MATERIALS RECOVERY FOR THE FUTURE

FEBRUARY 23, 2023
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MRFF FINAL PROJECT REPORT

PREPARED BY: RRS | recycle.com

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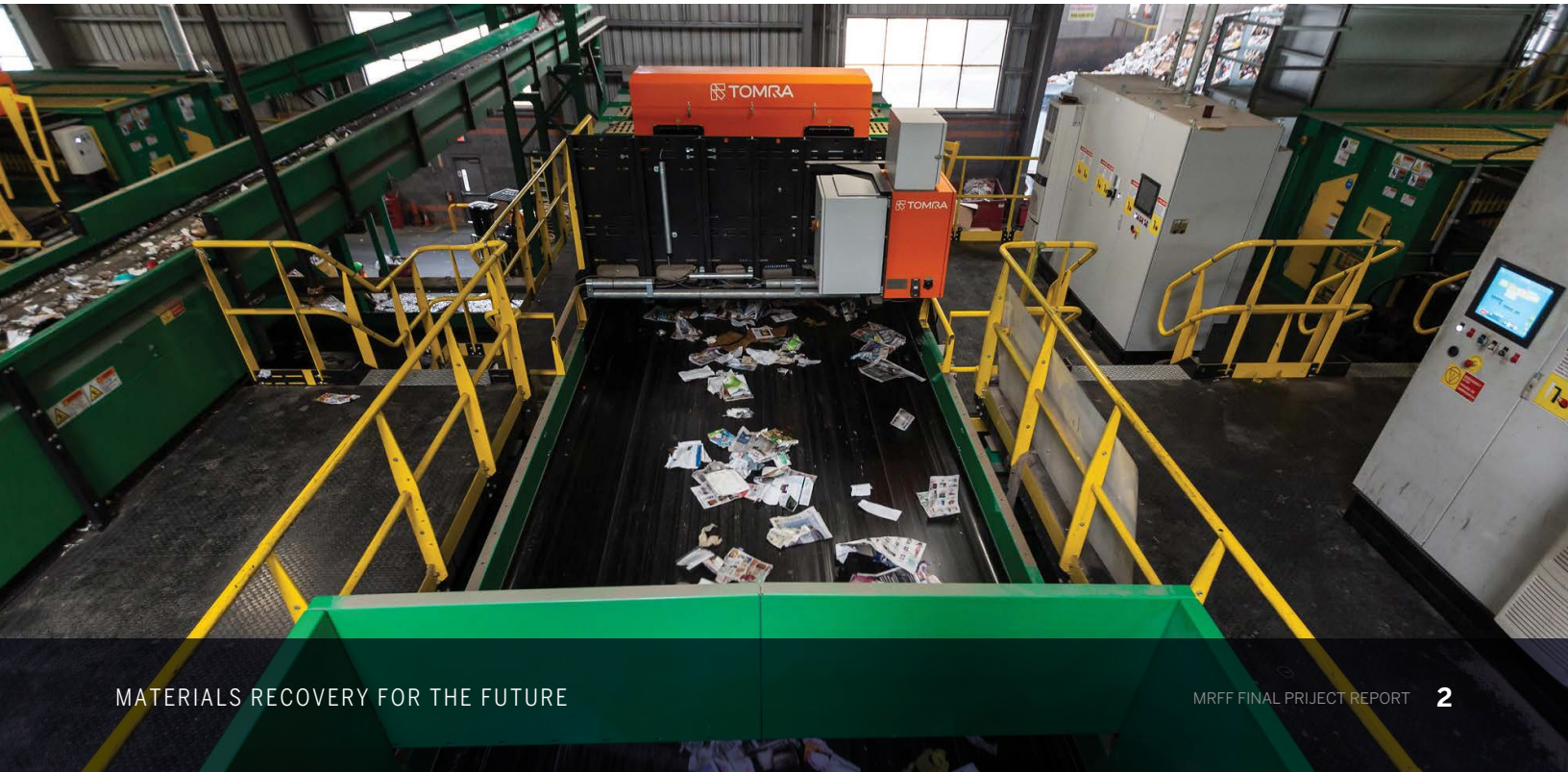

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EXECUTIVE SUMMARY

The learnings in this report are published as a follow on to the TotalRecycle MRF Pilot project, which served as proof of concept for material recovery facility-curbside recycling of flexible plastic packaging (FPP). The report is intended to aid further scaling of results and increase recycling of this material which is predominantly landfilled today. It is the third and final report of the Materials Recovery for the Future Project and covers the period between August 2020 and the end of 2022.

As of December 2022, the TotalRecycle MRF, operated by J.P. Mascaro & Sons, had successfully diverted over 2,728,250 pounds of flexible plastic packaging from the landfill as a result of their new curbside recycling program. While numerous markets have tested the bale, the primary market for the mixed FPP bale, known as rFlex, has been roof coverboard. Notable results were also obtained in trials to reprocess rFlex back into blown film.

In Summer 2020, J.P. Mascaro & Sons installed additional equipment at TotalRecycle to further improve FPP capture. Outcomes were difficult to measure during the COVID-19 pandemic, as unprecedented labor shortages disrupted MRF operations. These labor shortages also slowed the pace of development in manufacturing end markets interested in using rFlex as feedstock.

The MRFF project received additional funding via a U.S. Department of Energy REMADE Manufacturing Institute grant, enabling Idaho National Laboratory and RRS to study the economic and environmental feasibility of sorting and producing rFlex in commercial MRFs. Researchers compared the use of recycled FPP to traditionally used materials in four different product pathways – roof coverboard, plastic pallets, plastic pellets to be used in injection molding, etc., and film. The analysis demonstrates reductions in greenhouse gas emissions from use of rFlex are often greater than 25% compared to products made with virgin materials. Detailed results of this study have been published in the scientific journal ***Resources, Conservation and Recycling***.

This report provides recommendations from the RRS Research Team considering current conditions in both recycling infrastructure and domestic manufacturing. More carts for residential collection, an increased degree of automated MRF sorting, supply chain partnerships, and financial investment in MRF upgrades as well as major end markets sourcing PCR film and flexible packaging are recommended.

More information on this project can be found at **https://www.materialsrecoveryforthefuture.com/**

ACKNOWLEDGEMENTS

The RRS Research Team wishes to acknowledge the following project members who were instrumental to the results published herein. These collaborations were key to our collective success.

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Idaho National Laboratory Research Team – Ruby Nguyen

RFlex End Market Network – Scott Hammer, Charter Next Generation; Thomas J. Kelly, Kelly Green Products

American Chemistry Council – Shari Jackson

Research Sponsors – please visit **https://www.materialsrecoveryforthefuture.com/** for a complete list of brand owners and trade associations that sponsored this research.

Our Sincere Thanks,
The RRS Research Team
Susan Graff, Beth Coddington, Christopher King, Kerry Sandford, Anne Johnson, Rachel Perlman

INTRODUCTION

Materials Recovery for the Future was a collaborative project among resin producers, brand owners, packaging manufacturers, and recyclers to study the feasibility of adapting large recycling facilities to sort flexible plastic packaging (FPP).

This report serves as the third and final report of the MRFF project, covering the two-year period from August 2020 to the end of 2022. Previous reports prepared by RRS in 2016 and 2020[1] provided comprehensive results of automated MRF sorting technologies, the pilot stage of the project, and end market testing.

In 2019, the American Chemistry Council and MRFF industry sponsors received funding from the U.S. Department of Energy in partnership with the REMADE Institute to study the material efficiency and greenhouse gas emission impacts of flexible packaging recycling. This study included a life cycle inventory and compared the use of recycled flexible packaging to traditionally used materials as feedstock in several types of products. Federal funding also facilitated a study to optimize MRF sorting under different operating conditions and additional end market testing. A detailed scientific paper co-authored by Idaho National Laboratory and RRS researchers was published in the scientific journal *Resources, Conservation & Recycling* in 2023. This peer-reviewed paper discusses the findings of the material efficiency study in greater detail.

Yingqian Lin, et al., *Economic and environmental feasibility of recycling flexible plastic packaging from single stream collection* (Resources, Conservation and Recycling, Volume 192, 2023) https://doi.org/10.1016/j.resconrec.2023.106908

MRFF

VISION

The shared vision of the sponsors involved in this collective action project is that flexible packaging be recycled curbside, and that the recovery community captures value from it. The sponsors further articulated that recycling this material via this pathway achieve:

- **Highest and best value for recycled materials**
- **Positive environmental impacts based on life cycle assessment**
- **Net financial benefits for recyclers**
- **Healthy workplace for recyclers**
- **Widespread consumer access**

These goals are discussed in the Results section of the report as they relate to collection, MRF sorting, and end market steps for recycling FPP curbside. The project aim was to ensure that if FPP was accepted in curbside programs, it would successfully find its way to the rFlex bale, rather than ending up as residue or contaminating other MRF products.

BACKGROUND

FPP is a high-volume stream of consumer packaging. RRS estimated at the onset of the project that over 12 billion pounds of FPP is consumed annually in the U.S., twice the size of the PET bottle market, and the volume has steadily increased since then. The qualities of flexible packaging that make it environmentally preferable – its light weight, the small quantity of raw material needed in its production, and its superior performance in reducing food spoilage – have motivated its use. But this lightweight quality comes with a price to recyclers: equipment upgrades are required to sort this packaging stream.

Flexible plastic packaging comes in a wide array of shapes, sizes, and forms – from four-ounce baby food pouches to chip bags to 35-pound dog food sacks. This project aimed to capture this entire assortment, except for extremely small packages (smaller than 2.5x4 inches) or anything made of PVC.

Many MRFs do not invite this modern packaging material into single stream systems, particularly since in most cases sorting systems are eight to ten years old. Even though FPP is not typically accepted, this material is present in MRF infeed at levels of 1-4.5% by weight based on composition studies by Van Dyk Recycling Solutions conducted in 2018.

Past RRS research for MRFF sponsors confirmed that FPP generally flows with paper in large single stream MRFs due to its two-dimensional shape. Thus, removing FPP on paper lines is the most efficient, scalable way to capture this material in large MRFs (see Figure 2). During this project, removal was accomplished via upgrades to optical sorters, air flow controls, collection hoods, and other peripherals on fiber lines in a large, modern MRF with anti-wrap screens.

Currently many modern MRFs negatively sort FPP and combine it with other residuals for shipping to landfill due to the relatively low quantities of uninvited material received. Given the potentially large size of the FPP stream available for recycling, the positive sort equipment upgrade installed was expected to provide multiple economic benefits for the industry:

- Improve paper bale quality for optimal quality and revenues from MRF ONP and Mixed Paper sales
- Decrease manual quality control (QC) staff required on MRF paper lines during sortation
- Decrease landfill costs
- Provide operator flexibility to make an additional plastic commodity bale as market demand for PCR plastic has risen

The MRFF research agenda did not include detailed design and testing of the reprocessing steps necessary to recycle the FPP bale for sale to plastic-only markets that make durable products, pellets, and film. Wash steps will be required, just as they are required to reclaim other resins such as PET, HDPE and PP. More detailed supply and economic analysis is needed to commercialize the necessary mechanical and chemical recycling steps. Supply would also increase if there were appropriate policy interventions to require more widespread collection and sorting instead of landfilling (see Figure 14).

1. Available online at Research Results - Materials Recovery for the Future https://www.materialsrecoveryforthefuture.com/research-results/

THE MRF EQUIPMENT UPGRADE TO SORT FPP

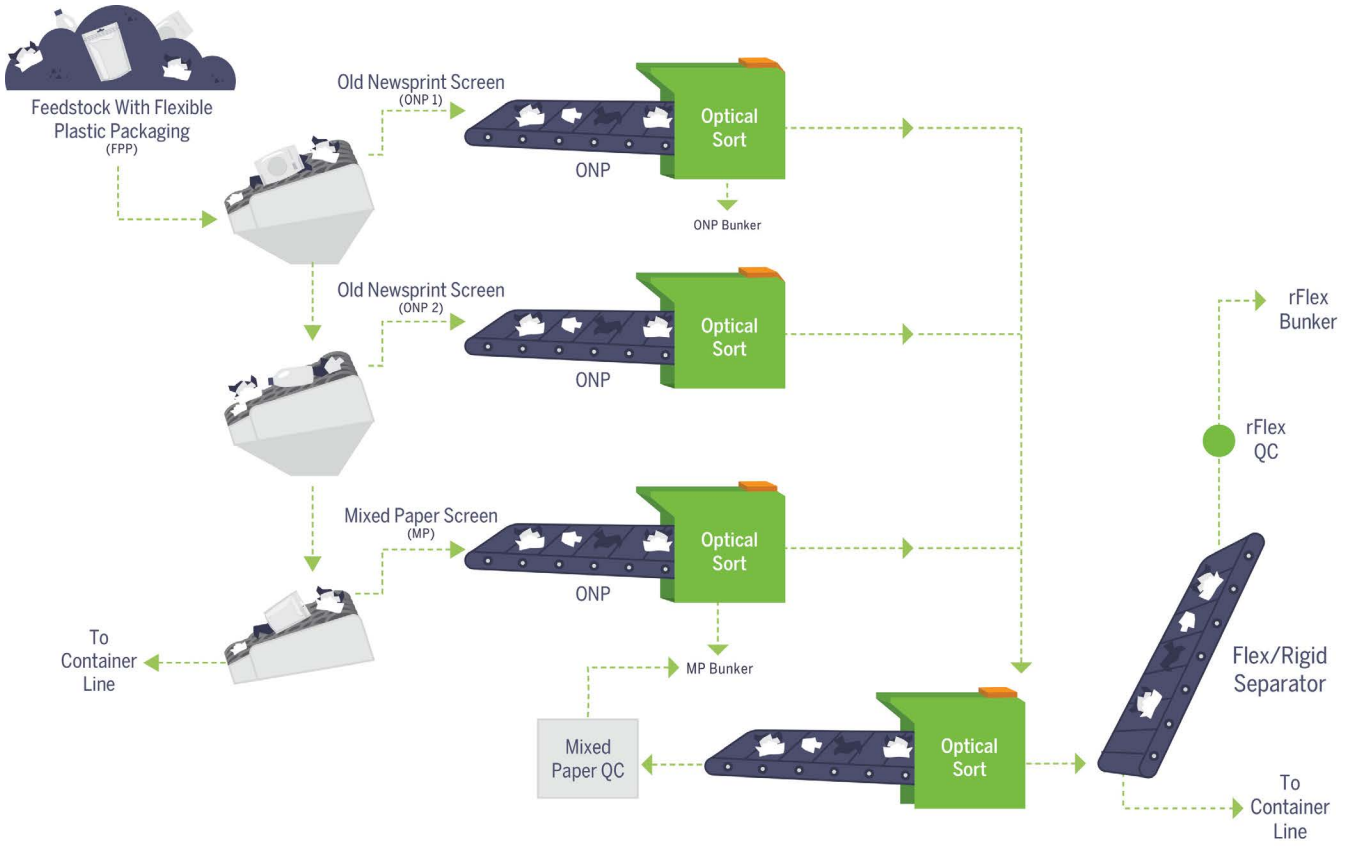
J.P. Mascaro & Sons, owners of the TotalRecycle MRF, was selected to partner on this research project. TotalRecycle is located in the town of Birdsboro in Berks County, Pennsylvania. During the pilot stage of the project in 2019, MRFF project sponsors collectively funded purchase and installation of the equipment specification provided by RRS. The solution proposed by Van Dyk Recycling Solutions, who had also built the original MRF system, was selected for the project.

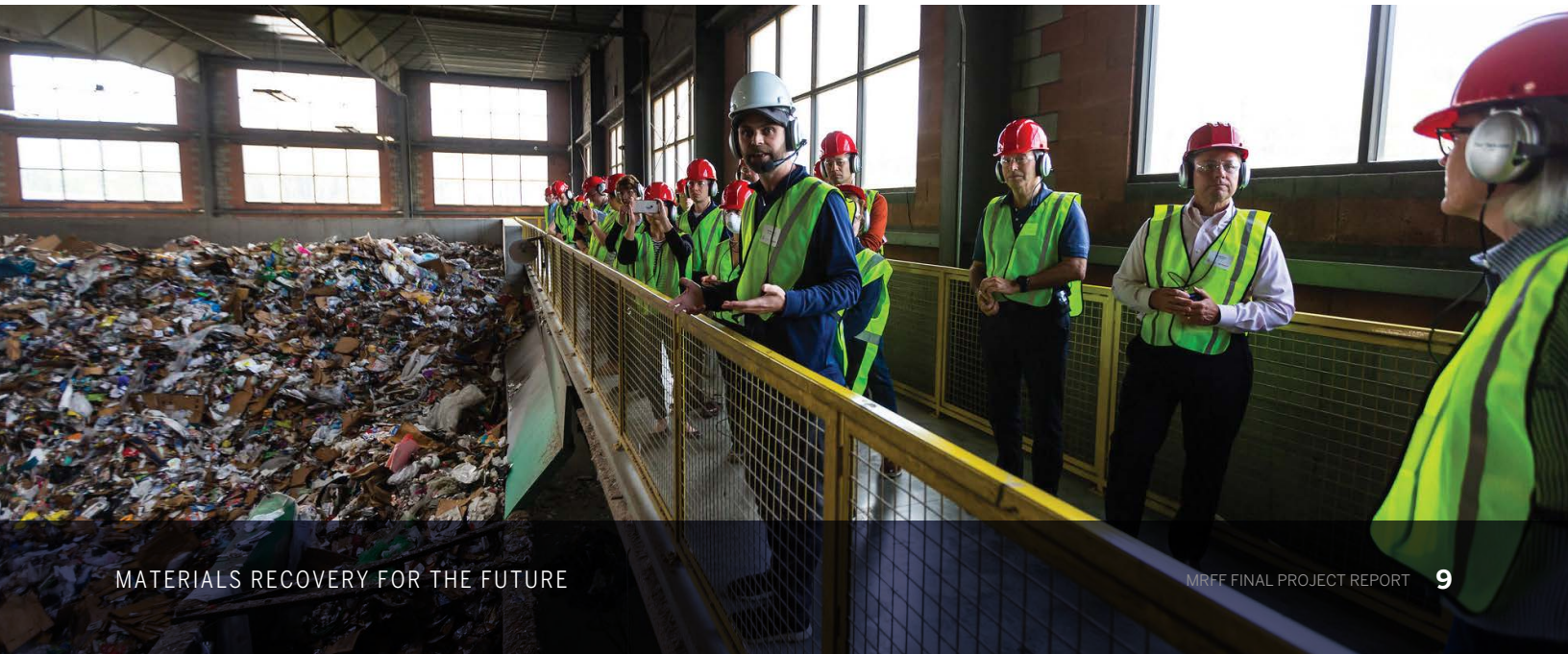
The VDRS team installed optical sorters on each of the MRF's three fiber lines to eject FPP from fiber. These high-end optical sorters had a wide build that allowed them to eject material across an entire fiber belt and work at high speeds with material spread out as far as possible. A fourth optical sorter cleaned up the resulting FPP stream by ejecting the remaining fiber after the three lines converged. Finally, a flex/rigid separator was installed to separate rigid items, such as containers, from the FPP stream.

FIGURE 1. TotalRecycle MRF

This equipment configuration operating as designed has the capacity to auto sort 3,100 tons (6.2 million pounds) per year of FPP into a commodity bale known as rFlex. As of December 2022, TotalRecycle has sorted 1,559 rFlex bales, diverting slightly more than 1364 tons (2,728,250 pounds) of FPP from the landfill since the program began. The main reason TotalRecycle is not producing greater tonnage is a shortage of curbside carts in the communities served. (See page 19 for further discussion)

FIGURE 2. FPP Sortation Steps at the TotalRecycle MRF

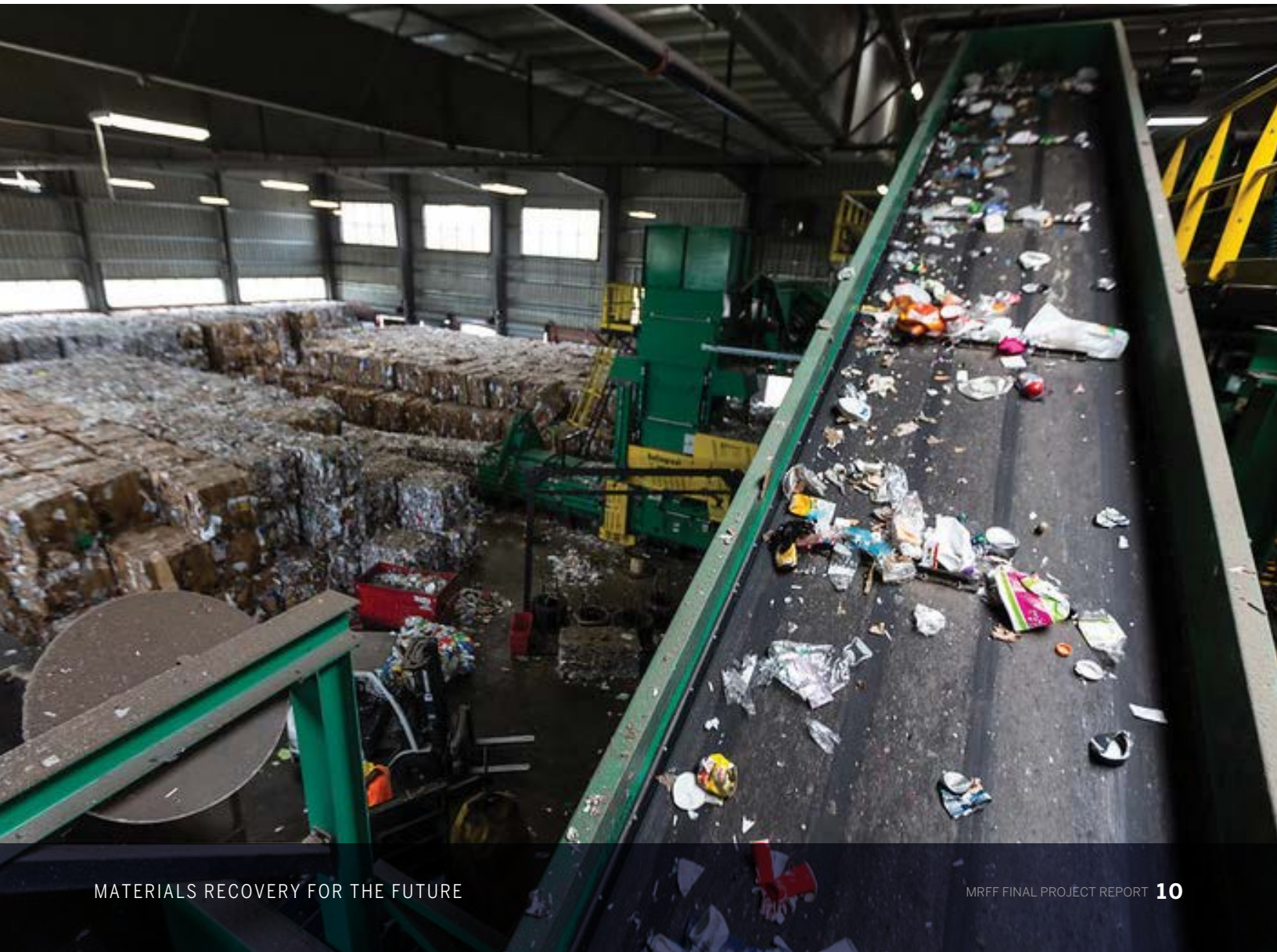




After equipment installation was completed, the TotalRecycle and RRS team began a six-month test phase before accepting material from communities. FPP was added to single stream recyclables during this test phase that was representative of the expected concentration when residents add the material to their carts. This was done to ensure the performance of the equipment and to ensure the quality of all the MRF commodities being produced. After that period was successfully completed, ten communities served by TotalRecycle consisting of 56,915 households were invited to recycle FPP along with other accepted materials in their curbside cart.

In 2020, J.P. Mascaro & Sons made another improvement, adding a manual quality control station as a human checkpoint after the automated sorting to pick any missed FPP for the rFlex bale.

At the same time these improvements were complete, the pandemic began to cause severe shortages in MRF labor across the country, and TotalRecycle was not an exception. Even though the automation upgrades reduced the number of manual sorters required in the MRF, the pandemic resulted in shortages as low as 20-25% of the already reduced manual labor required for the overall MRF system. This disparity makes evaluating system performance challenging. RRS performed two site visits – a final RFID Test in August 2020 and a visual MRF Assessment in February 2022 to monitor the upgrade, interview the management team, and identify additional automated equipment solutions to deal with labor shortages that now appeared to be persistent.



RESULTS

RFID Test Results

In August 2020, an RRS MRF Team performed RFID testing to trace sample packages through the MRF and calculate how many were ending up in the rFlex bale. This RFID test was the last in a series using the same protocol at the beginning, middle, and end of the project to track progress. Each test involved tagging thousands of packages, seeding them into the MRF system over several days of testing, and analyzing which tags were read by each of 10 RFID readers at specific locations in the MRF.

The RFID test process revealed areas of progress and areas where improvements were needed. First, the test showed successful capture of the majority of packages, and improvement over time – with average capture rates over 70% in the two later tests. Second, some packages in the mix were very efficiently captured, with a capture rate of 90% for the best performing package, retail carry bags, by the end of the pilot. However, smaller packages were much harder for the system to capture, and they were more affected by maintenance issues, weather, and other unknowns. This was especially visible in the final test. For example, as small baby food pouches were fed into the system, many fell through a spot where the disc screen was heavily worn, and thus never even had a chance to get captured into the rFlex bale. Larger packages were not affected in the same way.

MRF Assessment

In 2022 RRS conducted a TotalRecycle MRF Assessment in collaboration with The Recycling Partnership. The RRS team observed that labor shortages had impacted overall equipment

maintenance. Due to the pandemic, the MRF was not able to staff or maintain equipment as well as had been previously observed by the team. The General Manager reported that during the pandemic maintenance needs had increased as damage due to lack of QC staff increased, plus maintenance staff turnover had occurred.

The FPP recovery equipment appeared to be working relatively well. Optical Sorters 1 through 3 were firing on FPP and Optical Sorter 4 was ejecting collateral fiber back to Mixed Paper. The flex/rigid separator also appeared to be working well. The MRF Manager noted that the flex/rigid separator was recently serviced, and suction levels were improved as a result. None of the FPP manual QC sort stations were staffed during this visit.

According to TotalRecycle General Manager Jeff Furmanchin, while the extreme labor shortage was not anticipated in the design of the FPP recovery system, it was providing the MRF with a way to maintain the production of paper bales in the face of low staffing levels.

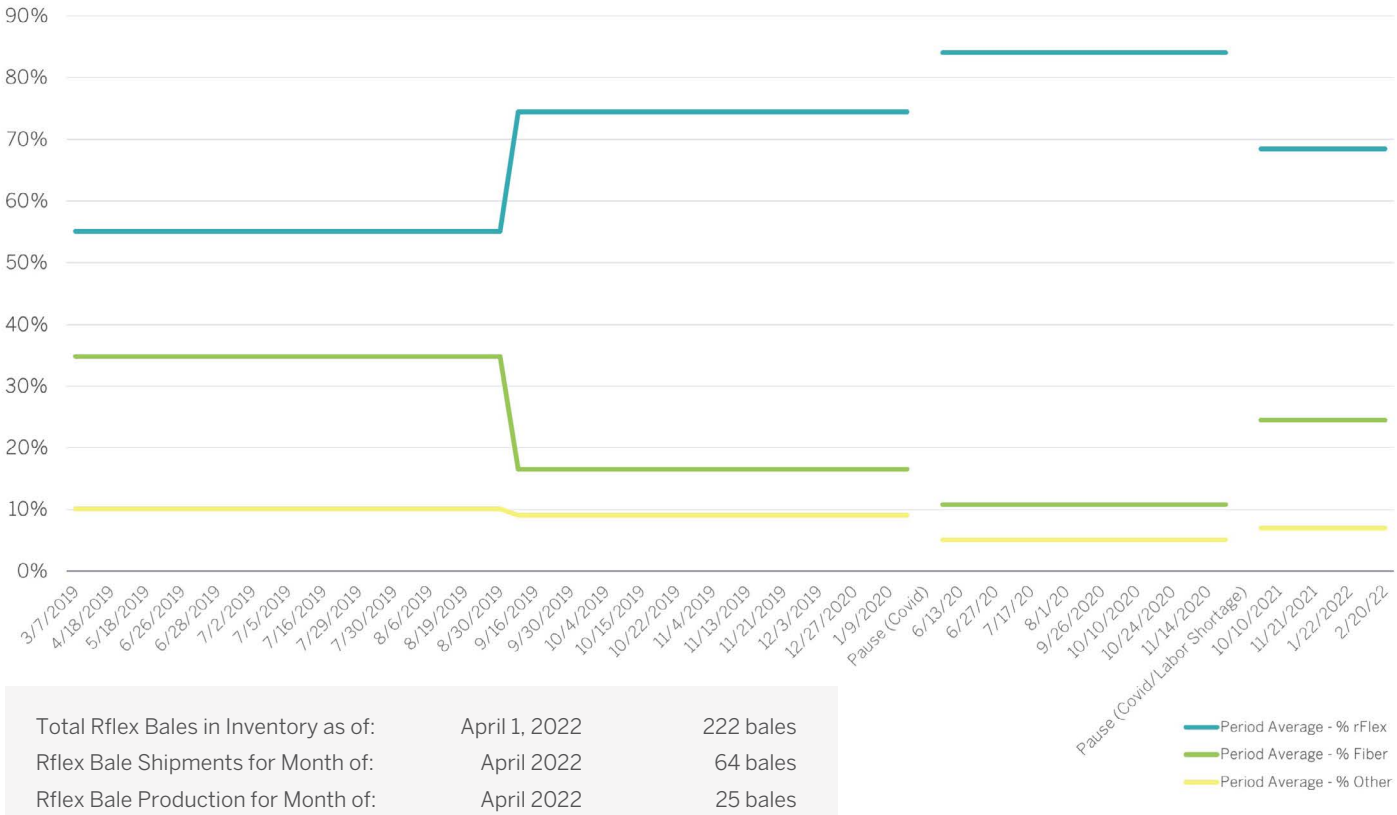
In 2021 and 2022, the MRF produced about one million pounds per year of rFlex. This is approximately 16% of the system's capabilities. In 2021, the MRF operated with significantly reduced staffing levels, 25-30% of normal staffing.

The bale composition was impacted by QC labor shortages as seen in the chart below depicting composition over the entire period of study. When labor was present, they were shifted to the pre-sort line to mitigate major equipment damage. Fiber lines where the FPP was separated were left unstaffed.

A key insight regarding bale composition was the need for MRF operator flexibility to meet the needs of spot and developing end markets. This was particularly important as operational (labor workforce) and regional (rainfall intensity) variables outside of the MRF's control impacted bale composition over time.

Furthermore, with regards to bale quantity or tonnage, a new MRF commodity requires realistic expectations among supply chain partners during periods where bale production is significantly below system capacity. J.P. Mascaro & Sons was able to weather this period of market instability and store bales until sales are made. This practice had an additional benefit; as bales dry further, they improve their marketability.

FIGURE 3. rFlex Bale Composition 2019-Present



Total Rflex Bales in Inventory as of:	April 1, 2022	222 bales
Rflex Bale Shipments for Month of:	April 2022	64 bales
Rflex Bale Production for Month of:	April 2022	25 bales
Total Rflex Bales in Inventory as of:	May 1, 2022	183 bales

MRF commodities typically don't have this level of detailed data on bale composition. RRS has received market feedback that this comprehensive data set has been a valuable asset to a diverse array of end markets investing in film recycling.

End Markets

RRS had identified over a dozen priority product opportunities for this bale in collaboration with the rFlex End Market Network. Additional trials were delayed due to COVID lockdowns and labor shortages, but results continued to trickle in during the period from July 2020 through 2022.

RRS analyses of the current landscape for plastic recycling shows there is much more demand than there is supply of outlets. CRDC Global, a successful enterprise currently scaling in the U.S. and other regions of the world, makes concrete products out of recycled plastic. Chief Operating Officer Ross Gibby reported that business customers are eager to recycle plastic and willing to pay for the service in order to meet sustainability (e.g., landfill diversion, zero waste) goals. The charge for plastic waste recycled by CRDC Global is less than landfill tip fees, and it is also sensitive to transportation. A key to CRDC Global's success is their ability to adapt a facility to the waste streams generated locally. For example, waste generated in York, Pennsylvania is very different than Samoa.

ROOF COVER BOARD

The primary buyer for the rFlex bale has been roof cover board manufacturers. To incorporate products made from recycled flexible packaging (i.e., films, wraps, bags, and pouches), The Kraft Heinz Company, a MRFF research sponsor and an inaugural member of the Association of Plastic Recyclers Residential Film Demand Champion program, launched a pilot project to demonstrate the use of roof board made from rFlex at 3 of their manufacturing plants. At end of life, the roof board is again recyclable.

The most consistent buyer of the rFlex bale for roof cover board has been Kelly Green Products in Waterbury, Connecticut. The company is a subsidiary of 2001 Company, a 42-year-old commercial roofing company with customers and projects across the U.S. Kelly Green Products manufacturers high-performing board for use and installation in commercial roofing. Between 50 and 60 clients of 2001 Company are the primary customers for the board.

FIGURE 4. The Kraft Heinz Company Manufacturing Plant Roof with PCR Content

Photo courtesy of KHC

FIGURE 5. Kelly Green Products Finished PCR Roof Cover Board Product

Photo courtesy of http://www.kellygreenproducts.com

RRS visited the Kelly plant in November 2022 to verify the suitability of rFlex bales as feedstock and assess the current roof cover board operation. The production line was not operational as a result of fires that occurred late spring and early summer. Most of the repairs had been completed and the photos included in this report were obtained. Procedures have been put in place to prevent a re-occurrence, and board production is expected to be resumed imminently. RRS was also briefed on the company's growth plan to assist in identifying potential investors for expansion from one to three production lines.

The current production line at the plant was designed and installed in collaboration with Jan Rayman of Upcycling Technologies. Rayman was founder and formerly President of The ReWall Company, the first manufacturer in the U.S. to make PCR roof cover board. With one line operating, the Kelly plant has capacity to produce 300 PCR roof cover boards per 20-hour day or four million square feet of product per line annually. This level of production requires eight million pounds of post-consumer feedstock such as cartons and flexible plastic packaging per year. The ratio of post-consumer material is 30% post-consumer plastic film or rFlex and 70% post-consumer or post-industrial cartons for desired

feedstock mix. Testing is planned to increase plastic content to 35%. The product also contains a fiberglass facer and thin layers of paper and film plastic that serve as outer layers. Kelly has the capability to blend in other PCR feedstock in small quantities to meet the PCR specifications of its customers.

Kelly finds the rFlex bale to be a low cost, environmentally preferable feedstock compared to traditional materials like gypsum that are used to manufacture this type of board. The plastic in rFlex provides superior performance, particularly in regions with frequent rainfall and/or hurricane intensity.

FIGURE 6. Kelly Production Line and Team, February 2023

FILM TRIALS

The most notable results using rFlex as feedstock were obtained through a collaboration orchestrated by RRS where Charter Next Generation (CNG) performed trials to produce blown films. CNG is a leading producer of specialty films with 12 facilities in the U.S. CNG capabilities include state-of-the-art blown film technology to process a variety of PCR (HDPE, LDPE, LLDPE) into blown or cast film.

One bale of rFlex was wet washed and pelletized for the CNG blown film trials. rFlex was wet washed by Herbold at a European facility and next pelletized using EREMA equipment. Herbold is a specialist in manufacture of size reduction, densification equipment and wash line systems for plastics.

EREMA is globally recognized for the development and manufacture of plastics recycling machines and system components. Upon receiving the pellets, CNG worked with two of their suppliers to evaluate whether additives would be required to produce the film after observing the moisture content was relatively high. The detectable ingredients were PE (~75-80%), PP (~12%), EVA (~3%), PVC (~3%), and PA (~3%).

CNG then processed the rFlex PCR resin with a non-PCR control and other PCR resins. As observed in the first trial photo below without additive, the film produced had numerous gels, carbon, etc. CNG was able to successfully produce film with a moisture management additive as seen in the second trial photo.

FIGURE 7. rFlex PCR Resin – 10 Minutes
Photo courtesy of CNG

FIGURE 8. rFlex PCR Resin with Additive
Photo courtesy of CNG

The resin also had an odor which remained in the finished film. CNG identified the potential to include a compatibilizer to address the color and appearance issues, and an odor management absorber in further development efforts.

Several film-to-film recycling end markets have reviewed rFlex bale composition data, visited the TotalRecycle MRF, and/or tested the bale. RRS believes that once threshold quantities of production in the range of three to five million pounds annually are reached at the MRF, a wash line to reprocess rFlex for film production will become economically justified.

The following table summarizes the products rFlex is currently used for or has been tested as a secondary feedstock, along with the product's key characteristics.

TABLE 1. PCR End Market Product Opportunities for rFlex – 2022 Update

PRODUCT	TECHNOLOGY	MATERIAL SUBSTITUTE	PERCENT RFLEX	RELATIVE SCALE OF MARKET	TIME TO MARKET	STATUS/ LIMITATIONS
Roof coverboard and subflooring	Compression molding	Wood	Up to 100% rFlex	Very large	Available now	Financing required to expand sites
Wall board		Gypsum		Very large	1-2 years	Testing incomplete
Resin aggregate for concrete e.g., CRDC Global	Mechanical and Chemical Cohesion	Sand	Up to 100% rFlex	Very large	Available now	Business model involves fee to MRF for processing feedstock
Films	Blown	Virgin Plastic	70% rFlex	Very large	1-2 years	Successful trial blown film Charter Next Generation. Further testing in order to eliminate gels/ odor
Chemical feedstock for PCR plastic production	Pyrolysis	Virgin Plastic				Enval. Some segregation needed

Environmental and Economic Feasibility

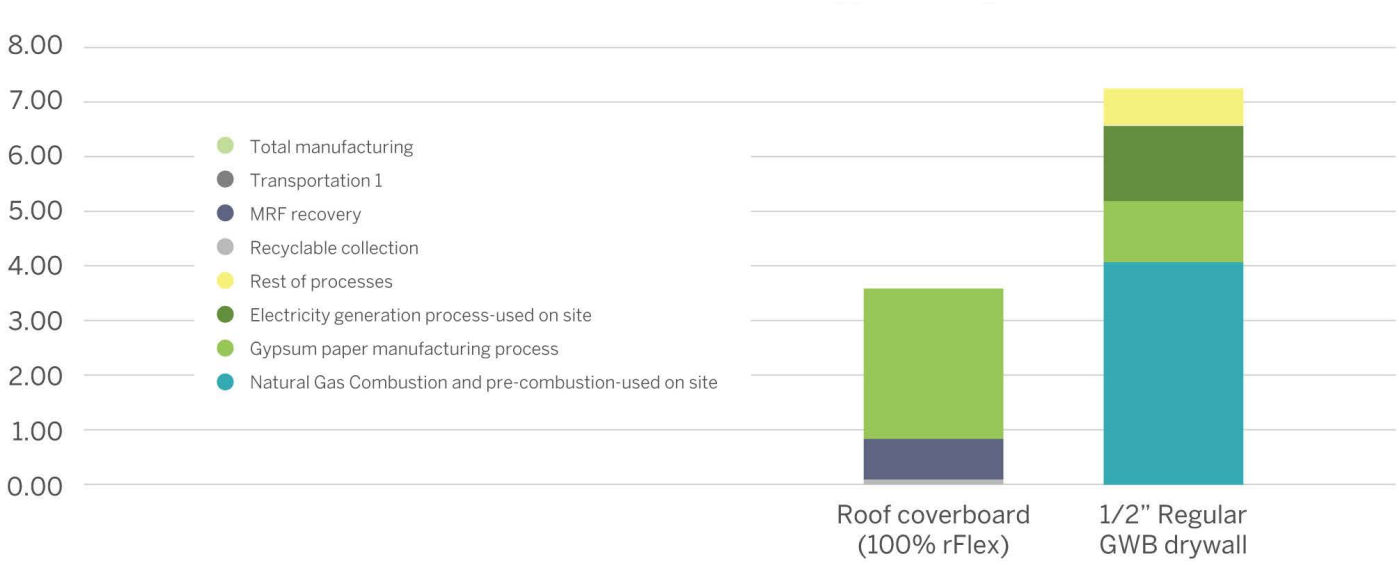
There is often healthy skepticism as to whether it is efficient to recycle certain products, whether there are truly environmental and economic benefits to doing so, particularly for light weight products like flexible films. Idaho National Laboratory and RRS researchers constructed a life cycle inventory and analyzed environmental and cost data to compare the use of recycled FPP to traditionally used materials in four different product pathways – roof coverboard, plastic pallets, plastic pellets to be used in injection molding, etc. and film. The high-level results of the environmental analysis are presented in the following section.

GREENHOUSE GAS REDUCTION BENEFITS

Roof Cover Board

Manufacturing one piece of roof cover board using 100% of the rFlex bale produces about 3.54 kg of CO2e emissions. Compared to its market comparator, gypsum drywall, rFlex roof coverboard can reduce carbon footprints by 53% per board.

FIGURE 9. GHG Emissions – rFlex Roof Coverboard vs. Gypsum Drywall.



rFlex-content Pallets

Using 10-30% of dry-washed rFlex pellets in plastic pallet production produces approximately 57.08-51.07 kg of CO2e per pallet, respectively. Compared to pallets made with 100% virgin plastic, this content can reduce carbon footprints by 5 to 15%.

FIGURE 10. GHG Emissions – rFlex Pallets vs. Virgin Plastic Pallets (kg CO2e per pallet)

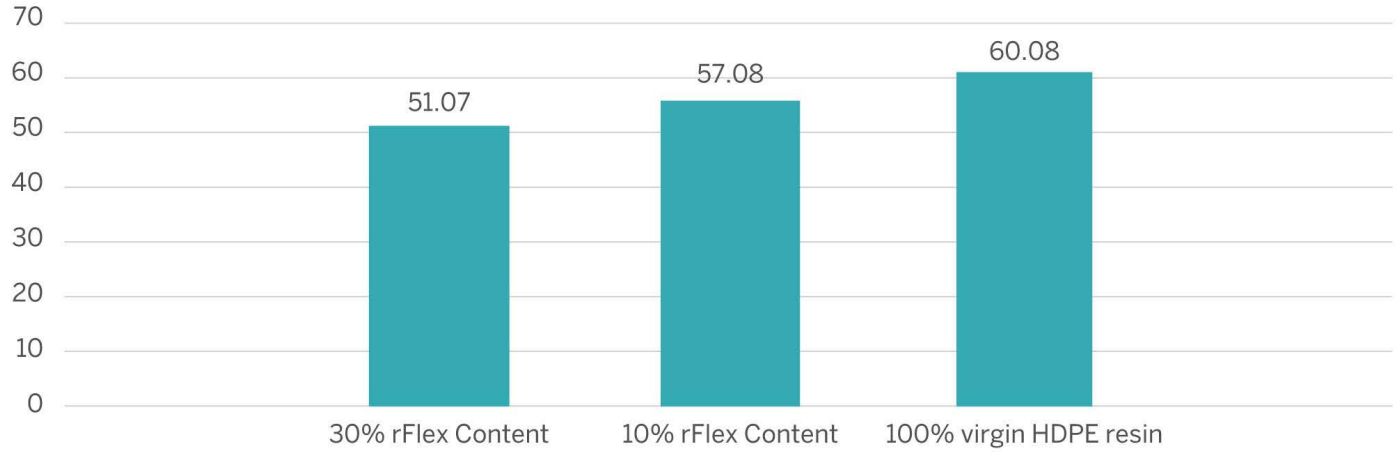
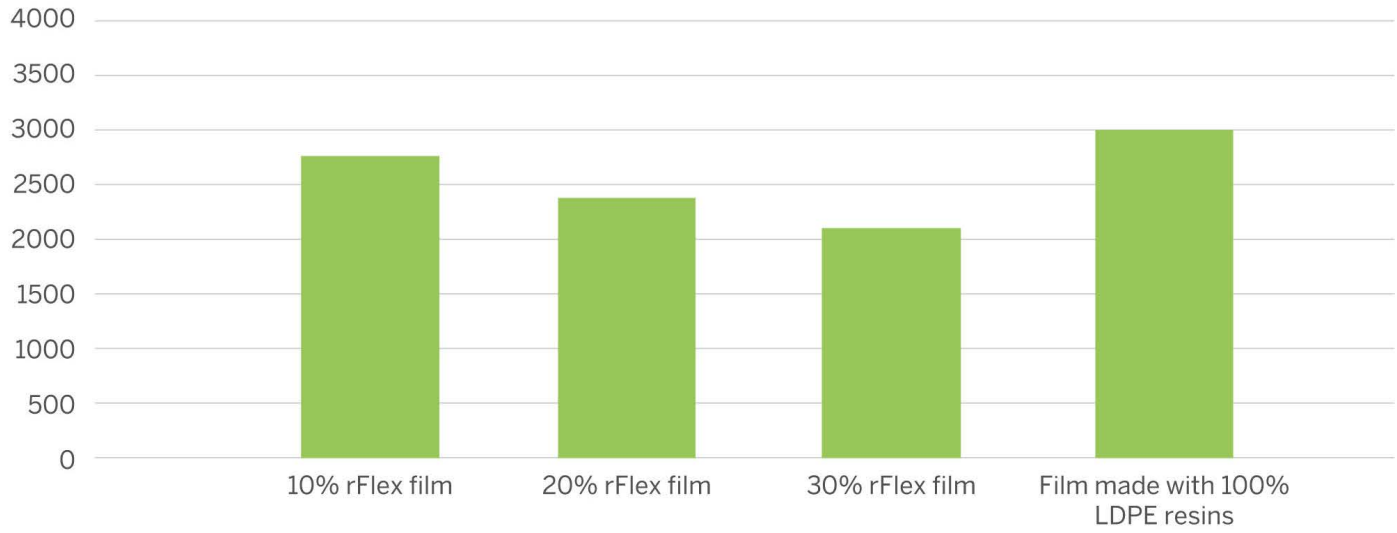


FIGURE 11. GHG Emissions – rFlex Pellets vs. Virgin Plastic Pellets (kg CO2e per tonne)

rFlex Pellets Used in Film

The production of one tonne of PCR film with 10% to 30% rFlex pellets generates approximately 2,983.46 to 2,696.59 kg CO2e, respectively. Compared to plastic film that uses 100% virgin material, the rFlex-content film has 5% to 14% lower total GHG emissions corresponding to 10% and 30% rFlex content.

FIGURE 12. GHG Emissions – rFlex Film vs. Virgin Film



In summary, these material efficiency analyses demonstrate reductions in greenhouse gas emissions from use of rFlex that are often greater than 25% compared to products made with virgin materials. This study will be published and discussed in greater detail in the peer-reviewed scientific journal *Resources, Conservation & Recycling* later in 2023.

CURBSIDE FEASIBILITY

As the technical feasibility of sorting FPP was established, another vital question for MRF operators and communities was whether it is economically feasible to recycle FPP curbside in carts along with other recyclables.

In 2018, RRS developed a financial model for analyzing the potential benefits of collecting and sorting FPP in single stream for large MRFs. The benefits were three-fold: 1) moving FPP from residue destined for landfill to a potentially profitable bale; 2) reducing labor needed to clean the fiber lines; and 3) improving the quality of the fiber bales, even with increased levels of FPP in the stream. The economics were most favorable in areas with higher landfill tip fees due to the avoidance of residue disposal costs.

As the project progressed, these potential benefits were borne out. Starting in September 2019, residents in local communities were gradually instructed to start including FPP in their curbside recycling. Today almost 60,000 households in 10 municipalities conveniently recycle FPP in their curbside carts with other recyclables.

All these communities have their recyclables collected by J.P. Mascaro & Sons[2] and processed at TotalRecycle. They range in location from 10 to 40 miles from the facility.

Under normal operating conditions, prior to the pandemic, as the volume of FPP increased the amount of labor needed to run the system was reduced by 38%. Audits of fiber products showed a significant reduction in contamination as well – from 1.4% to 0.3% in old newsprint (ONP), and from 1.6% to 0.5% in Mixed Paper. When these efficiency benefits were taken into account, the RRS pro forma model showed that FPP recovery equipment can be a reasonably priced addition to residential collection contracts, on par with the addition of automated sorting of other materials. And as additional markets develop for rFlex bales, FPP recycling has the potential to grow into a profitable commodity on its own.

TABLE 2. Communities Participating in the TotalRecycle Flexible Packaging Program

MUNICIPALITY	HOUSEHOLDS IN MUNICIPALITY	COUNTY	ROLLOUT DATE
Pottstown Borough	9,321	Montgomery County	Sep-19
Lower Providence Township	8,769	Montgomery County	Nov-19
South Heidelberg Township	2,590	Berks County	Dec-19
Alburtis Borough	881	Lehigh County	Jan-20
Ambler Borough	2,604	Montgomery County	Jan-20
Newtown Township	4,871	Delaware County	Jan-20
Quakertown Borough	3,649	Bucks County	Jan-20
Warminster Township	12,874	Bucks County	Jan-20
Whitemarsh Township	6,744	Montgomery County	Jan-20
Wyomissing Borough	4,612	Berks County	Jan-20
Souderton Borough	2,641	Montgomery County	Jan-22
Total Households in Pilot Communities	59,556		

2. The program is described on the company website: https://www.jpmascaro.com/green-initiatives/flexible-plastic-packaging.aspx

Lack of Carts Remain a Key Barrier

There is one requirement for communities wishing to recycle flexible packaging - they must have lidded carts for curbside collection, which is considered recycling best practice in the U.S.

While J.P. Mascaro & Sons processes recyclables from a service area of roughly 300,000 households, the 59,556 households recycling flexible packaging represent only those communities directly collected by the company that also utilize lidded carts.

The lack of lidded collection carts, both in this area and in recycling programs nationwide, remains the most significant infrastructure gap to collect flexible packaging while increasing the use of collection best practices for all curbside recyclables.

FIGURE 13. J.P. Mascaro & Sons Curbside Recycling Cart

CONCLUSION THE FUTURE OF FLEXIBLE PLASTIC PACKAGING COLLECTION, PROCESSING AND END MARKETS

FPP recycling has been commercialized by TotalRecycle, and more communities will continue to add the service.

Many large MRFs are currently investing in optical sorting to clean up paper and capture smaller OCC boxes into higher value commodity grades. In the future, MRFs may also separate white paper from Mixed Paper. The RRS Project Team believes flexible packaging manufacturers have a significant opportunity to work with MRFs and the paper industry to justify the equipment upgrades that will increase the quantity and quality of PCR supply for post-consumer recycled content products.

The market environment for the production of MRF paper bales, such as Mixed Paper and newspaper, has been in a great deal of flux since the start of the pandemic. Factors impacting the recycling industry include increased demand for fiber bales, as well as persistent shortages in MRF labor. While none of this was anticipated as part of the design of the pilot FPP recovery system in the above diagram, it has provided the MRF with a way to maintain the production of paper bales even with staffing levels at the MRF as low as 20-25% of the designed system requirements.

According to TotalRecycle MRF General Manager Jeff Furmanchin, the positive impacts of the FPP system on MRF fiber production include:

- **Automation** has allowed the MRF to produce acceptable paper bales with very low staffing levels, which has been a major benefit especially during severe stages of the pandemic.
- **Movement** of the Mixed Paper commodity has been steady, with strong demand from domestic markets and some from export. Supply chain issues such as getting bookings and containers have presented challenges to the export market. At the present time, the MRF is producing only Mixed Paper bales as the price differential for newspaper (ONP) bales is minimal, thus eliminating the financial incentive to produce two different grades.

- **Quality** of the paper bale has been viewed positively throughout the period of accepting FPP from communities. There has not been a negative impact on the level of contamination in the resulting fiber bales, and they have not received any negative feedback from paper buyers regarding any film present in the paper grade.

Prior RRS MRF testing performed within one year of the FPP equipment installation showed the most immediate benefit of the FPP system upgrade for the MRF was cleaner, higher quality paper bales. The reduction in contamination for two traditional commodity bales, ONP and Mixed Paper, was measured at over 70%.

RRS RECOMMENDATIONS

The following recommendations are provided to achieve the shared vision of success articulated by Materials Recovery for the Future. They are consistent with RRS best practices illustrated in Figure 14.

Supply Chain Partnerships. Long-term feedstock supply agreements between MRFs and end markets are the best approach to justify investments in MRF sorting that supply recycled flexible packaging at scale. Today's sustainability imperative demands that resin producers and PCR manufacturers cultivate recycling industry relationships to create a stable supply of feedstock. There's a valuable lesson to be learned from the paper industry. Fiber recycling in the U.S. has improved significantly over the past 30 years. As a result of industry engagement with the recycling industry, paper recycling rates approach 70% today.

Collection. Lack of collection equipment is a barrier that can be remedied through proper investment in residential carts, consistent with recycling best practice. Large MRFs like TotalRecycle who invest in FPP sorting should receive priority funding to achieve more diversion and increase the supply of PCR. RRS estimates an $11 million investment is required to cart the remaining communities in the TotalRecycle service area.

Technology. This research project shows that existing automated sorting technologies, specifically optical sorters, can be used to sort flexible plastic packaging and improve paper bale quality at promising levels of efficiency. In the last few years, robotics have developed with smaller space requirements that are ideal for retrofits. In light of new MRF labor market realities, these types of automation should be employed to improve sorting, which has direct economic returns for the MRF.

Policy. Extended Producer Responsibility (EPR) has implications for this category of packaging. For example, in Canada FPP is included in recycling programs and is collected at depots. As states across the U.S. choose to adopt EPR, films and flexible packaging should be evaluated as a high-volume addition to community collection programs given the technical and economic feasibility and greenhouse gas benefits associated with use of this feedstock.

FIGURE 14. Best Practices for Building Circularity