernization of the existing RFEP in BC (or on the establishment of additional capacities in Western Canada), and on the introduction of one new RFEP in Ontario and Québec, respectively, to support FPP recycling in Eastern Canada and Atlantic regions. Based on the preliminary feasibility analysis carried out, the cost of a new reclaiming facility including RFEP is estimated at around $50 million.

A period of 18 to 24 months is required for building and commissioning. The essential conditions for setting up such a network are as follows:

- Supply guarantee for a minimum of 10 years;
- For a new plant, a minimum supply of 50,000 TPY of mixed plastics, including FPP; and
- For an existing plant, a minimum supply guarantee of 12,000 TPY of FPP.

Finding 9: End-markets for FPP collected through curbside collection systems remain limited, especially for hard-to-recycle materials.

Recommendation: Through supply chain collaboration, support the building of viable end-markets for all types of collected FPP, including hard-to-recycle materials.

As explained at the outset, the biggest obstacle to improving the value of FPP is the absence of a consistent market. The fact that plastic markets can rely on the supply of low-cost virgin resin remains a major disruptor for recycled resin. Continuing to invest and engage in the use of more recycled content is the best way for producers to boost demand.

Furthermore, as history has shown, economic recessions cause major disruptions in the consumption of goods, with the exception of one sector: food. The food packaging sector is among one of the few not experiencing the same financial disruptions as experienced by other sectors during the down economy. This resilience was recently confirmed by a reclaimer who observed a slowdown across all markets except for food packaging, which

[55] CPT (2022) Preliminary analysis of improving sorting capacity for flexible packaging using digital watermarking technology Link

continues to maintain a full order book. This is why special emphasis should be placed on the development of markets linked to the production of FDA approved PCR.

At the same time, new outlets should be identified and developed for specific FPP, such as monoPP or multi-materials. Recent work has shown the potential of growing the demand for those markets, which would help the viability of the whole value chain.

7.2. Success factors

The success and sustainability of FPP recovery and recycling also relies on the following critical success factors:

Feedstock guarantee

Among the reclaimers surveyed who have demonstrated interest, the most important criterion respecting their intention to invest in new treatment capacities is the guarantee of supply. These individuals have experience in the recycling industry, are proficient in its operation, have a network of suppliers and buyers, and have an advanced knowledge of the properties of resins.

From their perspective, having consistent access to high-quality feedstock over a guaranteed period holds far greater importance as a decision-making criterion than obtaining financial support.

Innovation

To reach regulatory performance goals and enable reclaimers to produce recyclates meeting PCR content demands, investments in MRFs and recycling infrastructures are essential. These upgrades will ensure a steady supply of feedstock, supporting producers in meeting their PCR content requirements. As new EPR models are being progressively adopted in different Canadian jurisdictions, the time is now to modernize our recycling infrastructure and promote innovation in sorting by material attribute.

One of the positive points of this project is that the interested promoters are known and have considerable expertise and experience in the recycling of FPP in Canada.

8. Conclusion

The objective of the PRFLEX study was to identify favorable conditions for improving the capture and recycling of FPP in Canada. It first paints a picture of the quantitative generation and collection of FPP for each province, whether from the residential or ICI sector, and highlights the shortcomings of the current collection system. It also highlights the potential to obtain value-added post-consumer plastics feedstock that are currently not accessible to reclaimers.

The research presented in the PRFLEX study demonstrates that the current state of MRFs won't allow for high-capture rates of FPP, let alone the regulatory targets that will eventually be in force. The technical assessment carried out exposes technological and physical issues that limit the ability of MRFs to improve their performance. The absence of markets and income from the sale of this material inevitably forces them to concentrate their efforts on more lucrative materials, and to manage FPF in the same way as other contaminants. The observations and analysis carried out show that:

- MRFs in their current state cannot adequately manage FPP and will be even less able to do so in the future with an increase in the quantities collected. New infrastructure development is essential in the near-term and must integrate the most efficient and versatile technologies to meet future needs.
- MRFs that receive and sort FPP collected in a dual-stream system benefit from a simplified process, where separating the FPP from the stream requires only a few pieces of equipment. This simplified method not only reduces the effort needed to extract FPP from the stream but also facilitates the decontamination of fibers due to the low proportion of FPP present in the fiber stream.
- The FPP collection offered in depots also make it possible to reduce the impact of this material when sorting, in addition to making it possible to get hold of material of equivalent or superior quality, as demonstrated by Recycle BC.
- Requiring MRFs to sort by resin poses significant challenges due to functional limitations. The complexity of FPP packaging, with its varied structures and constraints, makes it impractical to produce bales that align with reclaimers' specifications. This complexity essentially rules out the feasibility to produce corresponding bales to reclaimers' specifications.

Finally, the study demonstrates the need to structure and improve the current network of reclaimers across the country, and to encourage the establishment of new infrastructures through long-term contractual commitments. Today, no reclaimer has the capacity to effectively separate FPP by type of resin or possibly by attribute at a large scale. This underscores the need to establish facilities capable of removing contaminants and separating FPP according to its properties and the criteria of the manufacturers or their attributes. However, the discussions confirmed a real interest on the part of end-market operators with great expertise to get involved in the development of the network.

Current outlets make it possible to integrate mechanically recycled resins; however, the contribution of chemical recycling is inevitable considering the demand for the production of food-grade and transparent rPE, especially when considering that the production of food packaging remains insensitive to economic contractions. Canada will soon have three sites for chemical recycling, including two under development in central and eastern Canada, which will complement mechanical recycling.

The PRFLEX study yields nine key recommendations:

1. Aim for better harmonization of FPP through design for recyclability measures following established industry guidelines.
2. Improve the understanding of FPP composition and markets.
3. Accept all FPP in curbside collection and make MRFs responsible for capturing FPP.
4. Set up dedicated collections of FPP in ICI.
5. Evaluate the feasibility of dual-stream collection.
6. When dual stream is not suitable, evaluate the feasibility of building new single-stream MRFs designed to sort FPP more efficiently.
7. If building a new single-stream MRF is not feasible, implement solutions for reducing loose FPP, such as depots and bag-in-bag collection programs.
8. Develop new capacities for FPP separation at reclaimers and implement emerging sorting and recycling technologies.
9. Support the building of viable end-markets for all types of collected FPP.

These recommendations are accompanied by key factors, tagged as essential to the success of the optimization process.

In conclusion, this study highlights the complexity of managing FPP, and stresses the involvement of all supply chain actors to improve the system. No miracle solution for sorting and market development is possible. The deployment of new infrastructure adopting the latest technologies, as well as a synergy between producers and end-market recyclers who take charge of the materials once collected, will be necessary. It is unthinkable to believe that performance targets will be reached quickly; it is more reasonable to envision a development and optimization plan that will extend over a ten-year horizon. The actions and pilot projects proposed in this report will also make it possible to identify opportunities in the coming months that will enhance this development and optimization plan.

It is up to each PRO to determine the solution that best suits the context of the province(s) where they operate to enable the organization to achieve regulatory targets. It is up to each recycler, existing or prospective, to determine how involved they wish to be in the development of new processing capacities. That said, producers must prioritize investing in materials that are actually recyclable. This step is crucial, also considering that producers are among the primary beneficiaries of recycling efforts.

This report was intended to provide a sufficient baseline to implement industrial scale solutions for FPP recycling. While there is sufficient information to develop the local business cases, some immediate actions can be taken to ensure the implementation of future investments.

Appendix A – Sources for assessing FPP generation and recovery

Sources for Deposit Return Schemes Data

Province / Region	Supplied	Generated	Collected	Sorted	Recycled
All programs	Based on 2022 annual report 2022 or data supplied by the program operator.	Same as supplied.	Based on 2022 annual report 2022 or data supplied by the program operator.	Same as collected.	Based on a yield factor.

Sources for Residential Data

Information on plastic packaging supplied, collected, and sorted from the residential sector (i.e., households) were derived from two main sources:

1. The published annual reports of regulated EPR systems for PPP that operate in British Columbia, Saskatchewan, Manitoba, Ontario, and Québec. In most cases, data for plastic packaging supplied and collected were available through the system operators though there is significant variation in reporting between PPP system operators.
2. Municipal government waste management data were collected from each province and territory. This includes data related to:
    - residential waste disposal rates;
    - waste composition studies;
    - recycling inbound and outbound studies; and
    - recycling collected and sorted tonnes.

For residential sector data, the generated amount is greater than the amount reported as supplied by PROs operating regulated EPR systems for PPP. This is because all the PPP systems in Canada apply a de minimis that excludes small producers generating materials in quantities and/or dollar values below a defined limit. On the other hand, waste characterization methodologies have limitation that could overestimate the data, such as the potential presence of small ICI in the samples, the number of samples taken, or the weight of moisture / residue in PPP.

Waste audit and waste composition studies were used to assess the amount of designated material generated to account for the quantity supplied by exempt producers. However there remains little consistency in the municipal waste data collected Canada-wide, especially related to the types of plastic resins and packaging formats that are tracked in the waste audits (i.e., conducted at curbside, inbound loads to the MRF, outbound loads at from the MRF) or in waste composition studies (i.e., conducted at landfill). There is also significant variation in how often waste audits and waste composition studies are undertaken (annually, biannually, or longer) and the sampling frequency used for each study (e.g., monthly assessments, seasonal assessments, or one assessment per year). Wherever possible, seasonal audits with more detailed categories were used.

The table below provides a summary the data sources used to inform residential sector plastic flow analyses. Recycling for all regions was calculated using a yield factor based on discussions with the downstream processors.

Province / Region	Generated	Supplied	Collected	Sorted
British Columbia	Calculation and extrapolation based on waste composition studies (2021/2022).	Based on Recycle BC Annual Report (2022).	Based on Recycle BC Annual Report (2022).	Estimated marketed tonnes and calculation based on post-collection contract obligation and collected tonnage
Alberta	Calculation and extrapolation based on waste composition studies from two municipalities (garbage) and inbound composition from two MRFs (collected) and inbound quantity based on ACES report.	N/A	Calculation and extrapolation based on inbound composition studies from two MRFs (collected) and inbound quantity based on ACES Report.[56]	Calculation and extrapolation based on sorted tonnes from Calgary, Edmonton, and Lethbridge MRFs.
Saskatchewan	Calculation and extrapolation based on Saskatoon (2019) waste composition study (waste and recycling).	Based on Multi-Material Stewardship Saskatchewan Annual Report (2022).	Calculation and extrapolation based on waste composition studies (waste and recycling) (2019).	Calculation and extrapolation based on sorted tonnes from Regina's MRF.
Manitoba	Calculation and extrapolation based on (waste composition studies (waste and recycling) (2019).	Based on Multi-Material Stewardship Manitoba Annual Report (2022).	Calculation and extrapolation based on waste composition studies (waste and recycling) (2019).	Calculation and extrapolation based on sorted tonnes from Winnipeg's MRF.

[56] For the 2022 reporting year, the City of Edmonton made significant improvements to its MRF and began to collect a wider array of plastics.

Province / Region	Generated	Supplied	Collected	Sorted
Ontario	Calculation and extrapolation based on (waste composition studies (waste and recycling) (2021/2022).	Based on Stewardship Ontario Pay-In-Model Data (2022).	Calculation based on CIF/SO waste composition study and RPRA Datacall (2022).	RPRA Datacall (2022) for sorted tonnes.
Québec	2022 Province wide waste composition study (Garbage and Recycling).	2022 Schedule of Contribution calculation.	2022 Province wide waste composition study (Garbage and Recycling).	Calculation based on 2022 price index and marketed tonnes from RECYC-QUEBEC.
Atlantic Canada	Calculation and extrapolation based on New Brunswick composition studies (2019).	N/A	Calculation and extrapolation based on New Brunswick composition studies (2019).	Calculation and extrapolation based on Nova Scotia and Prince Edward Island marketed tonnes and Central Newfoundland MRF.
Territories	No data available for the residential sector.	N/A	No data available for the residential sector.	No data available for the residential sector.

Appendix B - Protocol for flexible composition study

Sorting categories

Sorting by resin

1. Small Format Flexible (all resins) < 2” or < 51 mm
2. #2 #4 PE Flexible (carry-out bags)
3. #2 #4 PE Flexible (all other)
4. #1 PET Flexible
5. #3 PVC Flexible
6. #5 PP Flexible
7. #7 Bio Flexible (PLA, PHA, PHB)
8. Multilayer flexibles and non-labelled stand-up pouches
9. Flexible plastic non-packaging
10. All other Flexible Plastic Packaging without RIC (temporary category)

Sorting by size

1. < Format A4 (21x30 cm)
2. > Format A4 (21x30 cm)

Sorting by print coverage

1. <25 %
2. Between 25 % and 50 %
3. >50 %

Sorting steps

1. Separate flexibles by resin according to the RIC, otherwise group uncoded flexibles in the temporary category “Flexible without RIC #10”
    a. All packaging without RIC, but known by the supplier to be LDPE flexible plastic packaging (e.g., bag cleaner film, transport film) will be classified under category #3.
    b. All stand-up Pouches (unless labelled with a single RIC, other than #7) will be classified under category #8.
2. Weigh each category of resin and the “non-coded plastics” category.
3. Group all flexibles.
4. Separate flexibles by size and print coverage.
5. Weigh the 6 categories combining size and print coverage.
6. From category #10, create 4 sub-samples of 50 uncoded flexibles (total of 200 units).
7. Use a resin identification device, model microPHAZIR, to identify the type(s) of resin, by applying the following steps:
    a. Clean the film surface;
    b. 2 successive readings on the outer layer;
    c. 2 successive readings on the inner layer;
    d. If the device identifies the same resin on the 4 readings, classify the film in one of the categories #3 to #7;
    e. If the tool identifies different resins on at least one of the 4 readings, classify the film in category #8; and
    f. Apply the proportions obtained to the weight of category #10 for a distribution under categories #3 to #8.

Appendix C - Review of equipment and cost

Various equipment configurations can achieve FPP separation, some of which are listed below to provide an idea of the technical offer. The technical and financial data presented in this section serve solely for informational purposes and do not bind the equipment vendors or the authors of this report in any way. The prices provided do not include integration (engineering, installation, commissioning, transport, etc.) and peripheral equipment, if applicable.

Pre-sort

ID	Equipment	Description	Vendors
A	Pre-sort screen	Star mounted shafts of high radius allowing for material to be screened in a thin layer of the screen deck (screen size: 9 to 13 ¾ in.)	AWS 880 by Lubo Recycling Solutions Link
		Current price range: to be determined	
B	Auger Separator	Spiral shaft or auger screen separating large size items (screen size: variable)	Auger Screen by CP Group Link SPLITTER screen by Günther Link
		Current price range: $380 000 to $550 000	
C	Trommel	Rotating drum that separates material flow to the desired fraction size. It might also be provided with knives inside to open the plastic bags. (screen size: variable)	Mach Trommels by Machinex Link Trommel by Sherbrooke OEM Link Sparta Manufacturing Link
		Current price range: $300 000 to $375 000 (Standard 20 ft long, 8 ft diameter, three cuts)	
D	Oversize remover	Retracting and extending driving spikes mounted on rotor to remove any 2D in medium and oversize fractions	Oversize separator by Matthiesen Link
		Current price range: $220 000 to $250 000 *(Bag opener's price as shown is approximately $400 000)*	

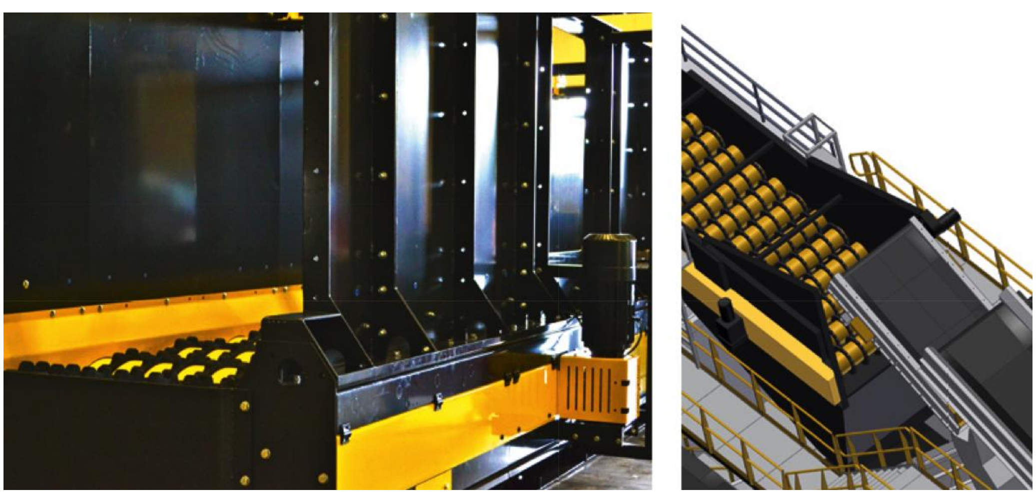


Figure 22 Lubo AWS 880 (A)

Figure 23 CP Auger Screen (B)

Figure 24 Machinex Trommel (C)

Figure 25 Matthiessen Oversize separator combined with a bag ripper and air separation (D)

Sorting

ID	Equipment	Description	Vendors
E	Film grabber	A revolving drum with inward and outward moving pins removes films from a recyclables stream (fraction larger than A4 size).	Bollegraf (BRS) Machinex
		Current price range: 150-250 000$	
F	Film extractor	Conveyor composed of a mesh belt and fans in its interior portion, to be used on a container line to remove paper and film from the material stream	Machinex
		Current price range: to be determined	
G	Air knife	Equipment designed to remove lightweight material from a stream. Based on the differences in particle shape and density, a light item can be lifted up in the air stream as the heavies are discharged at the bottom. Most commonly marketed equipment are zig zags and airknife separators.	Nihot Impact Air Andela Product Ecocept by Alfyma
		Current price range: $80 000$ to $180 000	
H	Optical sorter	Passing at high speed under a light source, a portion of the wavelengths is reflected and captured by lenses that transmit the signal to a spectrometer or to the camera, which associates each reading with a specific curve. When the material passes under the lenses, a command is sent to the corresponding ejection nozzles that will then blow the material into the appropriate chute.	NRT (BHS) Pellenc ST Eagle Vizion Tomra (VDRS) MSS (CP Manufacturing) Mach Hyspec (Machinex) Staedler
		Current price range: $400 000 to 700 000 (price determined by options: stabilizing device, induction module (ferrous detection), profile and colour detection)	
I	AI/Robot for film	AI-powered automation system for film removal and recovery optimized for quality control on fibre lines.	Vortex by Amp Robotics
		Current price range: $530 000	

Figure 26 Optical sorter, nrt (H)

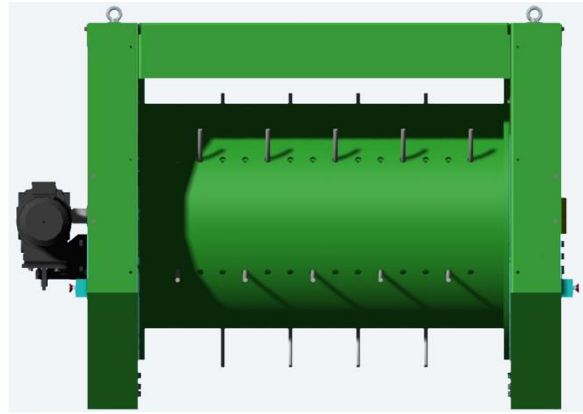


Figure 27 Film grabber, Bollegraf (E)

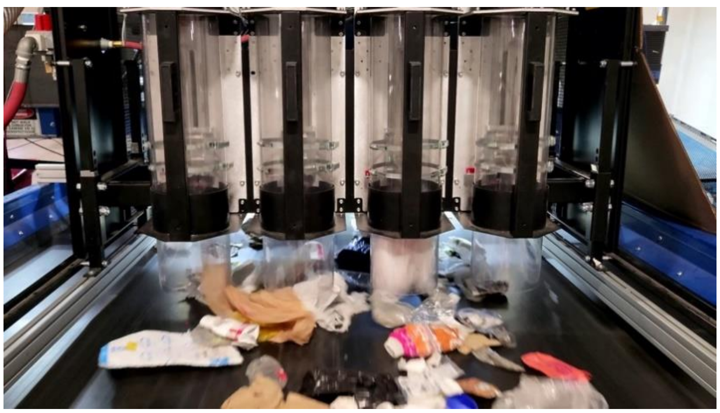


Figure 28 Vortex, AMP robotic (I)

Appendix D – FPP Detection trials

Project	Detection trials on targeted flexible packaging with optical sorting technology Part 1 – Static testing
Client	PRFLEX (CPT) N23-132
Testing site	Recup Estrie 2180 Claude-Greffard Street, Sherbrooke, Qc (Residential curbside MRF)
Equipment	Pellenc ST Mistral+ 2800 binary optical sorting equipment with induction detector Date of installation: March 2020 Program: settings adapted for MRF operation, importation of Pellenc ST's testing program for flexible
Date	June 5th, 2023
Technical project managers	Patrick Bergeron, NovAxia Gregory Mattioli, Expert Process

Scope of test
Determine the detection capacity of optical sorting for targeted packaging.
Sample selection and preparation
The targeted FPP samples were selected based on their material, their multi-layer composition, their colour, and the presence of metallized barriers. The samples are shown on pages 64 to 68 of this report. A photographic report is sent to the technical adviser to assess whether pre-programming of the equipment is required.
Preliminary Verification
Prior to carrying out the tests, the technical project managers checked the following points:

- Safety tour with plant manager and risk assessment;
- Compliance with internal rules on the wearing of personal protective equipment;
- Equipment inspection: maintenance log, calibration, camera, pneumatic and electrical connection, etc.;
- Presence of alerts and error logs;
- Status of critical components (solenoid valves, halogens, reflective glass, nozzles, etc.); and
- Operating software status (start-up, data acquisition, signal processing, etc.).

Photos and videos were taken, if required, and observations were recorded in a technical report.

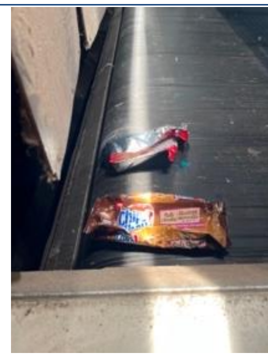
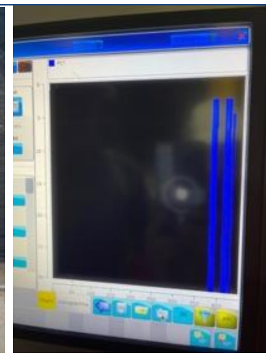
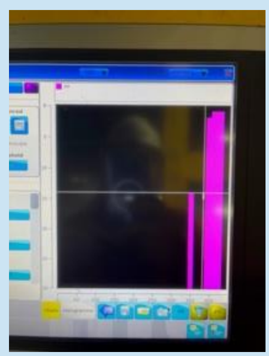
Execution of static tests
For each targeted FPP, the following methodology is followed:

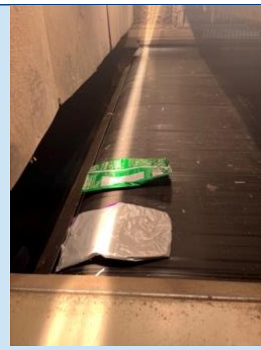
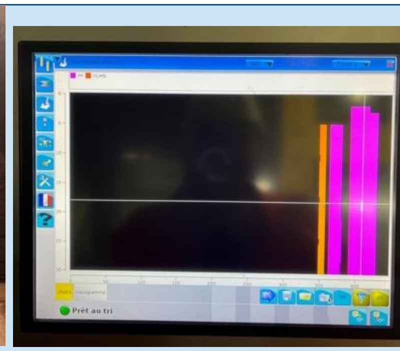
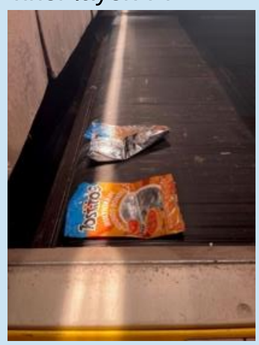
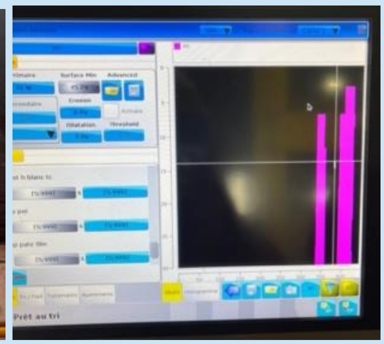
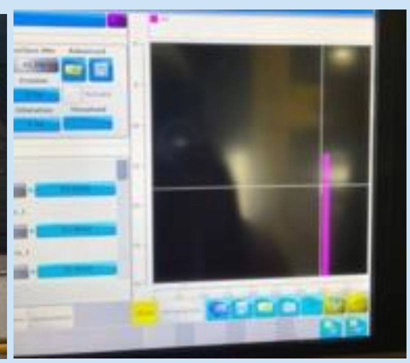
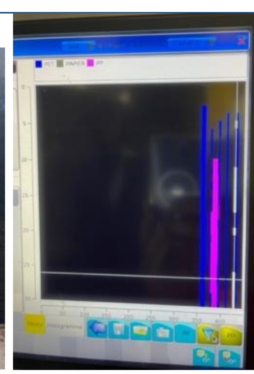
- Ensure that the receiving (post-ejection) conveyors is clear of any material, tools, etc.;
- Complete the data sheet with preliminary information;
- Place the packages on the belt;
- Confirm operating status and detection capability (If this fails, recalibrate the optical sorter);
- When detection capability is confirmed, enter the information on the form;
- Take a photo of the composition chart. (Note any observations relating to technical problems); and
- Repeat until three identical results are obtained.

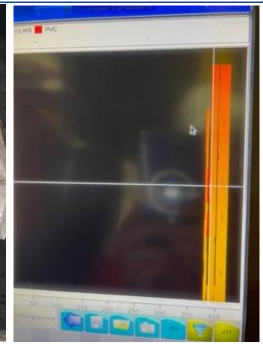
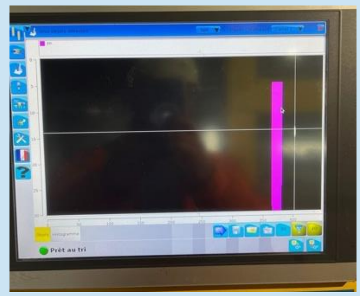
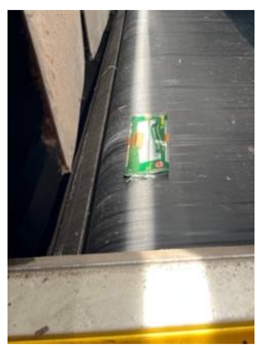
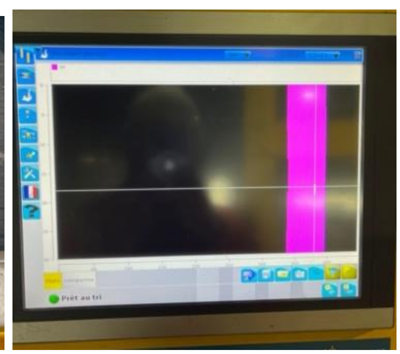
Results

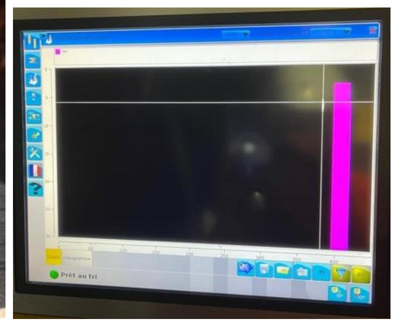
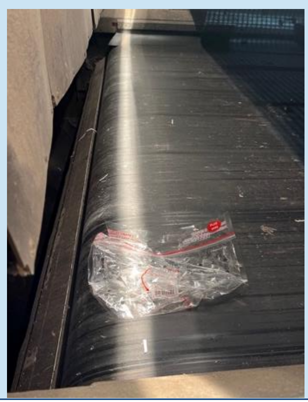
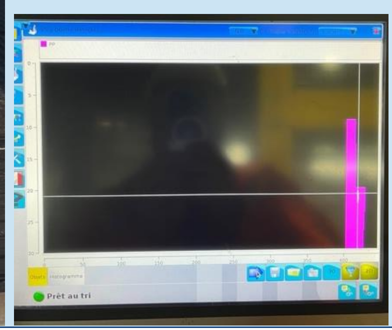
The 12 targeted FPP samples were all detected by the optical sorter, which was able to identify the composition of whether the material was a plastic or a fiber. However, the optical sorter camera was unable to identify internal metallic coatings and returned a zero result, unless a laminate covered the metalized surface (e.g., PET laminate over the cookies packaging inner surface). Since the optical sorter used for this test had an inductive sensor capable of detecting metals, a FPP with a metallized surface was detected by the sensor and ejected adequately.

It should also be noted that at present, only a few MRFs are equipped with optical sorters that have an induction sensor. In the absence of this sensor, no detection of a FPP with metallic layers is possible.

Packaging	Product detected	Identified material
Cookies packaging	☑ Yes ☐ No	Outer layer: PET Inner layer: PET
		 
Potato chip packaging	☑ Yes ☐ No	
		Outer layer: PP Inner layer: PP  
		Outer layer: PP + LDPE Inner layer: PP

		 
		Outer layer: PP Inner layer: PP  
		Outer layer: PP Inner layer: --  
Cat nutrition packaging	☑ Yes ☐ No	Outer layer: PET-PP-fibre Inner layer: PE-PVC
		 

		 
Twix chocolate bar packaging	☑ Yes ☐ No	Outer layer: PP Inner layer: --
		 
Pasta packaging	☑ Yes ☐ No	
		Outer layer: PP Inner layer: PP  
		Outer layer: PP Inner layer: PP  

		Outer layer: PP Inner layer: PP   Seasoning bag: Due to its dimensions and depending on the equipment placed upstream, it is possible that this sachet of seasoning does not reach the optical sorter. Nevertheless, the tests show if it did that it would not be detected by the camera but could be managed by the induction separator.
Grape packaging	☑ Yes ☐ No	Outer layer: PP Inner layer: PP
		 
Bed sheet bag	☑ Yes ☐ No	Outer layer: Fibre+PET (zipper)+PVC