



RSE USA

Sustainable Product Solutions

The Closed Loop Foundation

Film Recycling Investment Report

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Glossary of Terms

Technical terms used in this report are defined below.

Blown film	A film manufacturing process that uses air pressure to blow and stretch single or multi-layer molten film, causing it to thin, after which is cooled, slit, and wound onto rolls.
Cast film	A film manufacturing process in which a molten plastic resin is passed between two cold rollers to produce a single-layer film.
Co-extrusion	A plastics manufacturing process in which two or more side-by-side extruders layer molten sheets of different plastics on top of each other.
Extruder	A piece of equipment that melts plastic raw material. Extrusion is a plastics manufacturing process that includes placing a die at the end of an extruder to produce continuous sheets or other profiles.
Film	Plastic items with a thickness of less than 10 mils (i.e., 0.010" or 0.25 mm) that are at least 85 percent (by weight) plastic with up to 15 percent other closely bonded or impregnated material, which may include printing, coatings, or fillers
Heat seal	A process of sealing two surfaces together using heat and pressure, causing the two surfaces to weld to each other.
ICI	Industrial, commercial, and institutional.
Laminate	A film layering process that uses an adhesive to join two separate mono or multi-layer films together. Laminations are used when one layer requires printing or metallization coating, and when the processing temperatures of different film layers are widely different.
MRF	A materials recovery facility (MRF) is a facility that takes mixed residential recyclables and sorts them into market grades, and further processes them into a form for economical shipment to market.
Oriented	A process in which plastic film or fibers are heated and stretched, causing the film to become stronger in the direction it is stretched (e.g., OPET is oriented PET; BOPP is biaxially oriented polypropylene – PP that has been stretched in two directions).
Post-consumer	Used for its intended purpose. Post-consumer material may be from commercial businesses (post-commercial) or from residences (post-residential). This term does not include manufacturing scrap plastics (industrial scrap).
Resin	A term used to describe the chemical type of a plastic material. It also refers to plastics when in their pure raw material form.
Retort	A package filling process in which the product and package are heated and filled at a very high temperature to sterilize them, and then promptly sealed so that the filled package is shelf-stable and doesn't require refrigeration. Plastic films used in retort packaging must be strong and heat stable.
Thermoforming	A plastic manufacturing process in which a sheet of plastic is reheated to soften it, and then clamped and drawn down into an empty mold.

Executive Summary

Introduction

Bags and wraps are frequently made of a single plastic type. Alternatively, flexible packaging is commonly made from several layers of different types of plastics bonded together, with each layer serving a function to protect and keep the contents fresh, which most often is food. Because different types of plastics are not compatible with each other when melted down together, this presents recycling challenges for flexible packaging because it is not currently technically possible or feasible to separate the materials in the different bonded layers.

The good news is that more than half of film is polyethylene film, which is recyclable today. Furthermore, the ability to recycle multilayer films that are primarily made from polypropylene with polyethylene layers is promising. For the other film types, changes in package design and continued research into new recycling technologies can minimize the quantity of films that are not yet able to be recycled.

Film Recycling Value Chains

The vast majority of film that is currently recycled is commercial polyethylene film, with an estimated 21 percent recycling rate. This film primarily comes from large commercial generators, and is clean clear bags and pallet wrap, which in many cases does not require washing prior to recycling. Much of this film is recycled into trash bags and thicker gage commercial film.

Residential polyethylene film is the second most recycled type of film, with an estimated 4 percent recycling rate. This film is primarily collected through film bag and wrap drop-off collection programs offered by retailers, which is available to nearly all U.S. households; however, consumers only return a small percentage of film bags and wraps for recycling. This film can be recycled directly into composite lumber products without additional cleaning.

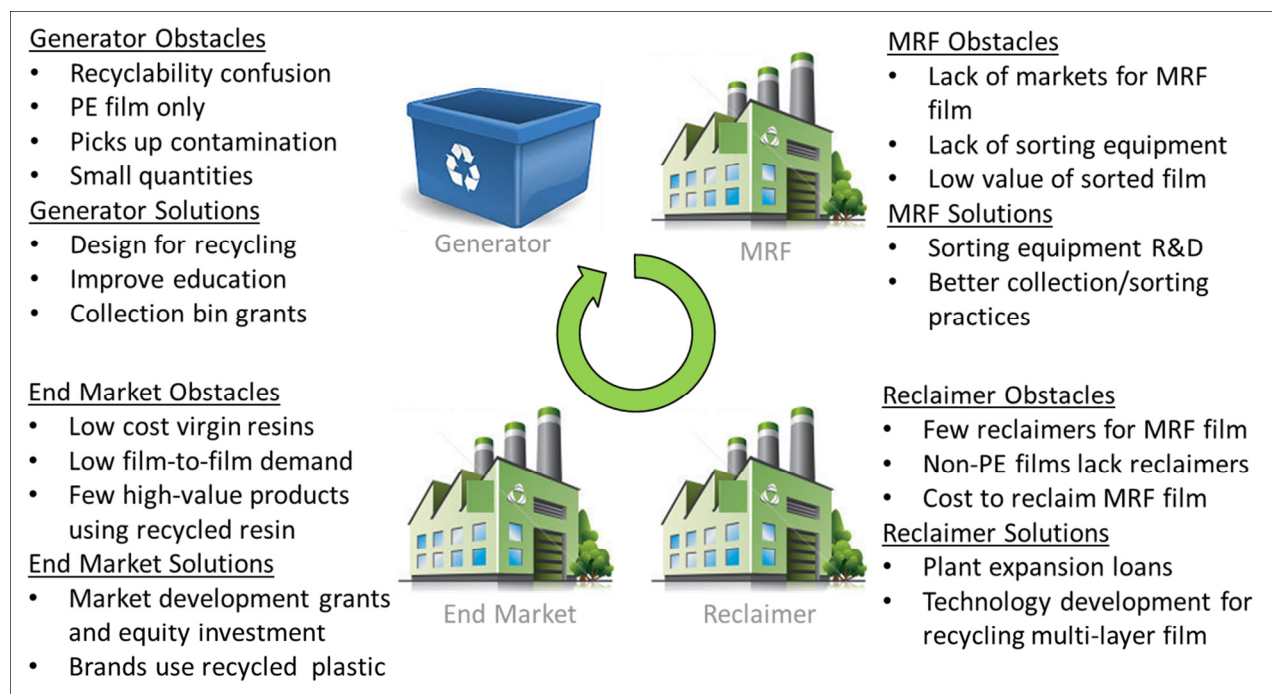
Although very few residential curbside recycling programs accept film in their programs, many recycling program participants place it in their curbside carts anyway in the hope that it will be recycled. Although over twice as much film is placed by residents in their municipally-sponsored curbside recycling programs than is returned by them to retail collection programs, nearly all of this curbside film is disposed because it becomes contaminated in the recycling collection process (only approximately 3 percent of film placed in curbside collection programs is able to be marketed). There are only two North American markets that regularly purchase such film and they have very limited demand for the material, which is why material recovery facilities (MRFs) dispose of this film.

Currently there is only a minimal quantity of non-polyethylene film recycled from residential sources. The recycling that does occur is solely through boutique recycling programs that rely on mail-back of comparatively small quantities of flexible packaging. The extremely high cost of these programs are either self-financed by ardent recyclers or paid by a handful of product manufacturers for branding and marketing reasons, and only for their own selected brands, excluding packaging from other brands. Other than woven polypropylene sacks, virtually no other non-polyethylene film is recycled from commercial sources.

Summary of Obstacles and Solutions for Increasing Film Recycling

Figure 1 shows principal obstacles to higher levels of film recycling, and solutions to overcome those obstacles.

Figure 1 – Obstacles and Solutions for Increasing Film Recycling



As the figure shows, there are obstacles at different points in the recycling value chain, and a variety of solutions that can be employed by both private and public sector stakeholders.

Recommendations

Investments in the film recycling industry would be most effective if prioritized in the following areas, which are generally arranged in the order of what we feel would be most beneficial:

- Grants and loans for new wash plants for curbside polyethylene film.
- Grants and loans for equipment that increases the scale and efficiency of wash plants for curbside polyethylene film, including overall capacity expansions, equipment and silos that enable bulk shipment of reclaimed resin, blending and compounding equipment, and high efficiency dryers.
- Grants and loans for solid state shear pulverization equipment at reclaimers of curbside polyethylene film.¹
- Grants for polypropylene film recycled product development, including test manufacturing runs, recycled content product testing, and post-development blending and compounding equipment (merchant reclaimers) or integrated product manufacturing for ongoing recycled product manufacturing.
- Loans for end user silo, blending, and extrusion equipment so existing manufacturing companies can begin using recycled film in currently virgin resin products.
- Grants and equity investment on end market innovation to drive up value of material.
- Grants for research and development and demonstration of MRF film sorting and baling equipment.
- Grants and loans for equipment to expand the number of market outlets for non-recycled film, primarily for fuel preparation for cement kilns.

¹ The Closed Loop Foundation approved a \$200,000 grant to Zzyzx in the fall of 2016 to scale up its technology to a commercial machine and install it at a plastics recycler.

In addition to the focus areas listed above, grants are needed in the following areas:

- Development of MRF film separation/sorting equipment by MRF equipment companies and developmental technology companies.
- Research, development, and testing of multilayer pouches that are compatible with PE and PP film recycling systems.
- Research and development by film reclamation equipment companies for high efficiency dryers.
- Funding a demonstration single-stream MRF open for tours that is designed for mixed film separation.
- Research and development grants to develop new technologies to separate PET and nylon layers from multilayer pouches.
- Grocery store collection bin grants, possibly in partnership with FFRG's WRAP initiative.²

Key Conclusions

- There are a number of areas where the investment community can help to improve film recycling in the U.S. These areas include expanding reclamation capacity and growing recycled content product manufacturing.
- A number of organizations have initiatives underway to improve film recycling, in some cases duplicating each other's efforts, whereas in other cases no one is addressing other obstacles. Coordinating efforts among stakeholders will help to advance film recycling.
- Film recycling loans, grants, and venture capital investments are all needed to overcome film recycling obstacles.
- More than half of polyethylene film collected in the U.S. for recycling is exported, although demand from export markets has begun to decline and this is expected to be a long-term trend. Thus it is essential that the U.S. expand its infrastructure to sort, reclaim, and manufacturing products using recycled plastic PE film.
- Reclaimers and markets for non-polyethylene film are virtually non-existent. There is a need to develop a recycling infrastructure and recycling markets for the polypropylene-based film portion at a minimum, in order for comprehensive film recycling to occur.
- It is important for film manufacturers to design film products and packages for recycling so that the economics of comprehensive film collection and recycling programs can improve. This includes designing products that are compatible with the polyethylene recycling stream.

² The Flexible Film Recycling Group is an initiative of American Chemistry Council members that seeks to increase polyethylene film recycling. Its Wrap Recycling Action Program (WRAP) specifically focuses on increasing the recycling of residential polyethylene wraps through return to retail collection programs. This program can be considered a lower priority for private sector investment because of the existing investments into this program and individual investments by retailers in collection containers for their own establishments.

1. Categorization of Film

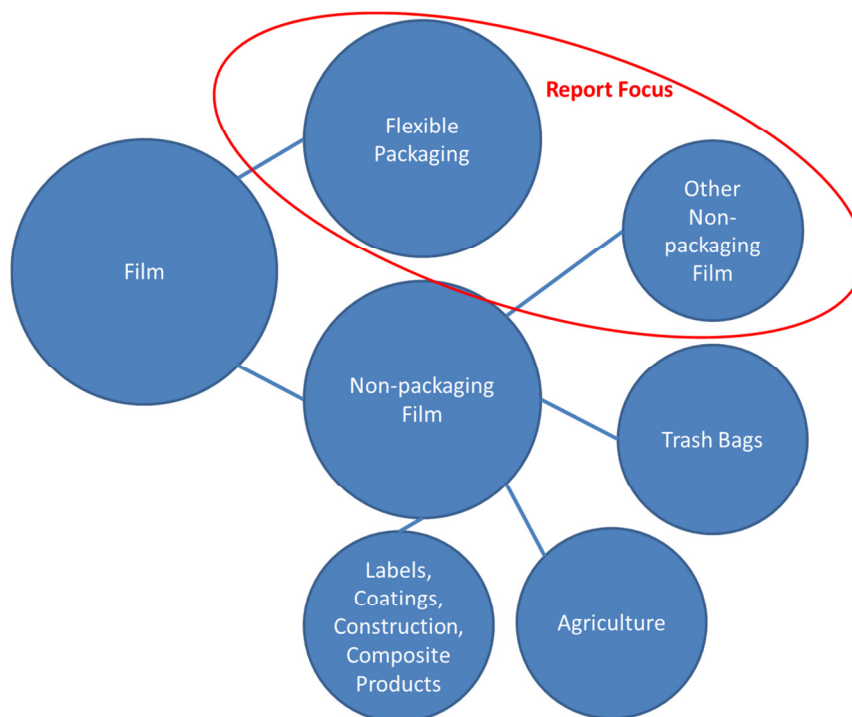
The Closed Loop Foundation (CLF) retained RSE USA to advise it on where it can best target its investments to improve film recycling rates in the United States. This section categorizes film into groupings with a focus on introducing film characteristics and uses that present recycling challenges and opportunities. Later sections of this report discuss recycling challenges and opportunities in much more detail.

1.1. Overview of Film/Flexible Packaging Types and Project Focus

Plastic film is generally defined as plastic items with a thickness of less than 10 mils (i.e., 0.010" or 0.25 mm) that are at least 85 percent (by weight) plastic with up to 15 percent other closely bonded or impregnated material, which may include printing, coatings, or fillers. This thickness criterion is not a hard and fast criteria since the wall thickness for certain other plastic packaging products not considered to be film may be at or below this threshold as well.³ Film may be better defined by the process by which it is made – blowing or casting – as opposed to molding and sheet extrusion. Film, when used in packaging, is referred to as flexible packaging. The shape of flexible packaging typically changes when it is full of a product compared to when it is empty, whereas the shape of rigid packaging generally remains the same.

This report only focuses on certain types of film as shown in Figure 2.

Figure 2 – Types of Film and Report Focus



³ Ultra-lightweight PET water bottles, pill blister packs, some resealable lunchmeat packages made by thermoforming multilayer plastic sheet, and some toothpaste tubes may also have wall thicknesses near to or below these thresholds.

What's Included in this Report

The focus of this report is on film and flexible packaging generated in households and commercial businesses, which is recognizable as film (i.e., not coatings on or part of other products). Packaging film includes applications such as cereal box liners, bread bags, juice pouches, tissue overwraps, chip bags, multi-pack shrink wraps, and resealable pouches. Other film products that are classified as transport packaging are also included, such as retail carryout sacks, industrial pallet stretch wrap, and bulk bags used for shipping industrial materials.

Other non-packaging film categorized in this report includes film that consumers specifically purchase as a product for their own use, such as sandwich bags and kitchen wrap.

What's Not Included in this Report

Films that are used as part of other products are not part of this report – these types of applications include film used for coating paper or glass, film used in building membranes and geomembranes, carpet backing, diaper film, films that are converted to labels that are applied to rigid packages, tape, and other similar uses for film.

Although film used in agriculture has its own recycling challenges, the Closed Loop Fund's focus is not on this sector, and so film used for ground cover, silage bags, and greenhouses is not included. Finally, garbage bags are not able to be collected for recycling because they are to contain waste until it is placed in landfills or waste-to-energy plants. While the amount of film used to produce garbage bags and trash can liners is discussed in this section of the report for context and because garbage bags often use recycled film, recovery and recycling of garbage bags themselves are not discussed.

This report also does not include semi-flexible packages such as tubes for toothpaste and thin gauge thermoformed packages, even though some of them may approach the film thickness definition, may be made from the same or similar multi-layer structures that are used in flexible packaging, and may face the similar challenges to recycling as the flexible packaging that is discussed in this report.

1.2. Overview of Flexible Packaging

The universe of flexible packaging is large and diverse. Packaging is defined as materials used for the containment, protection, handling, delivery and preservation of goods from the producer to the user or consumer. There are three primary usage forms of packaging:

- 1) Primary or sales packaging is packaging that directly contains the product being sold to the user or final consumer – examples include a film bag that holds frozen vegetables purchased by a consumer and a film bag that holds fasteners purchased by an auto assembly plant.
- 2) Secondary or group packaging is that which unitizes a number of otherwise separable packages into one sales unit – for example, shrink wrap that unitizes several plastic water bottles into a multi-pack.
- 3) Tertiary or transport packaging is packaging that is used to group primary and/or secondary packages together for the purpose of transportation. Transport packaging includes retail carryout bags and sacks and commercial stretch wrap used to secure a number of cardboard boxes onto a pallet for shipping.

Primary flexible packaging is broadly segmented into single-layer packaging made from a single type of plastic resin, and multilayer packaging made from several layers of different plastic resins. Some 63 percent of film available to be recycled and discussed in this report (i.e., excluding trash bags, agricultural film, etc.) is single-layer film and 37 percent (and growing) multilayer film. Secondary and tertiary packaging is usually single-layer packaging made from a single type of plastic resin.

Multilayer film is a recycling challenge because the layers don't readily separate and because the different plastics in each layer frequently are not compatible with each other when recycled. The following discussion provides an overview of what multilayer flexible packaging is and the reason why many film products are made from multiple layers.


Multilayer film combines desirable characteristics of multiple materials into one structure to achieve desired package performance that any one material on its own would not be able to provide. Functional performance of different layers includes:

- **Print layer** – inks stick better to some plastics than others – print layer is needed to convey product information and advertising/sales graphics.
- **Tie layer** – ties two incompatible layers together that otherwise would delaminate, using either a distinct co-extruded film layer or as an applied adhesive.
- **Barrier layer** – provides a barrier to oxygen, moisture, odor, or light for improved shelf life and reduced product losses/spoilage.
- **Structural layer** – provides thickness, stiffness or strength so the film can support its own weight and so it has the strength needed to be formed, filled, and sealed using high-speed equipment.
- **Protective layer** – provides a layer that resists punctures.
- **Sealant layer** – layer that seals to itself with heat at high machine speeds.

Not all flexible packaging needs all of these layers. Furthermore, some film products that could be made in a single layer are made in two or three layers in order to use recycled material. The recycled content inner layer can provide the necessary structure while the outer layers provide protection and appearance. Below are examples of two multilayer flexible packages, the role provided by each layer, and how the layers are assembled.

Figure 3 – Example Flexible Packages and Their Layers

Microwavable Vegetable Bag	Material (listed in order from outside to inside layer)	Purpose
	PET or oriented polypropylene	Clear print layer, also provides high temperature strength
	Printing ink	Reverse printed on inside (resists scuffs)
	Adhesive	Glues the outside print layer to the rest
	C8 LLDPE	Machine strength layer
	C4 LLDPE	Flexibility and thickness – lower cost
	C4 LLDPE	Flexibility and thickness – lower cost
	C8 LLDPE	Machine strength layer
	C8 LLDPE	Layer tailored for heat seal

Potato Chip Bag	Material	Purpose
	BOPP-biaxially oriented polypropylene	Clear print layer
	Printing ink	Reverse printed on inside (resists scuffs)
	Adhesive	Glues the outside print layer to the rest
	LDPE	Flexibility and thickness – low cost resin
	Adhesive	Flexibility and thickness – lower cost
	Aluminum	Oxygen barrier
	BOPP	Substrate aluminum deposited on
	LDPE	Heat seal layer

Source: Nova Chemicals, RSE

The film structures illustrated in Figure 3 come flat and on a roll. To form the final package, the flat film is folded over so that the printed layer faces out and the heat seal layer folds over onto itself on the inside, forming a bag. The bag is then filled with the product and heat sealed using hot clamps that cause the heat seal layer to weld to itself, completely sealing the bag.

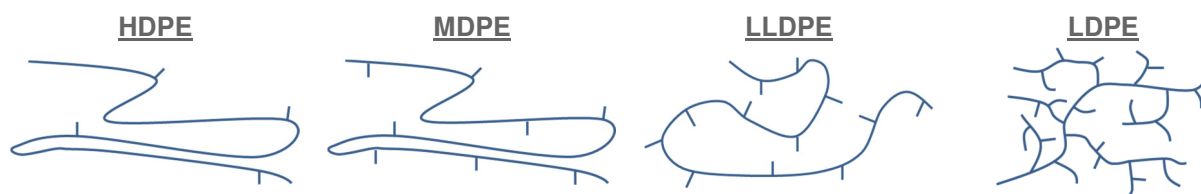
Some of the plastics comprising the layers depicted above are compatible with each other and others are not. Generally, different plastics are not compatible with each other and in most cases must be separated from each other to be recycled (i.e., PET, PP, and PE must each be separated from the others) unless they either compose a very small percentage of the total, or unless the film is to be down-cycled into very low-performing products. Polyethylene plastic is made by polymerizing ethylene gas – this simply means that many individual molecules of ethylene are strung together until they form very long chains. All forms of polyethylene (HDPE - high density polyethylene, MDPE - medium density polyethylene, LLDPE - linear low density polyethylene, LDPE - low density polyethylene) are essentially the same chemically – polyethylene – and so are compatible with each other. However, they are made with different processes and catalysts, and with controlled small amounts of other additives that result in occasional irregularities, which gives them tailored densities and differing physical properties, but otherwise leaves them chemically the same and compatible. Figure 4 illustrates the structural, but not chemical, differences of the different types of polyethylenes.

Compatibility of Different Plastics Types

Plastics are long chains of connected molecules with a regular repeating chemical structure. Because of this regular repeating structure, the molecules of many types of plastics are able to arrange themselves to tightly fit together, like interlocking puzzle pieces, to form crystals.

Molecules of two different plastic types are chemically different from each other, and in most cases cannot fit together, and so tend to separate into different areas, just like oil and water separate when mixed. In this report, we call plastics that separate when mixed, or plastics that have vastly different melting temperatures (so that one begins decomposing before the second reaches its molten processing temperature), incompatible.

Figure 4 – Different Types of Polyethylenes



The different types of polyethylene will mix and blend, so having those together in a multilayer structure is not problematic for recycling from a compatibility perspective; however, other materials if recycled together with polyethylene will separate, much like oil and water separate after being mixed, which could be problematic. If materials separate, the boundary between them is weak, which can cause products to fail. This is why single-layer films made from different resins need to be sorted from each other, and why there are challenges to recycling multilayer film products.

For example, polypropylene is incompatible with polyethylene. Because oriented polypropylene does not heat seal to itself, bags made from oriented polypropylene (such as chip bags) need an inside polyethylene sealant layer if the oriented polypropylene film is to be formed into bags, filled, and heat sealed. The incompatibility of the different resin layers, however, causes recycling and recycled content manufacturing challenges. However, there are also opportunities to overcome these challenges, which will be discussed later in this report.

2. Film Generation, Trends, and Future Growth Estimates

2.1. Film Generation, Trends, and Future Growth Estimates

This section provides estimates of film generated in the United States by product type, including the relative proportions of resins used in those products. RSE has grouped types of film into categories considering the potential for recycling, based primarily on grouping film products with the potential to be compatibly recycled together. For example, as discussed above, polyethylenes are by nature compatible with each other, and are currently recycled. Polypropylenes have both the volume and the potential to be recycled as a polypropylene grade, if other obstacles to be discussed later in this report are overcome. Other resins and multilayer structures are simply grouped into a third category, recognizing that the film products listed have more significant obstacles to recycling.

Estimates of discard quantities, in the groupings discussed, are provided in Table 1 below. The term “discard” used in this report means used for its intended purpose and available for recycling – it excludes manufacturing scrap plastics generated by plastics product manufacturers (which itself may be recycled or disposed) and plastic products not able to be collected for recycling (being used as trash bags, for example). Table 2 provides a summary of growth trends for the resins used film. The growth trends of Table 2 were used to forecast film composition in 2022, which is shown in Table 3, and depicted below in Figure 5. In this figure, blue represents polyethylene categories, green polypropylene categories, and yellow Other categories.

The percentages shown in Table 1 and 3 represent resin percentages used for the package formats and detailed forms listed. In some cases, different resins are used in monolayer structures for the product listed – for example, some 1/3 of retail carryout sacks are made from monolayer LDPE and some 2/3 of carryout sacks are made from monolayer HDPE. For other lines, the percentages represent the relative quantities of materials typically used in such applications – for example, stand-up pouches on average are made up of 60 percent PET layers by weight with lesser amounts of LDPE, and in some pouches, including a layer of

aluminum foil as well, which are all laminated together into one multi-layer structure. Individual manufacturers make their own individual package design choices, so the percentage in the tables represent what collectively would be collected prior to any sorting or resin separation.

Figure 5 – Relative Categories and Formats of Film in 2022

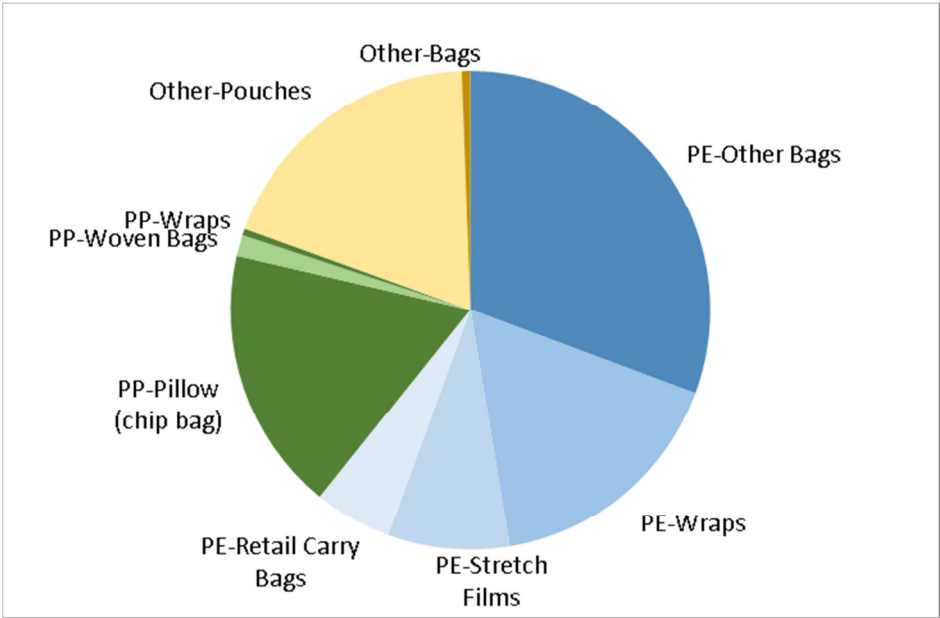


Figure 5 shows that the largest type of film is polyethylene film, nearly all of it monolayer, composing 56 percent of the total. PP-based film composes 20 percent of the total, though the vast majority of it is multilayer (primarily with polyethylene layers). The Other category composes 23 percent of the total, again, the vast majority multi-layer films. Currently, only monolayer polyethylene film is recycled in any significant quantity. The large combined total of PP-based film and Other film, at 44 percent, makes it cost-prohibitive for film recycling programs to collect all film and sort and dispose of nearly half of what would be collected.

The grouping with the highest growth rate is the Other category, composed primarily of multi-layer lay-flat and stand-up pouches, which is forecasted to grow at a 3.1 percent compounded annual rate from 2012 to 2022. However, because the PE and PP categories are also growing (though at lesser rates), and because the PE and PP categories collectively are much larger than the Other category, the Other category is only expected to grow from 22 percent to 23 percent of the film types included in this report by 2022. This small relative growth means that the relative percentages of either year, 2012 or 2022, are suitable for the purposes of this study, and that growth trends are not expected to radically change the relative quantities of film types over the next decade.

Table 1 – Estimates of Film Generation (2012)

Format and Detailed Form	Notes or Examples	Discards MM lbs	Composition Percentage by Weight										
			LDPE	HDPE	OPP	OPET	PP	PVC	Foil	Nylon	Other Barrier	Comp- ostable	
CATEGORY 1: SINGLE PE RESINS OR BLENDS OF COMPATIBLE PE RESINS													
Retail carry bags		695	100%	33%	67%								
Other Bags		3,148	100%	76%	24%								
Heavy duty shipping sacks	ICI ¹ use	1,709	54%	100%									
Box liners	cereal, mixes, bulk boxes	827	26%	10%	90%								
Storage Bags	sandwich and zip top bags	612	19%	100%									
Plastic wraps		2,006	100%	98%	2%								
Misc. roll wrap	consumer & ICI roll film	983	49%	100%									
Shrink bundling	multipacks (bottled water)	866	43%	100%									
Towel-tissue overwrap	cut and glued	157	8%	80%	20%								
Stretch Films	pallet wrap	938	100%	100%									
Total Category 1 Discard Volume		6,787		82%	18%								
Percent of Total Discard Volume		57%											
CATEGORY 2: POLYPROPYLENE FILMS OR BLENDS													
Pillow	chip bags, sachets (single web)	2,241	100%	47%		39%	14%						
Woven bags	pet food, rice, feed, and seed bags; bulk bags	168	100%	100%									
Wraps		55	100%										
Bar Wrap	candy, health bar wrappers, cheese	49	89%										
Tray Wrap	cookie tray wrap (half metallized)	4	7%										
Ream Wrap	OPP cut and glued	2	4%										
Lidding, tamper seals	dairy/yogurt cups, fruit cups, tray seals	1	100%										
Total Category 2 Discard Volume		2,465		43%		38%	13%	7%	<1%	<1%			
Percent of Total Discard Volume		21%											

1. ICI stands for industrial, commercial, and institutional.

Format and Detailed Form	Notes or Examples	Discards MM lbs		Composition Percentage by Weight									
				LDPE	HDPE	OPP	OPET	PP	PVC	Foil	Nylon	Other Barrier	Comp-ostable
CATEGORY 3: OTHER RESINS OR BLENDS													
Bags		542	100%	89%							<1%	<1%	11%
Single film	bread bags, merchandise bags	541	100%	89%									11%
Coextruded	business to business barrier	1	<1%	50%							30%	20%	
Pouches		2,042	100%	27%		5%	62%	<1%	<1%	5%	1%	1%	
Lay Flat	hot dogs, bacon, condiments, frozen pizza	1,080	53%	23%		10%	64%		<1%	1%	1%	1%	
Standup pouches	Capri Sun, dried fruit	946	46%	32%			60%			8%			
Retort Pouches	pet food, salmon/tuna	16	1%				18%	42%		40%			
Frozen tray lidding		3	100%	100%									
Total Category 3 Discard Volume		2,587		40%	0%	4%	49%	<1%	<1%	4%	<1%	<1%	2%
Percent of Total Discard Volume		22%											
TOTAL DISCARD VOLUME		11,839											

Source: the data shown above has been derived from multiple sources, but principally from the Flexible Packaging Association.

Trash bags, which are not available for recovery, are not shown in the table. Furthermore, many carryout sacks are reused for pet waste cleanup and as trash can liners, and RSE's estimate of those quantities has similarly been excluded from the table.

Table 2 – Film Resin Uses and Growth Trends

Resin	CAGR 2013-2018 ¹	Largest Current Markets	Growth Markets	Declining Markets	Competition	Use in Multi-resin Laminates or Blends
CATEGORY 1: SINGLE PE RESINS OR BLENDS OF COMPATIBLE PE RESINS						
LLDPE/LDPE	2.2%	Food packaging, box liners, stretch wrap, overwraps	Snacks, industrial, pharma/medical, construction	Retail shopping bags, garment bags, stretch wrap	Resins with better barrier or printability, PP, laminates, imports, bag restrictions	Used in all laminates
HDPE	<1%	Secondary packaging, retail bags	Snack foods, pharma/medical,	Retail shopping bags, industrial liners	LLDPE, PP, bag restrictions	"Recyclable" multi-layer bags, dry snack barrier bags
CATEGORY 2: POLYPROPYLENE						
PP	2.5%	Food packaging, especially snack foods	Food packaging, pharma/medical, shipping sacks, shrink wrap	None	Lower-cost PE resins, PET	Retort pouches, metallized barrier, microwavable vegetable pouches
Woven PP	2.0%	Pet food, grain sacks, bulk sacks	Pet food, shipping sacks	None	Laminates	Not generally used
CATEGORY 3: OTHER RESINS OR BLENDS						
PET	1.8%	Snack foods, meats	Pouch refills, frozen food, medical/ pharma	Tobacco film, photographic, magnetic tape	Metallized PP, nylon	Used with PP & nylon for retort pouches, moderate oxygen/ moisture barrier uses
Barrier	1.3% - 3.9%					Nylon, PVDC, EVOH barrier layers
Degradable	2.4%	Food packaging	"Environmentally friendly" market, lawn & leaf bags	Retail bags as part of general decline of category	Established resins, questions about actual compostability	Blends with PE for bag rollstock
PVC	<1%	meat, poultry, seafood	fresh red meat	Produce, baked goods	Environmentally preferable or better performing resins	Not generally used
PS	1.7%	Food packaging, especially produce	Produce and fresh food packaging	Labeling, high temperature filling	Degradable resins, lower cost PE, PET	Not generally used

¹ CAGR stands for compounded annual growth rate. Estimates in this table come from discussions with industry sources.

Table 3 – Estimates of Film Generation in 2022

Format and Detailed Form	Notes or Examples	Discards MM lbs	Composition Percentage by Weight											
			LDPE	HDPE	OPP	OPET	PP	PVC	Foil	Nylon	Other Barrier	Comp-ostable		
CATEGORY 1: SINGLE PE RESINS OR BLENDS OF COMPATIBLE PE RESINS														
Retail carry bags		767	100%	33%	67%									
Other Bags		3,687	100%	78%	22%									
Heavy duty shipping sacks	ICI use	2,083	57%	100%										
Box liners	cereal, mixes, bulk boxes	941	26%	15%	85%									
Storage Bags	sandwich and zip top bags	663	18%	100%										
Plastic wraps		2,445	100%	98%	2%									
Misc. roll wrap	consumer & ICI roll film	1,198	49%	100%										
Shrink bundling	multipacks (bottled water)	1,056	43%	100%										
Towel-tissue overwrap	cut and glued	191	8%	80%	20%									
Stretch Films	pallet wrap	1,201	100%	100%										
Total Category 1 Discard Volume		8,100		83%	17%									
Percent of Total Discard Volume		56%												
CATEGORY 2: POLYPROPYLENE FILMS OR BLENDS														
Pillow	chip bags, sachets (single web)	2,601	100%	47%		39%	14%							
Woven bags	pet food, rice, feed, and seed bags; bulk bags	205	100%	100%										
Wraps		67	100%	98%										2%
Bar Wrap	candy, health bar wrappers, cheese	60	90%	98%										2%
Tray Wrap	cookie tray wrap (half metallized)	5	7%	100%										
Ream Wrap	OPP cut and glued	2	3%	100%										
Lidding, tamper seals	dairy/yogurt cups, fruit cups, tray seals	2	100%	100%										<1% <1%
Total Category 2 Discard Volume		2,875		43%		38%	13%	7%	<1%	<1%	<1%			
Percent of Total Discard Volume		20%												

Format and Detailed Form	Notes or Examples	Discards MM lbs		Composition Percentage by Weight									
				LDPE	HDPE	OPP	OPET	PP	PVC	Foil	Nylon	Other Barrier	Comp-ostable
CATEGORY 3: OTHER RESINS OR BLENDS													
Bags		593	100%	87%							<1%	<1%	13%
Single film	bread bags, merchandise bags	592	100%	87%									13%
Coextruded	business to business barrier	1	<1%	50%							30%	20%	
Pouches		2,769	100%	27%		7%	59%	<1%	<1%	5%	<1%	<1%	
Lay Flat	hot dogs, bacon, condiments, frozen pizza	1,343	48%	23%		13%	62%		<1%	1%	1%	1%	
Standup pouches	Capri Sun, dried fruit	1,400	51%	32%		3%	58%			8%			
Retort Pouches	pet food, salmon/tuna	26	<1%				18%	42%		40%			
Frozen tray lidding		5	100%	100%									
Total Category 3 Discard Volume		3,366		38%	0%	6%	49%	<1%	<1%	4%	<1%	<1%	2%
Percent of Total Discard Volume		23%											
TOTAL DISCARD VOLUME		14,341											

Source: the data shown above has been derived from multiple sources, but principally from the Flexible Packaging Association. Trash bags, which are not available for recovery, are not shown in the table. Furthermore, many carryout sacks are reused for pet waste cleanup and as trash can liners, and RSE's estimate of those quantities has similarly been excluded from the table.

2.2. Other Film Characteristics that Impact Recycling

The prior tables grouped film into three broad categories based on resin compatibility. There are other characteristics of certain film products that can impact the ability to recycle those products into certain recycled content applications, or to recycle them cost-effectively at all. These characteristics include design-related choices and use/application characteristics (impacts from choices of recycling collection approaches are discussed later in this report).

Design Choices

- Resins – multilayer structures can be designed with recycling in mind, including choosing resins used for barrier and other layers that can be compatibilized.
- Color – clear, white, and mixed color films (including printed films) have different market pricing and demand depending on the aesthetic requirements of the recycled content products being produced. Black plastic presents challenges to identifying the plastic resin of the product by optical sorting equipment; however, recycled plastic is often pigmented black to mask the otherwise unappealing color that results when mixed colors of plastics are recycled together.
- Adherents – tapes, labels, and aluminum foil applied to film can result in recycling challenges for certain recyclers.

Use Characteristics

- Size – very small pieces of film (e.g., candy wrappers) may not be able to be collected or cost-effectively sorted.
- Contents – film that was in contact with wet contents such as gels will be much more contaminated and require washing as part of the recycling process; film that was in contact with dry contents may not require washing.

Good data does not exist on most of the characteristics listed above. Based on the market segment data presented in Tables 1 and 3 above, RSE has made some estimates of the potential degree of content-contamination on the three broad categories of film, which may require the film to be washed as part of the recycling process, as follows:

- PE film: approximately 10 percent of film may be contaminated by contents and need to be washed;
- PP film: over 75 percent of film would likely be contaminated by contents and need to be washed;
- Other film: approximately half of film/flexible packaging would likely be contaminated by contents and need to be washed.

The above estimates are for the cleanliness of film at the point of generation. If film is recovered out of waste or collected with mixed residential recyclables, film may pick up contamination it originally did not have and need to be washed.

3. U.S. Film Recycling Value Chains

This section discusses the entities that are involved in film recycling value chains that manage film from the point where it is generated as a discard to being incorporated into recycled content products. For each link in the value chains, there is a discussion of how film recycling works at that level, drivers for them, their effectiveness, and obstacles to higher levels of recycling.

The discussions of this section are focused on monolayer polyethylene film because such film is collected

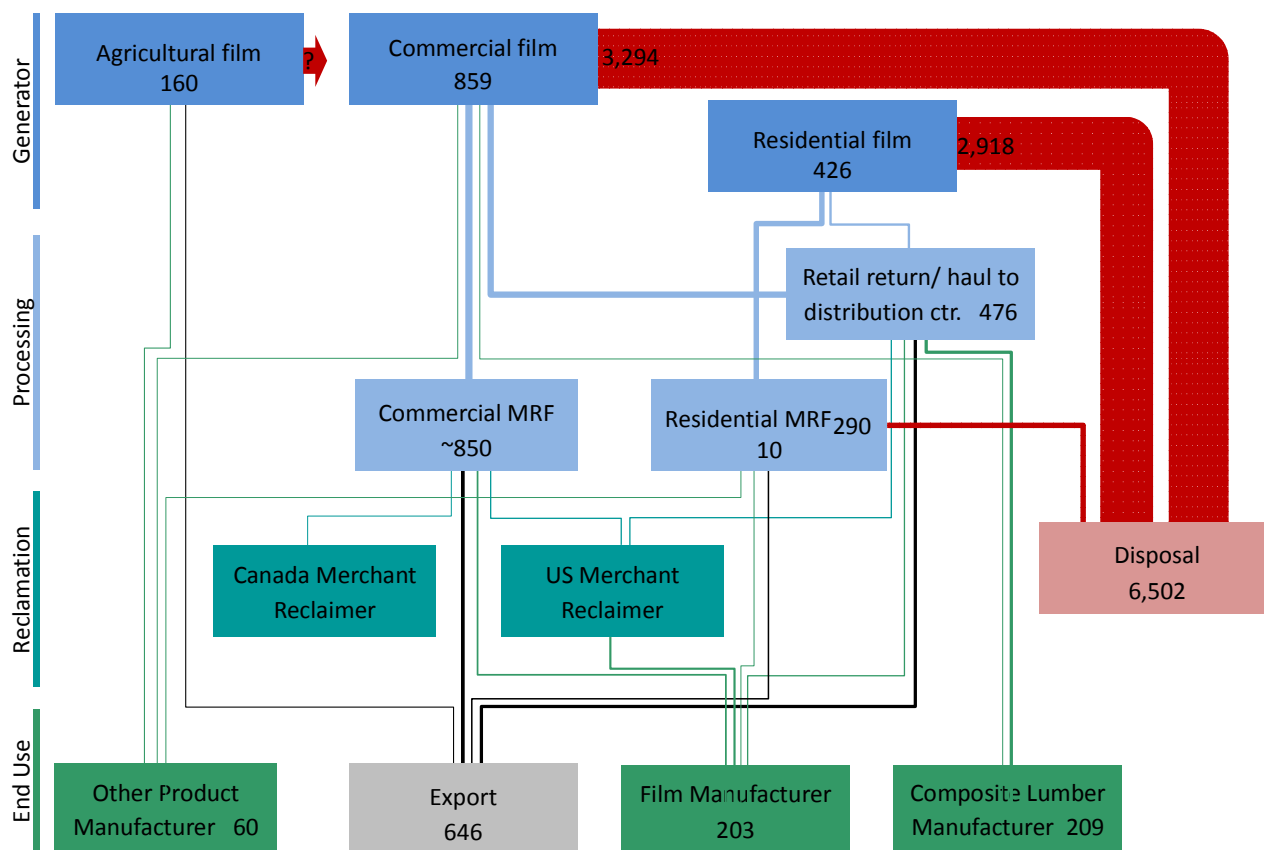
and recycled today, and a plan to overcome barriers can leverage existing investments and value chain structures to grow polyethylene film recycling. However, other types of film lack a current value chain for recycling and are disposed virtually in their entirety. Barriers to recycling these types of films are introduced in this section. Following report sections collect the obstacles identified here for each level of the value chains and link them together in terms of the extended film recycling value chains. Those following sections also identify opportunities where stakeholders, including CL Fund investments, can lead to higher levels of U.S. film recycling.

3.1. Overview of Film Value Chains and Flows

3.1.1. Polyethylene Film Value Chain and Flows

Figure 6 shows RSE's estimate of recoverable⁴ polyethylene film recycling and disposal stream flows.

Figure 6 – U.S. Polyethylene Film Recycling Value Chains and Disposal Flows



Note: Quantities are flows in millions of pounds and are based on American Chemistry Council annual film recycling report figures for 2014. Disposal of agricultural film is not shown because it is not a focus of this study, and because RSE desired to simplify this figure in order to focus on the flows of primary interest to CL Foundation (agricultural film recycling quantities are shown because they are embedded in the final quantity).

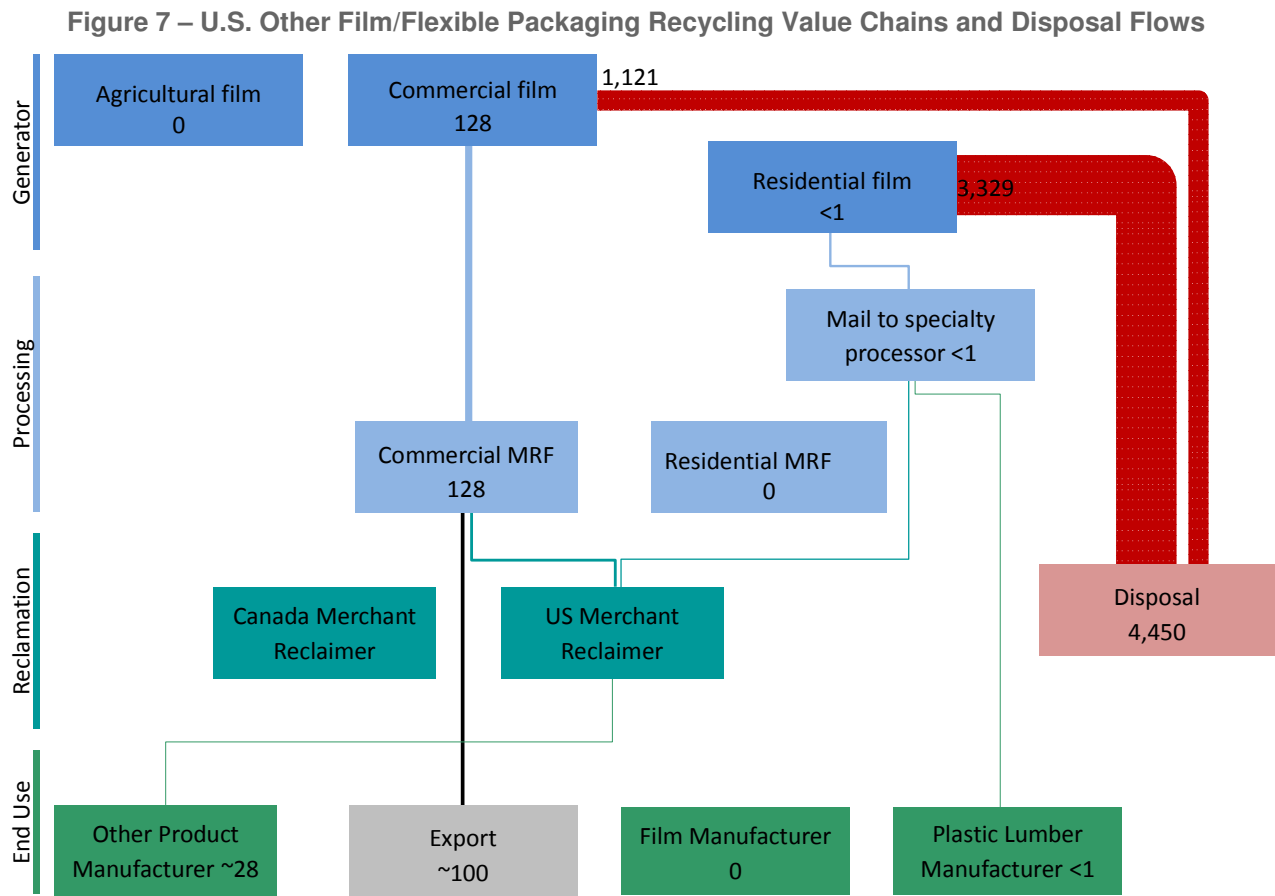
⁴ Recoverable film excludes film quantities used as trash bags and film that becomes part of other products (e.g., laminated paper and diapers).

end use numbers).

As Figure 6 shows, the vast majority of polyethylene film recycled is from commercial sources (859 million pounds, estimated 21 percent recycling rate), versus residential film (136 million pounds, estimated 4 percent recycling rate including both bags and wraps), most of which is recycled through retail return collection systems. Film that isn't recycled is disposed. According to the US EPA, 20 percent of the disposed quantity is sent to energy recovery facilities and the remaining 80 percent is landfilled.

3.1.2. Film Value Chains and Flows for Other Single-Resin Films and Multilayer Laminates

Figure 7 likewise shows flows for multilayer flexible packaging and for monolayer films from other resins.



Note: Quantities are flows in millions of pounds and are based on RSE estimates. Quantity flows to final markets are not known. Commercial film is mono-material woven slit-film polypropylene sacks.

Like Figure 6, Figure 7 shows that the vast majority of non-polyethylene recycling occurs for commercially-generated film, mostly for mono-material woven slit-film polypropylene sacks. Only a very small amount of multilayer films from residences (chip bags, bar wraps, and juice pouches) are believed to be recycled through a niche recycling services offered by a couple of recycling companies to consumer packaged goods companies for materials that otherwise would not be profitable or commercially viable to recycle in municipal or retail sponsored recycling programs.

3.2. Residential Film Recycling Collection and Processing

3.2.1. Return to Retail Collection for Residential Polyethylene Film

How it Works

Return to retail collection programs allow residential consumers to return film that becomes discards in residences to private retail collection sites. There are over 18,000 drop-off sites in the United States for residential polyethylene film. The vast majority of these sites is at retail locations and includes most grocery chains, Walmart, Target, JCPenney, Lowe's, and selected private recycler and municipal drop-off locations. These programs only accept clean and dry polyethylene film bags and wraps.

Figure 8 shows an example of the signage that is used by a small but growing number of retailers, which was developed by the Flexible Film Recycling Group, in cooperation with the Sustainable Packaging Coalition's How2Recycle™ initiative for the other polyethylene film that is accepted in such programs.

Drivers

Development of the film recycling infrastructure and return to retail recycling flows for residential polyethylene film summarized above has been driven in part by state laws. State laws that require stores to provide for retail return programs for carryout bags and sacks cover nearly 20 percent of the U.S. population, and include the following states:

- **California.** AB 2449 (2006), amended in 2012 by SB 1219, to extend the sunset date to 2020. Requires that retail stores that issued plastic bags have a recycling container in or outside each store allowing consumers to recycle plastic carry out bags, produce bags, and other plastic film and wraps.
- **Delaware.** 2009 DE H 15; Amended by 2014 DE H 198. Encourages the use of reusable bags by consumers and retailers, requires a store to establish an at-store recycling program that provides an opportunity for a customer of the store to return clean plastic bags, requires all plastic carryout bags to display a recycling message, requires stores to maintain records of collection and recycling of plastic bags, prohibits imposition of a plastic bag fee upon a compliant store, provides for fines and penalties.
- **Maine.** 1991 ME LD 1166. Retailers may only provide customers with plastic bags if there is a receptacle to collect used plastic bags with twenty feet of the entrance and all the plastic bags collected are then recycled.
- **New York.** 2008 NY A 11725. Retailers of stores are to establish in-store recycling programs that

Figure 8 – Retail Drop-Off Film



provide an opportunity for the customer to return clean plastic carryout bags to be recycled. The plastic carryout bags provided by the store must have printed on them “Please return to a Participating Store for Recycling.”

- **Rhode Island.** 2008 RI S 2565 (Promotion of Paper Bag Usage). Retail establishments must offer the use of a paper bag to the consumer. Every retail establishment that provides customers with plastic bags must provide conveniently located receptacles where customers can return their clean and dry plastic bags to be recycled.

These laws have helped to institutionalize return to retail as the primary route for polyethylene bag recycling in the United States.

Although the legislation cited above only requires retailers to accept carryout film bags, most retailers accept other clean polyethylene bags and wraps from their customers as well, including newspaper sleeves, dry cleaner bags, toilet tissue overwrap, and cereal box liners. The efforts of the Flexible Film Recycling Group and companies such as Trex have led most retail chain collection programs to accept other clean and dry residential polyethylene film in addition to carryout bags. The stores are willing to accept these other types of polyethylene film because it is typically clear and therefore valuable, incurs little additional handling cost on their part and provides them with additional positive revenues for the material.

Recovery Effectiveness and Performance

The extensive retail collection access provided for residential film bags and wraps essentially serves the entire U.S. population with somewhat convenient access (every family has to visit grocery stores on a regular basis anyway). However, this approach to collection has not proven highly effective to date. According to recycling data from the American Chemistry Council, RSE estimates that only 7 percent of retail bags that are available for recycling (i.e., not used as trash can liners or for pet cleanup) are returned by residents to stores for recycling. RSE also estimates that only 3 percent of non-retail bag residential polyethylene film is returned to stores for recycling.

Issues and Challenges

A 2014 survey by *Plastics Make it Possible*⁵ found that while nearly two thirds of Americans say they recycle on a “regular basis,” only 32 percent say they have returned plastic shopping bags to stores for recycling.⁵ It is not known what portion of those who have brought bags back to stores do so on a regular basis. Given the significantly lower recycling rate estimate of 7 percent, probably only a relatively small portion. There appears to be obstacles to consumers returning bags to retail stores and/or unwillingness on the part of many to do so. Furthermore, the difference between retail bag and other polyethylene film recycling rates indicates that educational barriers remain for many who recycle retail bags but don’t recycle the additional non-retail bag films shown in Figure 8. RSE believes that most individuals understand that retail bags are recyclable, but are unaware of which other film products and packaging can be returned to retail.

Consumer confusion over which film products may be accepted in retail return programs is compounded by a couple of factors:

⁵ “A Look at Plastic Film Recycling,” *Plastics Engineering Magazine*, January 2015.

- Approximately half of household film generated is not monolayer PE⁶ and of the proportion that is PE, a significant proportion is contaminated so that only a minority of residential film generated is accepted for recycling (at in store drop-offs) – by comparison, some 97 percent of all plastic bottles generated are PET and HDPE bottles, so recycling programs for those recyclables can simply ask for “all plastic bottles” and dispose of the small amount of non-accepted materials.
- Some 39 states have laws that require manufacturers to label rigid plastic containers with the resin type it is made from – film is not required to be labeled and most film is not. Consumers are therefore not sure about the acceptability of most individual pieces of non-retail bag film.



OTHER



LDPE

Despite these challenges, more non-retail bag film is returned to retail by consumers than retail bags. There are two reasons for this. First, there is a much greater quantity of non-retail PE film generated than PE carryout sacks. Second, consumers who are motivated to return film to stores for recycling are believed to be more environmentally conscious than the average member of the public, and are more likely to reduce single-use bag generation in the first place by using reusable bags.

3.2.2. Curbside Collection of Residential Polyethylene Film

How it Works

Moore Recycling Associates estimated for 2012 that approximately ten percent of the U.S. population was allowed to place film in their residential curbside collection programs.⁷ More recently, that figure is believed to have fallen, and today only a small percentage of residential recycling programs tell their residential participants that placing polyethylene film in their collection containers is acceptable.

All MRFs, whether they accept film from curbside programs or not, receive film and must sort it from other recyclables and either recycle or dispose of it – of the approximately 300 million pounds per year of residential film MRFs receive, only 10 million pounds is able to be marketed due to lack of recycling markets for MRF film. MRFs receive film even when collection programs don't accept it because:

- Program participants may understand polyethylene film to be recyclable since they can return it to retail sites, and therefore believe that if they place it in their recycling carts MRFs will recycle it too; and
- Residents of single- and multi-family dwellings commonly line in-home recycling cans with film bags and when they empty them, place the bag and its contents of recyclables in the setout container.

Municipal curbside and drop-off programs that accept film instruct participants regarding which types of film is accepted in their programs. This may include only retail bags, or it may include the broader array of clean polyethylene bags and wraps accepted in most retail return programs. No U.S. programs are known to accept all forms of film (e.g., PP bags, multilayer pouches).

A best practice for communities that accept film is for them to instruct residents to place their film into one retail bag until it fills, and then tie the bag tightly shut so that it is about the size of a soccer ball. This works on two levels – it makes sorting at the MRF less costly, plus it keeps the bags inside of the outermost bag

⁶ Or acceptable multilayer packaging of polyethylene-compatible layers.

⁷ “Plastic Film and Bag Recycling Collection: National Reach Study,” Moore Recycling Associates, April 2012. This figure does not include communities that use bag-based recycling collection systems and that otherwise do not accept film for recycling.

clean and dry, improving film quality. This best practice approach is based on manually separating film from other recyclables in MRFs.

How film is collected in municipal programs also depends on how the municipal programs are structured. In dual stream programs, residents may be instructed to only place polyethylene film in either the containers bin or the fibers bin. Film placed in the fiber stream stays cleaner than film collected in the containers stream; however, film will be found in both streams regardless of promotion and education messaging because:

- Residents who use film bags for storage and transportation of recyclables will not typically debag the recyclables and will toss them into whatever stream the contents of the bag belongs in;
- Residents often do not debag paper from film mailers or unread papers left on their driveways;
- Residents may not remember which stream they are asked to place them in and therefore place them in whatever stream they believe is best.

Once the film is received at MRFs, it is manually separated from paper and containers then, baled.

Some municipalities offer alternative collection points for problematic materials that are not effectively recycled through curbside systems. These municipal drop-offs may accept materials such as used electronics, household hazardous waste, bulky durable goods, shredded paper, polystyrene foam, and polyethylene film plastics. Because these sites are attended, and film is kept source-separated from other materials, it is usually of equal quality to that of retail return sites and has similar marketability. A challenge of course is achieving large enough collection volumes to accumulate sufficient quantities of film for marketing to film reclaimers. Because of this obstacle, residents are usually instructed to recycle their film through retail return sites in those communities that do not accept it in curbside recycling programs.

Drivers

Recycling programs that collect film curbside are driven by the desire to achieve higher recycling rates than that obtained through retail return systems by making recycling more convenient to generators. A driver against curbside recycling of film in the U.S., however, is the extremely small amount of market demand for curbside film from North American reclaimers up to this point in time.

Outside of the U.S., it is common to collect polyethylene film curbside, and in Europe the collection extends to all forms of flexible packaging (though in Europe it is typical to send non-polyethylene film to be combusted for energy in cement kilns). It should be noted that different drivers and different recycling infrastructures in these foreign jurisdictions have led to a different approach to film recycling there compared to that of the U.S. However, it is important to consider alternative approaches to film recycling compared to that currently used in the U.S. if they hold the promise of achieving higher film recycling rates in this country. Case studies of film recycling in the Canadian province of Ontario and in Germany, where film is commonly collected curbside, follow later in this report.

Recovery Effectiveness and Performance

As stated previously, all MRFs receive at least some film regardless of whether the collection programs that feed into them officially accept it or not. Figure 6 showed that an estimated 300 million pounds of film enters U.S. MRFs each year.⁸ The vast majority of this quantity is believed to be recyclables improperly set out in bags, as well as film that program participants place in their recycling carts in the hope that it will be

⁸ “WRAP: Best Practices for Boosting Plastic Film Recycling in Your Community,” Flexible Film Recycling Group presentation to EPA Sustainable Materials Management Web Academy, July 2015.

recycled.⁹ Unfortunately, most MRFs simply dispose of film due to the limited outlets for curbside collected film, its poor quality, and almost no market value. In 2014 only 9.7 million pounds (approximately 3 percent) of film that enters MRFs was recycled.

Specifically with regard to programs that officially accept film in their programs, RSE is not aware of data or studies from U.S. communities that report film recovery effectiveness. This is because few programs accept film curbside, there is variation in what is accepted (bags only, or polyethylene bags and wraps), and variation in MRF ability to sort film into a recycling stream and market it. The case study on curbside film recycling in Ontario that follows later in this report shows that curbside collection can result in increases in recycling of at least five times that currently recycled through the U.S. retail return approach.

Issues and Challenges

This section of issues and challenges to curbside recycling of film begins with a case study of San Antonio, which added film to its single stream recycling program less than two years ago. The sidebar to the right provides the city's perspective. The issues brought up by this case study are elaborated upon in the paragraphs that follow.

Although ReCommunity agreed to accept film in its San Antonio MRF in order to be responsive to the request of the city in its request for proposals, ReCommunity generally does not accept film of any kind in its other MRFs. A vice president of ReCommunity, not speaking specifically of San Antonio, stated the following regarding film in its MRFs in a March 2016 presentation:

- Lightweight, flexible packaging is difficult to sort and impairs overall recovery rates [for other materials];
- Flexible packaging is gaining popularity with brand owners and consumers, but these containers are non-recyclable and must be sorted out for disposal when they reach the MRF;
- Flexible plastics behave like paper products [in how they naturally flow in a MRF] and lead to higher levels of contamination in paper sent to market; and
- Most contaminants must be removed by hand – the current state of the art.

San Antonio Texas Curbside Film Perspective

San Antonio Texas added polyethylene film bags to its curbside recycling program beginning in August 2014. The bags were added at the same time that a new MRF contractor, ReCommunity, constructed a new MRF including design features for sorting film from other recyclables.

The city's and ReCommunity's websites instruct citizens to only recycle "plastic bags (clean, empty, bundled inside another bag)" - residents are also instructed to exclude black plastic bags from the program. RSE interviewed San Antonio's recycling contract administrator for insights on the city's experiences for this project.

San Antonio believes that it is important to emphasize the bag-in-bag approach for consumer education for curbside film recycling to have the best chance of success. Film collected through the program has proven to comprise less than one percent of all incoming materials [RSE notes that this percentage is consistent with collection volumes from other jurisdictions where film is collected curbside].

Although ReCommunity is able to manually sort the film, markets have been unreliable since the city began accepting retail bags. Originally, an in-state market accepted it and paid around \$100 per ton (5 cents per pound) for the material; however, in 2015 that market shifted to cleaner sources of supply. The MRF is currently stockpiling baled film as it searches for a replacement market.

In retrospect, the contact RSE spoke to from the city believes that it would be better to collect film through retail return than in the city's curbside system.

⁹ Many recycling program participants place items in recycling collection containers that they "aspirationally" believe may be recycled, or that they want to "send a message" to recycling program operators that it should be included. Of course, some of the amount is also likely simple confusion or misunderstanding.

Virtually all U.S. MRF companies express the same sentiment as ReCommunity. Since 2014 the nation's largest MRF company, Waste Management, has been reaching out to consumers through its Recycle Often Recycle Right initiative (<http://recycleoftenrecycleright.com/>) in an attempt to reduce contaminants in residential recyclables, which at the time Waste Management said reached 16 percent in its MRFs.¹⁰ Waste Management considers getting film out of the recyclables streams going to its MRFs as one of the “big three” things participants can do to improve recycling. Figure 9 shows the messaging that Waste Management uses on its website for plastics film in curbside programs that go to its MRFs.

Figure 9 – Waste Management’s Consumer Outreach Regarding Curbside Film Recycling



Like ReCommunity, Waste Management accepts film in some of its MRFs because its community contracts require it. However, as the above discussion illustrates, MRF companies generally do not believe that film should be allowed in residential recycling systems in the U.S.

So why are U.S. MRFs generally opposed to film entering their facilities? Reasons include:

- Loss of productivity and danger to workers because of the need to shut down and clean film from equipment one or more times per shift;
- Contamination of other commodity products by floating films and bags that easily flow with other materials;
- High cost of either manually sorting individual bags or pieces of film, or installing additional mechanical equipment to try to sort film;
- Minimal or zero value of baled film at the end of the sorting process because it becomes wet, dirty, contaminated by other materials, and/or contamination from mixed resin film materials.

The first reason, equipment problems, requires additional explanation. These equipment problems primarily occur in single-stream MRFs. Approximately 80 percent of the U.S. population that has residential recycling access is provided that access through single-stream collection, in which recyclables are separated from waste by residential generators and set out as mixed recyclables in a single cart or bin. The vast majority of single-stream MRFs in the U.S. uses mechanical screens to separate flat recyclables, such as paper, from “three dimensional” recyclables – primarily containers. Screens have a deck of rotating shafts with rubber or metal touch-points on them that push flat items up an incline, while three dimensional items tumble down and/or fall between gaps in the shafts. Unfortunately, highly flexible film like that used for retail carryout sacks has a tendency to get wrapped around the rotating axles of these screens, fouling them, and preventing them from separating paper from containers with the effectiveness for which they were designed. Figure 10 shows the effects of film on screens found in most U.S. single-stream MRFs.

¹⁰ “Sustainability Report,” Waste Management Inc., 2014

Figure 10 – A Film-Fouled Screen and a Clean Screen



Photograph credits – ReCommunity for the fouled screen, and BHS for the clean screen.

When a screen is fouled by film, the equipment must be shut down and workers must climb on the decks and manually cut and pull film from the shafts. It should be noted multilayer pouches do not get wrapped around the screen axes as do retail sacks because they are less flexible. Furthermore, there is other equipment that can be used in MRFs in combination with or as a replacement for screens that perform similar functions but that do not foul like screens do when film is in the incoming recyclables stream. This type of equipment will be discussed later in this report.

Currently, RSE estimates that over 90 percent of existing U.S. single-stream MRFs use screens similar to those depicted above, which are susceptible to fouling by thin highly-flexible plastic film. Because of film fouling of screens, MRF operators manually remove film from the mixed recyclables stream as early in the recycling process as they can, at a presort station. The amount of film, however, can be overwhelming; it is not uncommon for MRFs to have to shut down processing and clean these screens twice per shift due to film that slips by. Film that does not get caught in the screens flows throughout the MRF, most often with the paper, since film is flat or lightweight and rides with the paper to the top of the screen.

In addition to the lost productivity due to fouled screens, MRF operators resist having film in residential recyclables because of the expense of sorting it, which greatly exceeds its scrap value. The standard approach is to manually remove film by hand at the first stage in processing (i.e., at the presort station). The dollars per ton cost to do this depends on whether film has been placed by recycling program participants as numerous individual pieces in the recycling cart, or whether polyethylene film and bags have been placed by program participants inside retail sacks and tied off so that ball-shaped bags containing numerous film items can be removed manually with one grab. RSE has estimated that sorting individual loose pieces of film in a MRF can cost approximately \$150 per ton for the direct sorting labor cost alone, not

including other costs. Alternatively, if 80 percent of film is contained in tied off bags the sorting cost drops to \$30 per ton. Because MRF film typically has a value of \$40 per ton or less, and because most curbside recycling program participants do not sort and tie off film into a single ball of film, it is rare that MRFs are able to sort film profitably.

MRF film has a low scrap value. The only material processed by MRFs with a lower value is glass. There are only two North American markets that regularly purchase MRF film and they have very limited demand for the material; therefore, a majority of MRF film is exported. Transportation costs to distant markets, whether domestic or foreign, add additional cost to the recycling value chain of MRF film compared to other types of polyethylene films, which must be subtracted from the value of the MRF film. Reclamation costs for MRF film are also higher than that of other types of films for reasons that will be further discussed later in this report, so markets pay less scrap value for it. These factors result in scrap value obstacles for curbside-collected polyethylene film, such that it has minimal value and at times is worthless to MRFs. From the MRF perspective, the cost to process it far exceeds its value, and so they resist adding to recycling programs. Because residential recycling opportunities are available through retail return, and due to MRF resistance, most municipal residential recycling program sponsors do not press to add it to curbside recycling programs. By comparison, glass lacks an alternative recycling system, so most communities insist that MRFs recycle it at a loss rather than instruct their residents to dispose of it.

In summary, obstacles to curbside collection and processing of residential polyethylene MRF films include:

- Resistance by MRF operators for film to be included in convenient curbside collection programs;
- MRFs have not been designed to recycle film in the primary method of collection and processing used in the U.S. (single-stream MRFs); and
- MRF film has low and in some cases no value.

Obstacles to curbside collection and processing of majority PP bags and multilayer pouches include:

- Lack of film sorting equipment that could be used by MRFs to sort mixed types of films into polyethylene, polypropylene, and Other types of film (primarily multilayer laminates);
- Cross contamination that would occur of other MRF product grades because the flatter and stiffer PP bags and multilayer pouches would primarily be sorted into paper streams by single-stream MRF equipment; and
- Absence of recycling markets for these materials (a limited number of energy recovery markets for such material do exist, but are not able to offer scrap value for the material).

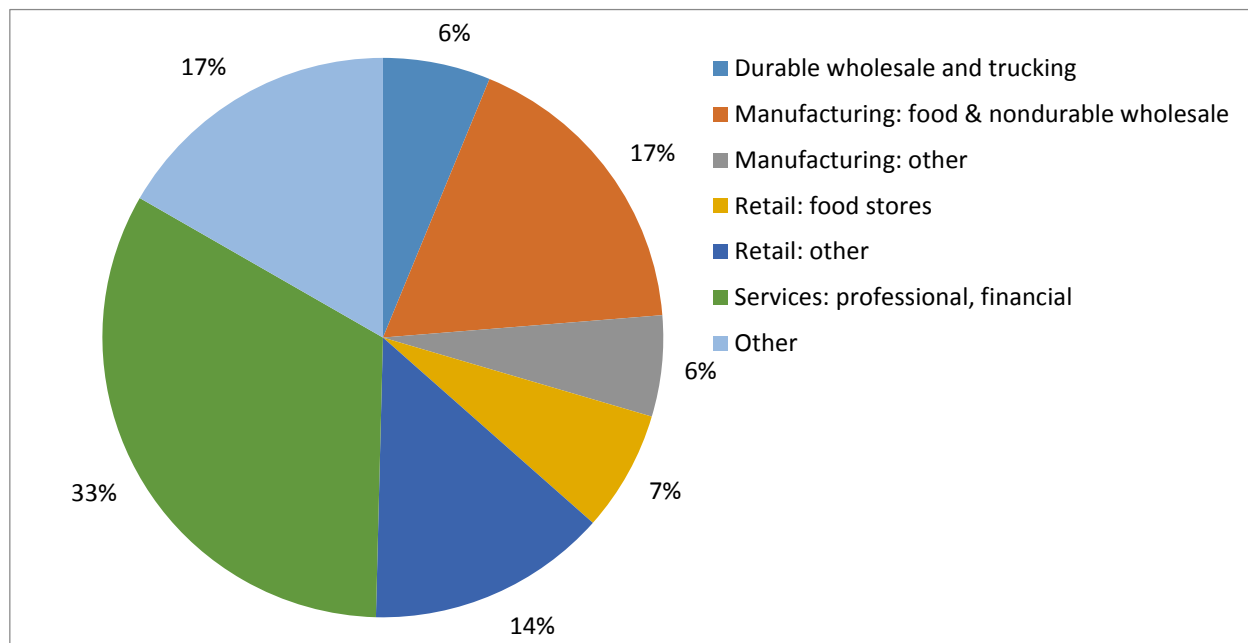
Equipment and technologies for film sorting are discussed in more depth later in this report.

3.3. Industrial, Commercial, and Institutional Film Collection and Processing

3.3.1. How it Works

California periodically gathers detailed waste and recycling composition data from different types of generators for state planning purposes. While California's economy has distinct differences from the overall U.S. economy, other states have not mapped out industrial, commercial, and institutional (ICI) waste by sector; therefore, California's data will be used to inform ICI film generation and recycling flow-paths for the purposes of this study. As an example, Figure 11 shows the ICI sectors where polyethylene film transport packaging is generated in California.

Figure 11 – California Polyethylene Film Transport Packaging Generation



Source: “2014 Generator-Based Characterization of Commercial Sector Disposal and Diversion in California,” California Department of Resources Recycling and Recovery, September 2015.

ICI film recycling occurs through:

- 1) Film recycler supply chain development; and
- 2) Local commercial recycler services.

These approaches, and their relationship to which business sectors generate which types of film, are discussed in the following subsections.

Film Recycler Supply Chain Development

As Figure 11 shows, much of the transport packaging film (primarily stretch wrap used to unitize goods on pallets, but also including bubble wrap, and large item overwraps) is generated by several key sectors. Film reclaimers know these sectors well, and have focused their efforts on developing relationships and recovered film supply chains in order to collect and channel clean polyethylene film from these sectors to their reclamation plants. Exporters also compete for film from these retail chain distribution centers, but often don’t have the same depth of relationships.

Large retail chains typically operate their own warehouse and distribution centers and distribute goods to their stores using their own fleet of trucks. Examples include:

- Grocery chains;
- Big box stores, such as Walmart and Target;
- Home improvement stores, such as Home Depot and Lowe’s;
- Pharmacy stores, such as CVS and Walgreens;
- Department stores, such as Macy’s and Sears;
- Furniture and appliance retailers, such as Rooms to Go and Best Buy;

- Restaurant chains, such as McDonalds and Darden (Olive Garden).

These chains generate large volumes of pallet wrap at their distribution center locations from incoming palletized products being received from multiple suppliers, some of which they break apart, re-palletize, and rewrap to resupply their retail locations. Because they operate their own fleet of trucks, they can back-haul film from their retail stores to the central distribution centers at virtually no cost since the trucks are returning empty anyway. Front-of-store residential return film is bagged and stored in the back of the store. Back-of-store film including stretch wrap and other protective polyethylene bags (e.g., clothing bags from department stores) are bagged, and stored for the backhaul along with bags of front-of-store residential film that are kept separate due to its lower value. When the fleet trucks arrive back at the distribution center, the bags of loose film are offloaded, combined with film from other stores (including the pallet wrap generated at the distribution center), and then baled and stored until truckload quantities are accumulated. Back-of-store material is typically baled separately from front-of-store (residential) material because of its higher value compared to that of colored retail sacks and other printed residential films.

Not all distribution centers have their own fleet of trucks. For example, e-commerce retailers such as Amazon.com receive pallet wrap and other film from their product suppliers at their distribution centers but use delivery services such as UPS to ship individual packages to homes. Smaller retail chains may also contract with distribution package service providers that may not offer a film backhaul recycling program, or that use common carriers or package delivery services to restock retailers.

Large retail chains manage sufficient quantities of film to bale and market their own film in truckload quantities.¹¹ However, there are many smaller organizations that cannot accumulate truckload quantities in a year, lack storage space for baled materials, or lack baling and material handling equipment. Several film recyclers have worked to develop supplier relationships for polyethylene film from these smaller quantity generators. Trex is one such example as described in the sidebar to the right.

Although a significant number of commercial generators still discard film, the effort in identifying new sources and developing successful recovery systems takes time. Therefore, recyclers are secretive about who their suppliers are and the amounts recovered from them. The importance of long-term supply chain relationships to commercial film recycling should not be underestimated. One recycler who was interviewed for this report admitted that their company employs at least one full-time employee who travels to supplier locations, monitors their recovery systems, and continually trains on best practices and minimizing contamination, in addition to maintaining supply chain relationships. Some of the integrated recyclers that manufacture trash bags report success in involving their suppliers in “closed loop” systems where the transport packaging film they generate is remanufactured into branded trash bags or film

Trex Supply Chain Development

Trex partners with dry cleaners, independent grocery stores, hospitals, furniture stores, manufacturing/assembly plants, convention centers, stadiums, malls, and many other types of generators to set up collection programs.

For those that generate enough film to equal a truckload per year, Trex will finance a downstroke baler for their use. Those that already have a baler need only accumulate 10,000 pounds of film for Trex to pick it up.

For smaller film generators, Trex will supply compressed-air mini-balers that produce 50-pound bales that can be manually moved without needing material handling equipment. These mini-bales must be collected and aggregated in one location until a truckload quantity is accumulated.

Trex is not alone in supply chain development. Other film recyclers have similar, but perhaps not as well developed programs.

¹¹ Truckload quantity generally means at least 37,000 pounds of baled material that can be loaded on a trailer using skid steer equipment.

products the supplying company can use or sell, guaranteeing the recycler a steady, high-quality supply and the brand company a less expensive recycled-content product.

A critical part of existing PE film recycling is distributors who backhaul clean generator-separated film from their customers, many of whom otherwise would not have film recycling programs.

Local Commercial Recycling Service Providers

The other flow-path for ICI polyethylene film is through local commercial recycling service providers. Some local recycling processors who focus on collecting and baling old corrugated containers (OCC) will allow bagged film to be placed in collection containers with the OCC. Other commercial recycling processors have sorting lines that allow them to collect and sort mixed recyclables – fortunately, these facilities often do not have the paper screens that residential MRFs have which can become fouled by film. Finally, other ICI MRFs collect and sort mixed clean and dry ICI waste to remove recyclables, and some of these processors bale film for recycling as well.

3.3.2. Drivers of ICI Film Recovery

The economic driver for ICI film generators who recycle directly with film reclaimers, as well as for distributors who backhaul, is the positive value they receive for the film they bale. Because waste haulers price ICI waste collection and disposal costs based on volume of waste to be collected, generators whose dumpsters contain large volumes of film can save significant disposal costs if they recycle their film.

Drivers for film recovery for establishments that do not generate large volumes of film are much reduced compared to that of large-quantity generators. Certain states or local jurisdictions require ICI establishments to implement recycling programs in order to help the jurisdictions meet waste reduction goals. However, film is not identified as a material that must be included in ICI recycling programs, nor is film subject to disposal bans like old corrugated containers are in some jurisdictions. The driver for film recycling from ICI establishments is the availability of commingled ICI materials recycling offered by some private recyclers that allows film to be included in the programs; however, most of these commingled programs do not accept film, which is a significant barrier. Some large brand-name companies with zero waste goals are also willing to recycle film plastics even though there may be an additional cost and not a cost-savings.

3.3.3. Recovery Tonnages and Performance

Some 86 percent of U.S. polyethylene film that is currently recycled (not including agricultural film) originates from industrial, commercial, and institutional film generators. Of the polyethylene ICI film that is recycled, RSE estimates that approximately 35 percent is pallet wrap and 65 percent is other bags and wraps. Furthermore, RSE estimates that nearly one-third of pallet wrap is recycled, but that only approximately 18 percent of other polyethylene film generated in the ICI sector is recycled. These figures obviously show that ICI polyethylene film recycling is much more successful in the United States than residential polyethylene film recycling.

3.3.4. ICI Film Recycling Obstacles

Obstacles that remain for film recycling from the ICI sector include:

- Low generation volumes of film at many different types of generators that make it cost-prohibitive to provide them with balers or mini-balers – for example, according to the California report referenced for Figure 11, less than ten pounds of recoverable polyethylene film are generated by the average hotel per day in California, and this quantity of film is too small for film reclaimers to develop supply chains targeting the average size hotel;
- Lack of storage space for baled film until sufficient amounts can be accumulated for a film recycler to pay for trucking;
- Training and motivating employees to separate film for recycling and keep it clean, especially when disposal is easier or less time-consuming;
- Lack of interest or awareness of the benefits of recycling film by company management;
- Fact that film is not accepted for recycling by most recyclers of commingled ICI recyclables; and
- Fact that many establishments are located in multi-tenant buildings, and building management, which arranges for waste and recycling service for all of the building tenants, but doesn't offer recycling service for film plastics.

3.4. North American Reclamation

3.4.1. Size of the North American Film Reclamation Industry and Principal Flows

“Integrated reclaimer” in this report means a reclaimer who primarily converts the plastic they recycle into products. “Merchant reclaimer” means a reclaimer whose primary business is to sell recycled plastic resin to other companies for manufacturing recycled content plastic products, rather than making intermediate or finished goods themselves. As Figure 1 showed, the North American (U.S. and Canadian) film reclamation industry (companies that purchase baled film) is composed of:

- 6 U.S. merchant reclaimers;
- 6 Canadian merchant reclaimers;
- 7 integrated film manufacturers;
- 4 integrated composite lumber manufacturers; and
- 4 integrated other product manufacturers.

A list of the U.S. and Canadian reclaimers that routinely purchase post-consumer film from U.S. sources can be found in Appendix A of this report. In addition to these reclaimers, there are additional plastics reclaimers that only recycle pre-consumer manufacturing scrap film plastics. Pre-consumer scrap recyclers are not included in this report due to its focus on increasing the recycling of post-consumer film in the U.S.

From the perspective of flows, export markets outside of North America purchase a majority of residential and commercial polyethylene film that is collected for recycling, followed by integrated recycler/manufacturers of film and composite products (at roughly equal amounts), with lesser amounts going to other product manufacturers and Canadian merchant reclaimers. Most of the material reclaimed by merchant reclaimers is believed to go back into film applications, either for recycled content trash bags, or to a lesser extent, recycled content pallet wrap.

3.4.2. Competitiveness of Integrated and Non-integrated Reclaimers

From a competitiveness perspective, integrated recycler-manufacturers have a cost advantage over merchant recyclers and their customers. Integrated recycler-manufacturers do not have physically separate reclamation and manufacturing locations, and so are able to avoid certain costs including an additional freight leg, additional extrusion and palletization steps, as well as the profit that two companies require compared to the acceptable profit margin of a single integrated manufacturer. As a result, RSE estimates that over 75 percent of the U.S. film that stays in the U.S. or Canada for recycling is recycled by integrated

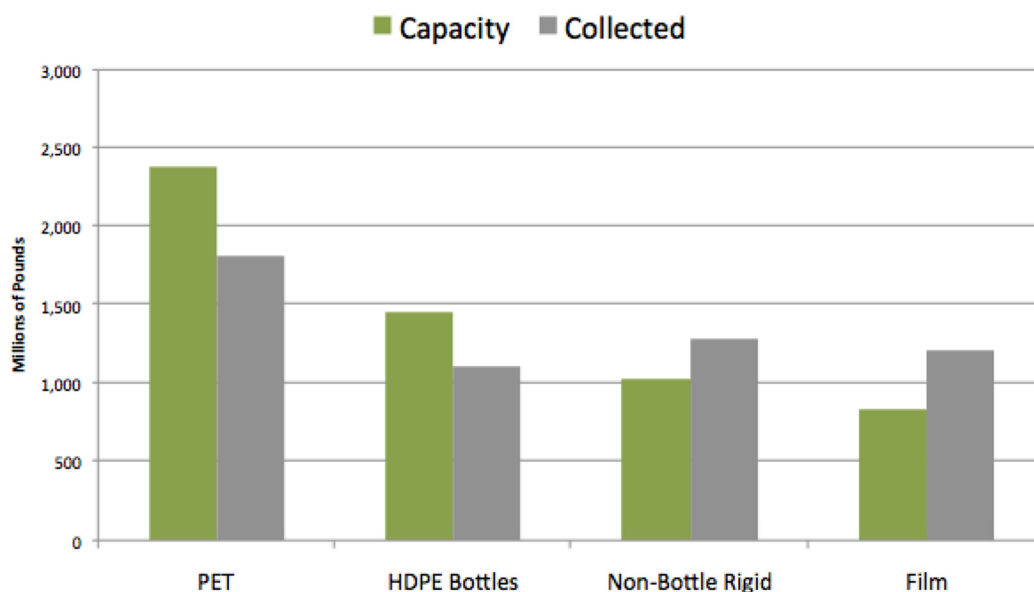
recycler-manufacturers.

A discussion of the competitiveness of North American reclaimers to export reclaimers is included in the section that follows this North American reclamation section.

3.4.3. U.S. Reclamation Capacity and Capacity Utilization

Figure 12 compares the balance between recycling collection and U.S. capacity for various categories of plastics packaging. As the figure shows, the polyethylene film reclamation capacity for U.S. film reclaimers, at 836 million pounds per year according to Moore Recycling Associates, is below what is collected and the excess must be exported for recycling. The existing film reclamation infrastructure is inadequate to handle the current available collection as well as any future increases that may occur. U.S. reclaimers of plastic bottles have the opposite problem – demand for reclaimed resin in the U.S. exceeds supply, and the infrastructure can easily support more collection for recycling.

**Figure 12 – U.S. Post-Consumer Film Reclamation Capacity
(millions of pounds in 2014)**



Source: Moore Recycling Associates

3.4.4. Scrap Value of Baled Polyethylene Film

Figure 13 shows the relative value offered by film recyclers for clear commercial LDPE film generated by retailers, mixed film (i.e., clean residential return polyethylene film and bags of mixed colors), and dirty curbside-collected residential polyethylene film of mixed colors. The three film categories compared above have been simplified to more clearly show the capacity and price differences for baled film based on generating sector and recovery method. However, those film categories also have subcategories with different reclaimer and export market pricing.

Figure 13 – Historical Pricing for Polyethylene Film

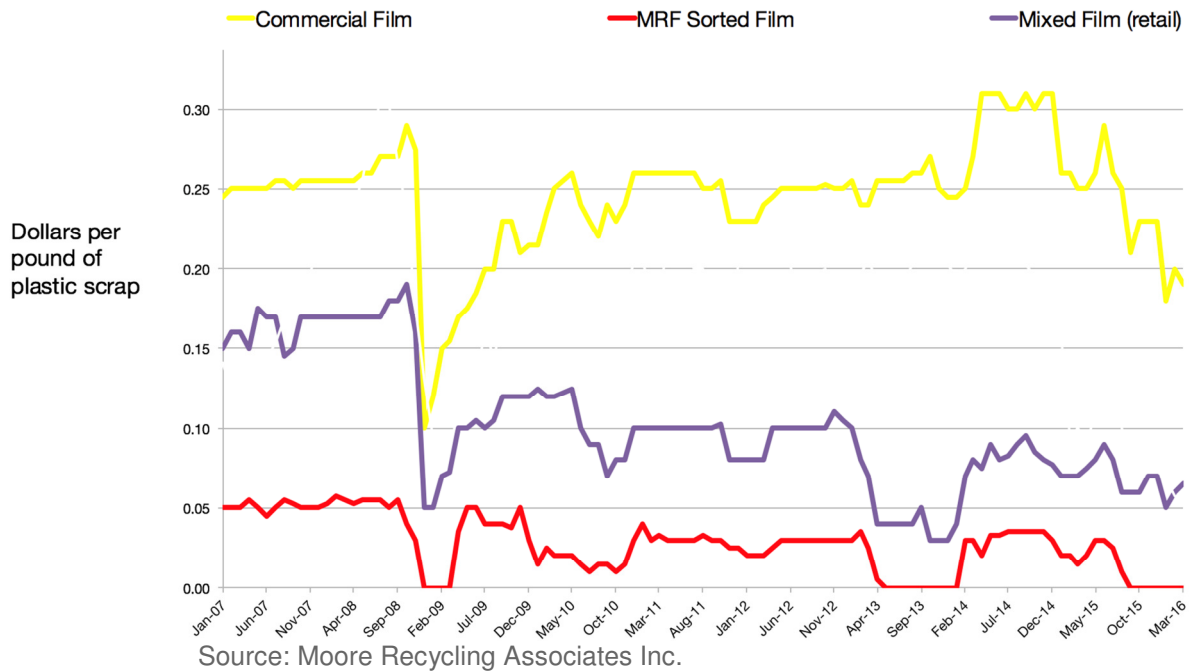


Figure 13 clearly shows the low value/cost disadvantage of MRF film in comparison to retail return film and clear commercial film. This low value, and a tendency of MRF operators to dispose of film rather than give it away for no value or pay markets to take it, has resulted in a lack of North American markets for MRF film – there are only two. This infrastructure gap is a barrier to increased recycling of film from U.S. curbside collection programs/MRFs.

3.4.5. Market Grade Specifications

Table 4 lists market grade specifications for polyethylene film that are offered by two different industry trade associations. They are listed in the table from the highest-quality film on the top to the lowest quality film on the bottom. In addition to these industry specifications, individual film recyclers may use their own company-specific specifications. The existence of market grade specifications is an indication that there are mature markets for materials included in the specifications.

Table 4 – Polyethylene Film Market Grade Specifications

Association of Plastic Recyclers	Institute of Scrap Recycling Industries
LLDPE Clear Film Grade A	Premium Film
PE Retail Mix Film	A+ Grade Film
Mixed Clear PE Film Grade A	A Grade Film
Mixed Clear PE Film Grade B	B Grade Film
LDPE Colored Film	C Grade Film
HD and LD Retail Bags	Grocery Film
LDPE Furniture Mix Film	
MRF Mix Film	MRF Film
PE Ag Film Not Including Mulch	Agricultural Greenhouse Film
PE Ag Film Including Mulch	Agricultural Ground Cover Film

Non-polyethylene or multilayer films do not have any published specification, which shows that markets for those materials are undeveloped. The lack of specifications is a barrier that limits investor confidence and market competition as buyers also are unsure of what is in the bales being transacted.

3.5. Exports¹²

3.5.1. Introduction

Some 55 percent U.S. film collected for recycling is exported rather than recycled domestically. The proportions of different types of film exported vary by source, with most residential retail return film remaining domestic, but most commercial film being exported, as shown in Table 5 below.

Table 5 – Relative Percentages of U.S. PE Film Collected and Exported in 2014

	Residential Retail Return	Residential Curbside	Commercial	Agriculture	Other	Total
Category Contribution to all Film Recycled	19%	1%	66%	14%	<1%	100%
Proportion of Category Exported	17%	51%	75%	15%	24%	55%

Source: Moore Recycling Associates

The overwhelming majority of exported film goes to China with only small amounts going to other countries. For the past two decades, shipping scrap plastic to China made economic sense because China is a huge manufacturer of finished goods, the country needed low cost raw material to produce products affordable to its population, and the country lacked the virgin resin production capacity and internally-collected recovered plastics needed for its growing demand. However, the growing middle class in China with its ability to afford higher quality virgin plastics products, increases in import and processing regulations, and a slowing economy in China is resulting in lower demand for imported plastic scrap. China has also developed its own internal recycling infrastructure and today, less than 30 percent of the plastic scrap used in China is imported from other countries.

Although some Southeast Asian nations are developing the capacity to reclaim scrap, because of their lower cost of processing and growing economies, they will not likely be able to replace the former capacity or the end-use demand that used to be in China for recovered plastics from the United States. Thus it is essential that the U.S. develop its infrastructure to sort, reclaim and reuse plastic film for our own domestic use.

3.5.2. History

The exponential growth of China's economy over the past two decades resulted in a huge demand for resources, thus China has dominated the scrap export market for many years, not only for plastics, but also for metals and paper. Using low cost labor, China's plastic reclaimers were able to convert almost all of the scrap plastic the U.S. sent them into lower cost raw material for their use. The plastic recycling efforts in China were achieved through the efforts of tens of thousands of independent plastic recyclers. Most of these facilities were small family-owned, labor-intensive operations utilizing hand sorting and domestically fabricated equipment.

¹² Content for this section provided by Moore Recycling Associates.

Most plastic film recycling takes place in the Chinese provinces of Shandong and Fujian. At the recycling facilities bales were opened and each piece of film was hand-inspected. Any labels or printing, which would contaminate the clarity of the film, were removed by hand with scissors. If the inspected clear material was clean enough it was fed directly into an extruder where the material was pelletized and made ready for shipment to the final user (commonly a manufacturer of film). If the material was not clean enough for immediate reuse it was subjected to a simple washing process, often without the wastewater treatment and discharge requirements faced by U.S. reclaimers. Colored material was sorted by color and processed in a similar fashion to clear film. Most of this material was made back into blown film. Inferior quality materials were used for applications that are less demanding, such as fish floats used by commercial fish farmers.

In addition to low labor and water use costs, the Chinese recycler gained economic advantage over U.S. reclaimers via the gap between U.S. and Chinese waste disposal costs. The Chinese did not have nearly as high of a cost of disposal as the U.S. and other developed countries, in part from a lack of environmental controls. This allowed them to extract the valuable materials and then dispose of the residue inexpensively. It is this gap between U.S. and Chinese residue disposal practices that garnered adverse publicity and resulted in a discomfort in exporting some types of scrap to China.

Green Fence

A few years ago China's government began an effort to improve the environmental performance of its manufacturing industry and increase the internal recycling of waste. This initiative included controlling postconsumer scrap imports into the country beginning in February 2013 as part of an initiative titled the "Green Fence." During much of the first half of that year, nearly all postconsumer scrap shipping containers imported into China were opened and inspected, and spot inspections continued throughout the year. Chinese customs officials imposed very tight contamination standards on the imported scrap.

The impact of the Green Fence continued into 2014, which showed the fewest number of exporters since 2005 contributing data to the American Chemistry Council's Curbside Film category. There was also a drop in export totals for Mixed Film (residential retail return film), with several exporters reporting significantly lower totals in 2014 compared to 2013 for Mixed Film.

The push for cleaner and more efficient processing is coming from the highest levels of China's national government. While the Green Fence enforcement effort ended, the stricter regulations passed in 2005 and 2009, and enforced broadly in 2013, have not been nor will be relaxed. In addition to stronger import controls, there is strong central government pressure for greater standardization in handling and processing regulations, material characterization, and operating procedures. Among the goals are improving the accuracy and increasing the transparency of records of the types of scrap imported, the final destinations and the reclaiming procedures to be used. Checks on import material quality and paperwork continue; suppliers find their export buyers less flexible than they used to be in the past.

Scrap processing facilities in China must now show that they can operate within current pollution and energy efficiency standards. Government support is available in the areas of IT, training, and operations and processing technology. The government is encouraging facilities to locate in recycling industrial zones, ten of which have been established so far. Each zone will have the infrastructure, including water treatment and solid waste management, to help reclaimers meet environmental standards. The zones are underutilized to date because scrap processors know they'll be subject to much closer scrutiny there than they've been accustomed to. But incentives to locate in the zones are likely to seem more attractive as regulation and strict enforcement become the norm everywhere.

3.5.3. Current Situation

Economic Obstacle

Plastic recyclers in China have much bigger things to worry about than the Green Fence enforcement effort. Factories and warehouses are constrained because of the slowing Chinese economy. The very rapid development of China in the past 30 years is over. China has lost the driving forces of the export and property markets, and domestic development is slower. China is transforming from production and consumption to sustainable development.

Another change is the former path of most U.S. scrap plastic imported into China: transloading in Hong Kong from overseas containers to regional containers then shipping to plastic recycling warehouses for purchase by small regional plastic reclaimers. Government regulations and the economy are shutting down small recyclers and warehouses in favor of direct ship to larger government-regulated facilities.

Better access to suppliers, primarily due to the internet, is narrowing the margins in trading; the users and suppliers are getting closer. This is gradually eroding the business prospects of traders. Easy access to intelligence is making the market more transparent and is forcing operational changes. It has become easier for end-user factories to access upstream suppliers overseas and vice versa. Some scrap traders question if there is a future for the business they've been in for thirty years.

Along with many businesses in China, successful plastic recyclers are adapting to the new economy. The plastic recycling industry is shifting from imports to internal collection and from small factories to larger more efficient factories with better quality. This change means more capital investment and a shift to vertical integration. Plastic recyclers in China are moving to customize their output based on specific customer needs and moving from lower value products to higher end products.

As a result of the Green Fence and increasing cost of processing material in China, some Hong Kong traders and Chinese end users are working with partners in Southeast Asia to grow the infrastructure in that region for sorting and high grading for ultimate shipment to end-users in China. However, this infrastructure does not have the capacity to process all the plastic film that formerly went to China, plus it incurs the expense of an additional transportation leg.

Strong Dollar

The strong dollar means that U.S. recovered materials are much more expensive than China's domestic scrap. A robust dollar and a strengthening economy are giving Americans more buying power, especially for products made overseas. The increase in the foreign-exchange value of the dollar, especially against the Chinese Yuan, has been a persistent source of restraint on U.S. scrap exports, as shown in Figure 14.

Figure 14 – Exchange Rate Cost Increases from the Perspective of Chinese Importers

Note: time period is for May 2014-April 2016

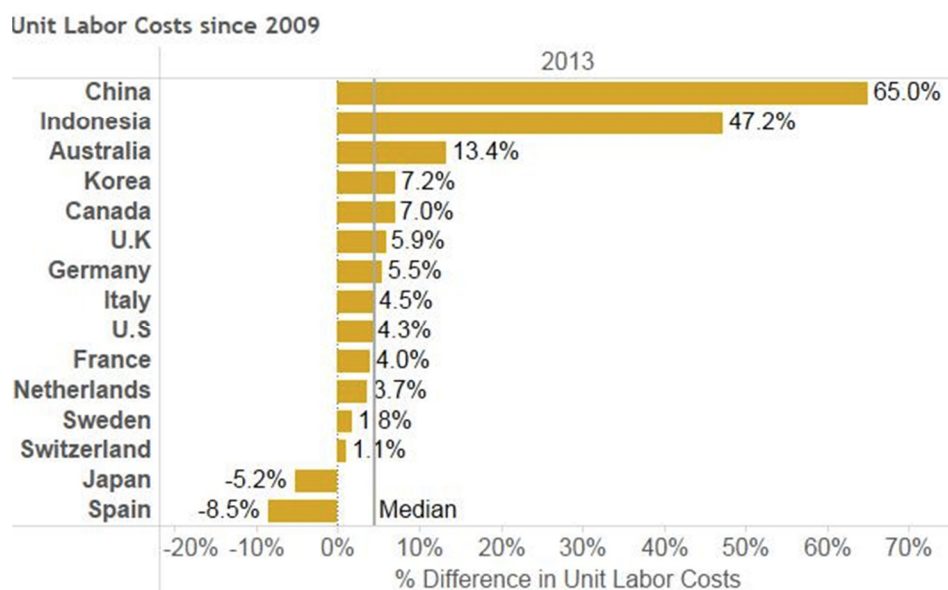
**Cost to Import into China**

Most postconsumer U.S. plastic enters China through the port of Hong Kong where port employees inspect the material. Dependent on the destination, containers are emptied and processed in Hong Kong or loaded into domestic containers for shipping to the mainland. It is a common misperception that the cost to ship scrap plastic to China is negligible. In fact, while the cost from U.S. ports to Hong Kong is minimal (current per shipping container costs are \$400 from the Port of New York, \$150-200 from Long Beach, and up to \$1,600 from the Midwest), the additional cost of shipping from Hong Kong to areas of high processing activity such as Guangdong, along with the import tariff and VAT (\$1,200 per container), makes shipping plastic to China as expensive, if not more so, than shipping recovered material from California to New York. Film follows the same transport path via Hong Kong as the other scrap plastic, except that clean commercial film is often direct shipped to mainland China.

Cost to Reclaim Film in China

Two things have driven up the cost to process scrap plastic in China: rising wages and tighter regulation. The aforementioned regulatory control, combined with dramatically increasing labor costs in China has significantly eroded China's recycling processing cost advantage. Large traders set up sorting and washing facilities in Southeast Asian countries with lower labor costs, including Vietnam and the Philippines, specifically for lower quality, lower cost material that cannot be handled elsewhere. The cleaned material is then imported into China to feed manufacturing demand. This increases the cost to process scrap and will exacerbate a trend that we are experiencing: both domestic and export buyers are pricing scrap based on quality and yield, and those spreads are increasing. Figure 15 shows how labor costs for selected countries relative to this report have changed over the period from 2009 to 2013.

Figure 15 – Labor Cost Changes from 2009 to 2013



Sources: Econometric Studios, Haver Analytics

For good quality film (low contamination) the cost to process (sort, wash, and pelletize) is approximately \$230 per ton. Costs go up with lower quality loads. The cost also varies depending on the region – it's more expensive in the South than the North (Hebei, Shandong).

Virgin Resin Production

The final factor affecting the export market is the global growth in virgin polyethylene resin production. As in the U.S. and other regions around the world, China is also expanding virgin polyethylene resin production capacity. Although global demand growth for PE continues to outpace growth in gross domestic product, there will be a global overbuild of virgin production during 2016 - 2018. This global oversupply of virgin resin production capacity is expected to keep the price of virgin resin low and in turn continue to put downward pressure on recycled resin prices. This is expected to reduce PE producer margins in US and the rest of the world resulting in increased buyer leverage: contracts will be fewer, meaning more spot purchases.

3.5.4. Future Prospects

All of the factors discussed above are expected to drive China's total demand for imports of recovered PE down by over two billion pounds (down by over 20 percent from a few years ago). Although China's seemingly endless demand has waned, China still has a huge economy in need of the lower cost raw material provided by PCR. In addition, other nations are experiencing some of the economic growth seen in China, including India, and demand may increase from those countries.

Recycled plastic has become an important global commodity, especially the higher grade commercial film with significant amounts flowing from not only the U.S. but Europe and Japan as well. Several exporters observed that commercial scrap film generated in the U.S. is better in quality than Europe, but not as good as film generated in Japan. Those with better quality film will likely retain the best market options.

3.6. End Use

3.6.1. End Uses for Recycled Film

Existing domestic end uses for recycled polyethylene film include:

- Retail carryout sacks;
- Pallet wrap;
- Industrial bags/sacks;
- Trash bags;
- Construction film/sheeting;
- Agricultural film;
- Composite lumber decking material, generally made from roughly equal parts recycled film and recycled sawdust;
- Roofing tiles;
- Transport packaging (pallets, slip sheets, trays, corner protectors); and
- Guardrail offset blocks.



The above uses are generally listed in order from most-demanding applications at the top to lesser demanding applications toward the bottom. More demanding applications include those that have stringent performance requirements (e.g., tensile strength, elongation at break), have demanding production methods that require resin homogeneity and consistency (e.g., blown film production), and products that are color sensitive (e.g., roofing).

Virgin resin producers tailor-make plastic resins for specific plastic product manufacturing technologies and for finished product performance requirements. The key measure of which plastic resins are suitable for different manufacturing technologies is the viscosity they have when melted. Some resins are made to have the viscosity of chewing gum when melted so that a plastic bubble can be blown – these resins are designed for blown film and blow molding applications. Other resins are made to have the viscosity of maple syrup when melted – these resins are designed for injection molding and rotational molding.

Because of the nature of the original virgin resins used in post-consumer film, the recycled material lends itself to certain plastic product manufacturing technologies and recycled plastic product applications. Because of the high-technology associated with making performance thin films and multi-layer film packaging, it is believed that there over one hundred different virgin resin formulations for PE resins used in film production. This results in variation when even seemingly similar film (e.g., pallet wrap from different companies) is recycled together. Blown film production is therefore very demanding and it is difficult to recycle film closed loop – but this is also what the resins were originally designed for and where they have the most value.

Figure 16 lists film categories on the left and plastics manufacturing processes and recycled product categories across the top. The figure indicates which plastics manufacturing processes and recycled content product categories are more favorable than others for the different film product types to be recycled.

Virgin resin producers tailor-make plastic resins for specific plastic product manufacturing technologies and for finished product performance requirements. The key measure of which plastic resins are suitable for different manufacturing technologies is the viscosity they have when melted. Some resins are made to have the viscosity of chewing gum when melted so that a plastic bubble can be blown – these resins are designed for blown film and blow molding applications. Other resins are made to have the viscosity of maple syrup when melted – these resins are designed for injection molding and rotational molding.

Because of the nature of the original virgin resins used in post-consumer film, the recycled material lends itself to certain plastic product manufacturing technologies and recycled plastic product applications. Because of the high-technology associated with making performance thin films and multi-layer film packaging, it is believed that there over one hundred different virgin resin formulations for PE resins used in film production. This results in variation when even seemingly similar film (e.g., pallet wrap from different companies) is recycled together. Blown film production is therefore very demanding and it is difficult to recycle film closed loop – but this is also what the resins were originally designed for and where they have the most value.

Figure 16 – End Use Recycled Content Product Favorability for Recycled Film Grades

Plastics Product Manufacturing Technologies	Blown & Cast Film					Blow Molding			Sheet Thermoforming & Profile Extrusion						Varies based on part	Compression Molding	Compounding	Injection Molding	Rotational molding
Recycled Content Product Applications	Carryout bags	Stretch wrap	Trash bags	Ag film	Construction film	HDPE blow molding	LLDPE blow molding	Nursery containers	Thermoform trays	Pallets	Drainage pipe	Lawn and garden	Composite lumber	Plastic lumber	Automotive	Durable goods parts	PP impact modifier	Housewares, various	Toys, trash cans
Post-consumer Film Types																			
All-PE films																			
Carryout bags	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
Stretch wrap	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
Other bags/wraps	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
PP-based films																			
Woven sacks (all PP)	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
Pillow pouches/bar wraps	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
Other resins/films																			
Degradable bags	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
Other bags/wraps	●	●	●	●	●	●	●	● ²	● ²	● ²	●	● ²	●	●	●	● ²	● ²	●	●

Notes:

1. Only as a minor blending agent in HDPE or PP resins.
2. Only if compatibilized.

Key ● Favorable
● Less favorable (better uses exist)
● Unfavorable

In addition to the considerations already mentioned, virgin resin plastics producers further process plastics resin for food-contact applications to extract chemicals that can migrate out of plastic resin into food in order to meet standards set by the U.S. Food and Drug Administration (FDA). This extra processing, which adds cost, is not done for non-food contact plastic resin. Because of the potential that plastics not approved for food contact are mixed and recycled with food-contact plastics, and because consumers may reuse containers to store hazardous materials, the U.S. Food and Drug Administration generally does not allow

recycled plastics to be used for food-contact applications, unless recycling companies individually demonstrate to FDA that the recycled resin they produce meets the FDA's food-contact standards. No current U.S. film recycler has a letter of no-objection from the FDA to sell recycled film back into food contact applications.

Virgin resin producers tailor-make plastic resins for specific plastic product manufacturing technologies and for finished product performance requirements. The key measure of which plastic resins are suitable for different manufacturing technologies is the viscosity they have when melted. Some resins are made to have the viscosity of chewing gum when melted so that a plastic bubble can be blown – these resins are designed for blown film and blow molding applications. Other resins are made to have the viscosity of maple syrup when melted – these resins are designed for injection molding and rotational molding.

Because of the nature of the original virgin resins used in post-consumer film, the recycled material lends itself to certain plastic product manufacturing technologies and recycled plastic product applications. Because of the high-technology associated with making performance thin films and multi-layer film packaging, it is believed that there over one hundred different virgin resin formulations for PE resins used in film production. This results in variation when even seemingly similar film (e.g., pallet wrap from different companies) is recycled together. Blown film production is therefore very demanding and it is difficult to recycle film closed loop – but this is also what the resins were originally designed for and where they have the most value.

Figure 16 and the discussion above was intended to show all of the following factors to be evaluated as they impact the ability to grow end use demand for recycled film, and indicate where growth in usage is best suited for end-use recycled content consumption:

- Mechanical performance requirements;
- Plastic product manufacturing technologies (blown film production is one of the most demanding of all technologies);
- Food-contact packaging or not;
- Aesthetic and/or performance sensitivities related to recycling clear versus pigmented films (trash bags are generally desired to not be clear; alternatively, stretch wrap is desired to be clear); and
- Ability to tolerate impurities and inclusions.

3.6.2. Drivers for Using Recycled Resin

Introduction

Drivers for product manufacturers to use recycled resin include:

- Lower price compared to alternatives, at times, dependent on market conditions;
- Enhanced product performance by incorporating recycled high-performance resins to compete against alternatives;
- Corporate sustainability commitments; and
- Legislated requirements.

Lower Price

Lower price is an obvious driver to use recycled resins; however, the price point of the recycled film resin must be below that of other alternatives (including recycled rigid plastic products) for recycled film resin to be competitive. Some examples of price-competitive alternative materials that recycled polyethylene film must compete with are shown in Table 6.

Table 6 – Competing Alternative Materials to Recycled Polyethylene Film Resin

Recycled Content Product	Alternative Competing Material to Recycled Film Polyethylene
Carryout bags	Paper bags, virgin resin, post-consumer recycled milk jug resin, reusable bags
Stretch wrap	Virgin resin
Trash bags	Virgin resin, pre-consumer scrap
Ag film	Virgin resin, pre-consumer scrap
Construction film	Virgin resin
HDPE blow molding	Pre- and post-consumer recycled HDPE bottles
LLDPE blow molding	Virgin resin, pre-consumer scrap
Nursery containers	HDPE and PP recycled rigid plastics (pre- and post-consumer)
Thermoform trays	HDPE and PP recycled rigid plastics (pre- and post-consumer)
Pallets	HDPE and PP recycled rigid plastics (pre- and post-consumer)
Drainage pipe	HDPE recycled rigid plastics (pre- and post-consumer)
Lawn and garden	HDPE recycled rigid plastics (pre- and post-consumer)
Composite lumber	Pressure treated wood, virgin plastics, all-plastic lumber, PVC
Plastic lumber	Pressure treated wood, HDPE recycled rigid plastics, virgin plastics, PVC
Automotive	HDPE and PP recycled rigid plastics (pre- and post-consumer)
Durable goods parts	HDPE and PP recycled rigid plastics (pre- and post-consumer)
PP impact modifier	Virgin resin, pre-consumer recycled material
Housewares, various	Virgin resin, pre-consumer recycled HDPE
Toys, trash cans	Virgin resin, pre- and post-consumer recycled HDPE

Commercial polyethylene film can be recycled for a cost savings compared to virgin resin and there is strong demand for such recycled resin – existing recycling is supply-limited.

Generally speaking, recycled polyethylene film resin from retail return programs can be produced for less cost than recycling rigid HDPE packaging because it doesn't need to be washed. However, because of the color, resin variation (HDPE and LDPE), and contamination it contains (paper receipts), it tends to only be used by integrated film recyclers/product manufacturers for captive product manufacturing use. Existing post-consumer rigid plastic reclaimers generally don't have film reclaim lines and existing merchant film reclaimers focus primarily on recycling commercial film. Demand for retail return film therefore is dependent on growing end-use product sales by integrated reclaimers, including sales of composite lumber, roofing, agricultural tubing, and other like products.

MRF film struggles with being cost competitive in comparison to cleaner types of films. Only two North American reclaimers purchase MRF film on a recurring basis. There is the possibility that this may change however. RSE is aware of one of the MRF film reclaimers that intends on opening a second film recycling facility, and at least one HDPE rigid plastic reclaimer that is investigating whether the price discount for MRF film is sufficient to justify the cost of washing MRF film compared to the cost of washing HDPE plastic bottles purchased from MRFs. The recycled resin produced can be compounded with existing HDPE resins for certain applications and this reclaimer believes there is sufficient market demand for large increases in the tens of millions of pounds for polyethylene film recycled in this manner. A separate dedicated film wash line would be required.

Enhanced Product Performance

Virgin film plastic resin is produced as high-performance resin needed for film product manufacturing. These performance attributes result in it being premium recycled resins as well. Composite lumber producers have been experiencing sales growth, and therefore recycled film demand growth over time. In 2010 composite lumber producers consumed approximately 100 million pounds of recycled film – this had

grown to double that amount (over 200 million pounds) by 2014. This growth is tied to the fact that composite wood fiber/recycled plastic lumber is considered a premium product with enhanced maintenance performance features that justify its higher cost compared to treated wood lumber.

Corporate Sustainability Commitments

Many companies have made corporate sustainability commitments to use recycled content in the products they manufacture. Procter & Gamble (P&G) is one example of such companies. P&G announced at the end of 2015 that they increased their use of recycled content resin in packaging to 30,000 tons. This represented a 12 percent increase since 2010. P&G's stated goal is to double its recycled resin use over the 2010 baseline by 2020.

Based on examples from other products (e.g., PET beverage bottles) and interviews with consumer packaged goods companies (CPGs) for this report, there is a willingness of some companies to pay for recycled content even if it has an equivalent or slight premium to virgin resin pricing, in order to support sustainability commitments and a circular economy.

Legislated Requirements

There are few laws that mandate recycled content in products. Both California and Oregon have laws that allow for the use of recycled content as one of a menu of compliance options in order for rigid plastic containers to be sold in their states (other compliance options include recycling rates and source reduction). RSE does not believe that recycled PE film is used as recycled content in rigid plastic containers sold in those states.

California in Part 14 California Code of Regulations, Section 17979, requires manufacturers of regulated trash bags (at or above 0.70 mil thickness) intended for sale in California to contain actual postconsumer material equal to at least 10 percent by weight of the regulated trash bags. The legislative intent was to provide for end-use demand for polyethylene bags through plastic postconsumer market development and encourage waste diversion of plastic bags from California landfills. This law was instrumental in increasing demand for film plastic recycling, albeit from ICI sources for LDPE trash bags (such as stretch wrap), or markets for natural HDPE milk jugs from residences for conversion into HDPE trash can liners and retail carryout sacks. Although this law did not provide market demand for collected carryout sacks, it has assisted in developing nationally the value chain for ICI film recycling.

California in Chapter 5.3 (commencing with Section 42280) to Part 3 of Division 30 of the Public Resources Code, which was enacted as Senate Bill 270 in 2014, imposes single-use bag fees and transitions the state to a ban on single-use plastic bags, which are to be replaced by paper and reusable plastic bags. The legislation also requires reusable plastic bags to be made from a minimum of 20 percent postconsumer recycled material by January 1, 2016 and a minimum of 40 percent postconsumer recycled material by January 1, 2020. This law also appropriates \$2 million for loans to California companies that manufacture plastic reusable grocery bags with recycled content. Implementation of this law is currently on hold pending a referendum to repeal the law to be voted on by California voters in November of 2016. This law may have the unintended consequence of curtailing the availability of return to retail film recycling opportunities in California, including for non-bag PE film not covered by the law. A spot check by Moore Recycling Associates in bag ban communities noted a 39 percent reduction in available collection bins for PE film.¹³

Although not an enacted law, the federal government is subject to executive orders that mandate the use recycled content products by federal agencies within certain parameters. As the nation's single largest

¹³ Moore Recycling Associates, private communication, May 25, 2016.

purchaser, this government policy has a similar effect on product manufacturers to use recycled content as that of state laws. Recycled content trash bags are available for purchase by federal agencies on the U.S. General Services Administration website.

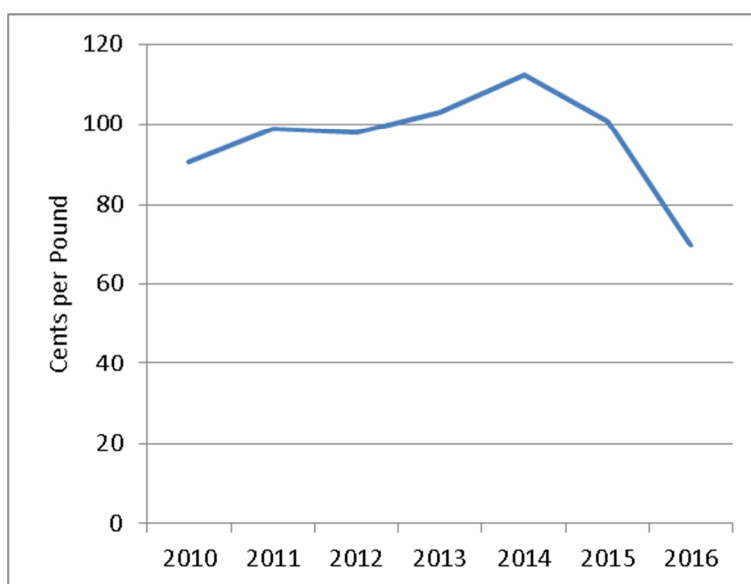
3.6.3. Obstacles to Increased End Use Demand

The largest obstacle to increased end use demand is virgin plastics resin pricing. The recent development of shale gas fields and low petroleum prices has resulted in natural gas price decreases, the primary feedstock for the production of polyethylene in the United States. The U.S. Energy Information Administration (EIA) forecasts ample supply and moderate energy prices for at least the next several years. These low prices have resulted in significant declines in virgin polyethylene resin prices in 2016, as shown in Figure 17.

The declines in virgin resin pricing (which similarly have impacted non-film grades of polyethylene) have resulted in declines of recycled resin prices as well. The cost of collecting, sorting, processing, and reclaiming doesn't change much, so the result is that film collectors/generators cannot be offered as much of a film scrap value than they used to be offered. This is an obstacle to increasing collection.

Pricing declines are not only due to inexpensive oil and gas. As discussed previously in the export markets discussion polyethylene production capacity is expanding globally, and especially in the United States. Overall, 27 virgin PE plant expansions have been announced for North America. If they all come to fruition, they'll add more than 34 billion pounds of capacity — a 75 percent jump over current capacity of roughly 45 billion pounds. While a significant amount of this additional production will be exported, it will also lead to low margins and pricing by virgin resin producers until U.S. and global virgin resin consumption rises to consume the new material.

Figure 17 – Virgin LLDPE Film Grade Price Trends



Some analysts believe that low virgin resin costs and global overcapacity for virgin polyethylene resin may dramatically reduce demand for post-consumer PE film and stymie growth in reclamation capacity for the next several years. Unfortunately it is difficult to predict if other drivers such as corporate sustainability commitments and development of new recycled products with enhanced product performance will result in

growing demand for recycled PE film in spite of lesser resin price savings.

Market saturation for recycled polyethylene resin from film does not appear to be an obstacle, and there is room for new and existing markets to absorb more recycled resin (reclamation capacity will need to be expanded if curbside recycling of film is to be expanded). This is especially the case for polyethylene film manufacturers. For example, California has certified 19 trash bag manufacturers as being allowed to sell trash bags in that state since they have at least ten percent post-consumer recycled content (meaning used for its intended purpose, coming from either ICI or residential sources) in their bags. California also names 55 trash bag manufacturers that are not allowed to sell trash bags in the state since they have not registered their bags with the State of California as having the required post-consumer recycled content.¹⁴ RSE estimates that the average post-consumer recycled content in trash bags in the U.S. is between 5 and 10 percent. Some manufacturers make trash bags with as much as 100 percent post-consumer recycled plastic, although such trash bags are not common.

Use of recycled content in trash bags is driven by government policy, as discussed earlier, and resin price savings. RSE does not expect new laws to drive recycled content in film. Because much film is used in business-to-business transactions (where price tends to be more of a driver than corporate sustainability commitments), and because recycled film does not bring enhanced performance, and with cost savings from recycled resin versus virgin resin declining, there are obstacles to increasing end use demand of commercial and residential film back into film products. An exception to this may be recycled content retail sacks, where the industry is under pressure to make carryout sacks more environmentally friendly. The industry may increase its use of recycled content to counter calls for bag bans and make a more favorable impression on residential consumers.

An additional obstacle to increasing recycled content in film products is that some of those products are used to contain food. Brands will continue to insist that film used in food contact applications have an FDA letter of non-objection before using recycled film in those packages. No current U.S. film recycler has a letter of no-objection from the FDA to sell recycled film back into food contact applications, and this is an obstacle, especially for brands that otherwise would be willing to use recycled film in their food contact packaging.

4. Case Studies of Film Recycling Value Chains in Other Countries

The purpose of investigating and summarizing film value chains present in Canada and Europe is to investigate technologies and approaches that have the potential to be employed in the U.S., as well as to learn how other government policies affect the value chains in those countries that may make their approaches not relevant here.¹⁵

4.1. Province of Ontario, Canada

4.1.1. Residential PE Film Recycling

In Ontario and under waste management legislation in place at the time this report was prepared, the cost

¹⁴ “Recycled-Content Trash Bag Program Summary of Manufacturer Compliance: 2014 Report Year,” California Department of Resources Recycling and Recovery, July 2015.

¹⁵ Government policies in other countries may include laws on resin type or required recycled content in bags, landfill bans, required recycling rates, recycling subsidies from extended producer responsibility laws, etc. The absence of similar laws in the United States may mean that different approaches that are market-driven and more applicable to the United States may be required.

to recycle residential printed paper and packaging through municipally-sponsored collection programs is evenly split between companies that place those materials on the Ontario marketplace (producers) and municipalities. The concept of having producers pay a proportion or all of the cost of recycling is called extended producer responsibility (EPR). Regardless of whether a producer's particular type of film package is collected in municipally-sponsored recycling programs or not, each producer is required to pay fees. This is done to ensure no incentive exists for producers to choose non-recyclable packaging materials that are not collected in programs (and so incur no recycling costs) over those that are collected and incur recycling cost. Like in the U.S., only polyethylene film is collected for recycling in Ontario – polypropylene chip bags and wraps and multilayer laminates are not accepted for recycling.

The legislative and financial framework noted above has resulted in widespread collection access for residential PE film by municipal curbside and drop-off collection programs.¹⁶ In 2014, 61 percent of the households in Ontario were provided with municipal collection of residential polyethylene film, with the vast majority of this collection through curbside programs. An additional 21 percent of Ontario households can return polyethylene bags and wraps to retail drop-off options similar to the predominant retail return system used in the U.S. Of the post-consumer film recycled in Ontario, a substantial majority is estimated to be recycled through municipal programs rather than retail return. All in all, approximately 82 percent of Ontario households have access to a PE film recycling program.

It is important to note that half of residential recyclables in Ontario are collected single stream, which is much lower than the approximately 80 percent of residential recyclables that are collected single stream in the U.S. Other than this difference in collection style, the equipment used to sort film in MRFs in Ontario is no different than the equipment used by U.S. MRFs. The prevalence of dual stream collection and processing in Ontario provides municipalities with the opportunity to organize the collection and sortation of film through either the fiber or the containers stream. Collecting plastic film through the fiber stream has been shown to result in cleaner film and at the same time avoids the sortation issues found on a mechanized containers and single stream sort line (e.g. film covering and weighing down aluminum and PET bottles at downstream mechanical sorting points).

Generally speaking, MRFs in Ontario were not designed with film recycling in mind, and older MRFs can fail to sort as much as 54 percent of the film received by the MRF into a recycled film grade (this figure comes from a dual stream MRF that RSE is familiar with that collects film in its containers stream). Newer and more advanced single stream MRFs in Ontario have placed a heavy emphasis on the removal of film at the front end using manual labor and pneumatic conveying systems. In addition to front end removal, two of the largest single stream MRFs in the province have had to install ballistic separators downstream of their paper screens to remove residual film from the container stream prior to further sorting of the mixed containers.

According to Stewardship Ontario's Pay-in Model for setting of producer fees, collecting and processing polyethylene film through municipal curbside and drop-off programs has a gross cost of CAD \$2,511 per metric tonne prior to revenue offsets of CAD \$29 (1.3 Canadian cents per pound).¹⁷ As can be seen from these values, recycling film through the Ontario municipal system is very costly.

¹⁶ Municipalities pay 100 percent of the cost to collect and dispose of materials in waste, and only half the cost to collect, process, and market materials in recycling. This provides an incentive for municipalities to divert as many materials as possible into municipal recycling programs.

¹⁷ Stewardship Ontario 2016 Pay-in Model (http://stewardshipontario.ca/stewards-bluebox/fees-and-payments/BB-2016_PIM.xls downloaded May 2, 2016), which is based on 2014 cost and tonnage data. Revenues are based on a 3 year average to smooth out volatility. Assuming a long term currency conversion rate of 1.25 Canadian dollars to one U.S. dollar, equivalent values are U.S. \$1,823 per short ton gross direct cost and \$21 per ton (1 cent/lb.) revenues.

Of the residential PE film generated by Ontario residents, RSE estimates that approximately 13.6 percent is collected through municipal recycling programs and sold for recycling (after excluding bags reused for pet cleanup and as trash can liners), and as much as an additional 1.4 percent may be returned for retail collection, for an overall recycling rate of available residential polyethylene film of approximately 15 percent.¹⁸ In comparison, in the U.S., RSE estimates that only 4 percent of residential polyethylene film available for recycling is collected and recycled. Clearly, the increased convenience of film collection through Ontario municipal recycling programs has resulted in higher recycling rates; however, the vast majority of such film is still not recycled.

In Ontario, there is one main end market (reclaimer) for municipal curbside and drop-off residential PE film. The capacity of this curbside film reclaimer is approximately 5,000 metric tonnes per year. Over 6,000 tonnes of curbside film were collected and recycled from Ontario in 2014, so this capacity is not even sufficient enough to cover Ontario film, let alone film from U.S. curbside collection programs. End use applications for PE film recycled by this reclaimer include trash bags, piping, bins/containers, etc. It should be noted that this curbside reclamation wash capacity was made possible by a \$500,000 grant in 2009 from Stewardship Ontario for film recycling market development, which was funded from supplemental EPR fees producers were asked to pay.

4.1.2. Commercial PE Film Recycling

Data are not available on the amount of commercial polyethylene film collected for recycling in Ontario; however, data are available on Canadian national film recycling quantities. In 2013 in Canada, 28.9 million kilograms (63.6 million pounds of post-commercial (excluding agricultural film) were recycled. This equates to 1.8 pounds per person recycled. By comparison, U.S. commercial polyethylene film recycled was 2.7 pounds per person.¹⁹ In many respects the Canadian and U.S. commercial sectors are similar, especially when use of film in transportation and logistics is considered, and RSE believes that generation quantities from both countries on a per capita basis are likely similar. This comparison therefore seems to indicate that commercial film recycling is more developed in the United States compared to Canada.

4.2. Federal Republic of Germany

4.2.1. Residential Film Recycling

Germany has a federal packaging ordinance that requires producers and retailers of packaged products used by private consumers (households) to collect the packaging from those products for diversion from landfill disposal. The legal targets apply to individual material types, and for plastics the target to be obtained is 60 percent diversion from landfill, with at least 60 percent of the collected volume recycled, with the remainder allowed to go to energy recovery (i.e., a minimum of 36 percent of plastic packaging generated recycled). Over 70 percent of residential plastic packaging in Germany is collected in the recycling stream, with approximately 70 percent of the collected amount sent for recycling, for an overall residential plastic recycling rate of 49 percent and a total diversion rate of over 70 percent. These figures vary slightly from year-to-year, but are generally stable. As the data show, residential plastics packaging recycling in Germany exceeds the targets set by the legislation. Unfortunately, data does not exist on the

¹⁸ Estimated by RSE using data from numerous source, include 2014 polyethylene film recycling data reported by Stewardship Ontario through municipal collection programs, estimates of retail return film, and estimates of film bag reuse.

¹⁹ "2013 Postconsumer Plastics Recycling in Canada," Moore Recycling Associates, February 2015, and "2014 National Postconsumer Plastic Bag & Film Recycling Report," Moore Recycling Associates, January 2016.

film portion of the packaging generated and recycled compared to rigid plastics packaging generated and recycled. The following paragraphs describe the German system in more detail.

Germany has a nationwide producer-funded system for collecting and recycling residential packaging made of plastic, paper, glass and metals. Collection is performed in three separate streams:

- 1) Lightweight packaging, which includes plastic film (of all types), rigid plastic containers, and metal cans;
- 2) Paper; and
- 3) Glass containers.

Lightweight packaging and paper are collected by curbside collection in separate streams, typically every two weeks on average (either in yellow bins but also in large yellow polyethylene bags). Consumers return glass containers for either a beverage container deposit, or recycle their food and beverage glass containers at glass recycling drop-off depots that are located throughout the country.

Lightweight packaging is delivered to a MRF that sorts the mixed plastics and cans into market grades. The majority of this sorting is performed using equipment, beginning with trommels to perform a large versus small separation:

- Large plastic bottles, pails, and film (primarily large polyethylene bags and overwraps); and
- Smaller cans, tubs/lids, and small/heavier film (such as multilayer pouches).

Next, magnets are typically used to sort out steel cans. The following step is to separate film from the other recyclables using air classifiers and/or ballistic separators. Optical sorting of the rigid containers then occurs, with a manual quality control of all of the streams. MRFs typically don't separate the various kinds of film by resin type and so bale them mixed for further separation at a downstream film recycler, although some MRFs produce a polyethylene film grade from the large size separation stream, which is mostly composed of large polyethylene bags. The value of MRF film is € 20 per metric tonne (approximately \$20/ton or 1 cent/pound). The film composition on average is:

- PE: 48 percent;
- PP: 16 percent;
- PET: 7 percent;
- Multilayer/others 29 percent.

Most residential film is marketed to European reclaimers, who further sort and process the films as follows:

- Water float/sink separation (separates PE and PP films from PET/PVC/PS/nylon majority films);
- Water wash for polyethylene film;
- Melt filtration; and
- Extrusion/pelletizing

While a couple of European film reclaimers have added optical sorters for film sorting at the reclaimer level, the technology has not yet become widespread in Europe.

4.2.2. Commercial Film Recycling

German law also requires the recycling of commercial transport packaging, including stretch wrap and protective bags and sacks. A variety of approaches to recycling these materials are used including waste disposal companies who pick up commercial recyclables and sort it and wholesalers/distributors who take back packaging materials and transport it back to their own warehouses. Because of the recycling requirement, funds from generators flow to commercial recyclers to pay the cost of recycling where the

scrap value is not sufficient to sustain recycling on its own.

In order to preserve film quality and maximize revenues to all parties, sorting is mostly done by hand by the generator of the film discards, and typically only polyethylene film is separated for recycling. This approach is very similar to the approach used in the U.S. Film is baled, either by the generator, commercial recycler, or distributor, and sold to European and Asian markets. Uncolored films are recycled back into stretch wrap or clear protective bags, and pigmented or lower-quality film may be recycled into construction films and trash bags. Commercial film has a value of €100-450 per metric tonne depending on color and cleanliness. As with residential film, separate statistics are not maintained on film versus rigid plastic recycling.

5. Equipment and Technologies

5.1. Summary

Separation means separation of one class of materials from another, such as paper from containers, metals from plastics, film from mixed recyclables – separation either is performed at the source by the generator (source-separated) or at a MRF. Once classes of materials have been separated from each other, sorting is also generally needed to prepare materials to market grades (e.g., sort polyethylene film from mixed flexible packaging). Sorting is most commonly performed at MRFs; however, for materials that make up small percentages of incoming MRF materials or materials that require costly specialized equipment for sorting, sorting may be performed by secondary processors. Secondary processors for plastics are called plastics recovery facilities (PRFs), and secondary glass processors are called beneficiaries. Currently, there are no PRFs for mixed types of plastic film in the United States. Once film has been sorted into market grades of compatible types, either by the generator or by MRFs/PRFs, it is sent to a reclaimer for cleaning, followed by sale to companies that can use it as a raw material in recycled content product manufacturing. Technologies for each of the above steps are summarized in this Summary subsection in Table 7, and further discussed in the subsections that follow.

Table 7 – Summary of Film Sorting and Reclamation Technologies

Technology	Capital Cost (per unit)¹	Annual Cost (capital & O&M)	Effectiveness	Comment
Separation				
Manual	None	\$200/ton	Highly effective	Cannot sort by resin type
Ballistic separator	\$145,000-200,000	unknown	N/A	Separates film with fibers – additional manual and/or mechanical sorting needed
Air separators	\$95,000-200,000	unknown	Not tested for film	
Mechanical separators	\$475,000	\$200/ton	30% (Film Grabber)	Film purity is 60 percent, which requires additional quality control labor cost to meet market specifications, plus labor to separate/sort film missed by the equipment; Film Grabber not effective in single-stream systems

Technology	Capital Cost (per unit) ¹	Annual Cost (capital & O&M)	Effectiveness	Comment
Optical	\$250,000- 500,000	unknown	40-90%	Effectiveness highly depends on number of optical sorters and multiple passes to get to high effectiveness; likewise, film separated typically has more paper contamination than film unless multiple passes refine the film's purity
Robotics	Not yet commercialized	unknown	Not tested for film	Potential for future technology development
Sorting				
Optical	\$250,000- 500,000	\$30/ton	85%	Sorting mixed film by resin type and monolayer versus multilayer
Reclamation				
Dry approach	\$1 million	\$200/ton		Generally limited to clean mono-material film <u>not</u> collected in residential curbside systems
Wet approach	\$1.8-3 million	\$400/ton		Significant energy required for drying washed film
Dilution	Not applicable	\$200/ton		Equipment cost incurred by rigid plastics being recycled
Compatibilizers	Not applicable	varies		Cost is in addition to wet or dry reclamation costs and varies with the composition of the specific multilayer film being recycled
Solid-state shear pulverization	\$750,000- \$1 million	\$200/ton		Produces low value resins for non-demanding products

Notes:

1. Highly variable depending on costs to modify existing systems and install ancillary equipment and conveyors – such additional costs typically exceed the cost of the individual equipment component itself.

5.2. Separation Technologies

This subsection first discusses separation technologies and then later discusses sorting technologies that could be employed.

5.2.1. Manual Separation

The majority of polyethylene film that is currently recycled in the U.S. is collected as a source-separated film-only stream and so does not need to be separated from mixed recyclables. However, few ICI generators of film produce sufficient quantities to make their own film bales or for a cost-effective dedicated film-only collection route. The only option for ICI establishments without balers is to use local ICI recyclers to collect/process mixed recyclables with film included as part of the stream, unless the majority of their film comes from a supplier that delivers to them using its own fleet of trucks and is willing to backhaul the film to be baled at its central warehouse and sent on to be recycled. Where ICI film is collected mixed with other commercial recyclables, such as OCC, it is manually separated rather easily on an ICI recyclables sorting

line and typically dropped down a chute into a storage bunker until a sufficient quantity is accumulated for baling. In this case the separation and sorting steps are performed concurrently – polyethylene film is dropped down one chute for recycling, and film lacking recycling markets would be dropped down a residue chute and be disposed.

Separating film from mixed recyclables in a residential MRF, as discussed previously, is much more difficult and challenging, especially for the roughly 80 percent of residential recyclables collected in single-stream systems. These MRFs attempt to manually pick film out of the mixed recyclables at the first point possible, which is the pre-sort station. The primary purpose of the pre-sort station is to remove materials that would not be properly sorted by or that can damage downstream sorting equipment because of size, shape, or flexibility (including debagging of recyclables). The secondary purpose is the beginning of contamination removal.

Some large-scale MRFs may be designed with overhead suction tubes at manual sort stations to collect and convey polyethylene film from at least the pre-sort and possibly other points in the MRF to one central point if they desire to try and market it instead of dispose of it. Sorters manually snatch and lift plastic film off the conveyor belt to over-belt suction tubes, which suck the film in and convey it to a storage bin where bale quantities are accumulated. This approach to manual film sorting is shown in Figure 18. Older or smaller facilities may manually pick out film only at the pre-sort and drop it down a chute into a bunker. Because of the depth of material on conveyors at the pre-sort, regardless of whether a film vacuum system is used or not, much of the film may be buried under other materials and may be missed. Secondary separation of plastic film is often needed downstream of the pre-sort and such film is typically dropped down residue disposal chutes and not recycled.

Figure 18 – Film Vacuum Takeaway System for Manual Film Sorting



Photograph credit – CP Manufacturing.

Manual sorting provides the potential to collect all types of film and sort it into one or two film product grades. This type of sorting is not currently performed in any North American MRF that RSE is aware of, although some MRFs may send polyethylene film bags for recycling and mixed paper and plastic residue

(which may contain other film types) to energy recovery.

When plastic film is delivered to a dual-stream facility, residents can be directed to include the plastic film either with fiber or containers and both options are in practice. In either case, the plastic film can be manually sorted from the line. Collecting plastic film in the fiber stream results in a cleaner plastic film product (no glass in the film) and avoids the problems that plastic film causes on mechanized container sort lines, including wrapping around axles in disc screens and confusing optical sorters.

As was mentioned earlier, some 80 percent of residential recyclables are collected single-stream and the vast majority of single-stream MRFs in the U.S. (RSE estimates over 90 percent) uses mechanical screens to separate flat recyclables, such as paper, from “three dimensional” recyclables – primarily containers. Screens have a deck of rotating shafts with rubber or metal touch-points on them that push flat items up an incline, while three dimensional items tumble down and/or fall between gaps in the shafts. Because individualized pieces of film (polyethylene film and bags as well as multilayer bags and pouches) are lightweight and relatively flat, screens sort the majority of individualized pieces of film into the paper stream rather than the containers stream. Highly flexible film like that used for retail carryout sacks also has a tendency to get wrapped around the rotating axles of these screens, but chip bags, bar wrap, and multi-layer pouches are not as highly flexible and so do not get wrapped around the axle.²⁰ If film is stuffed into a retail sack, which is then tied to close it into the shape of a ball, such film would likely go to the container part of the plant, though RSE is not aware of field data that has been gathered from MRFs to verify the percentages that would go in that direction. Furthermore, many recycling program participants would likely disregard the film accumulation and preparation instructions and place it into recycling carts as individualized pieces of film anyway.

Over the past few years, two new pieces of mixed recyclables separation equipment have become available on the U.S. market that perform a similar function to that of screens, but that doesn't have the same drawbacks with thin polyethylene film getting wrapped around screen axles. These pieces of equipment are ballistic separators and air separators.

5.2.2. Ballistic Separators

Ballistic separators are similar to screens in that they are designed to separate flat materials such as plastic film, paper, and OCC from three dimensional materials such as glass containers, plastic bottles and containers, and metal cans. Figure 19 shows a photograph of a ballistic separator.

²⁰ At the time this report was prepared, the Research Foundation for Health and Environmental Effects had a study (“Materials Recovery for the Future”) that was gathering field data at one single-stream MRF to further quantify the percentages of various film materials that may be sorted by screens into the fiber stream, the container stream, or that foul the screen, if not picked at the pre-sort station.

Figure 19 – Ballistic Separator



Photograph credit – Machinex Recycling.

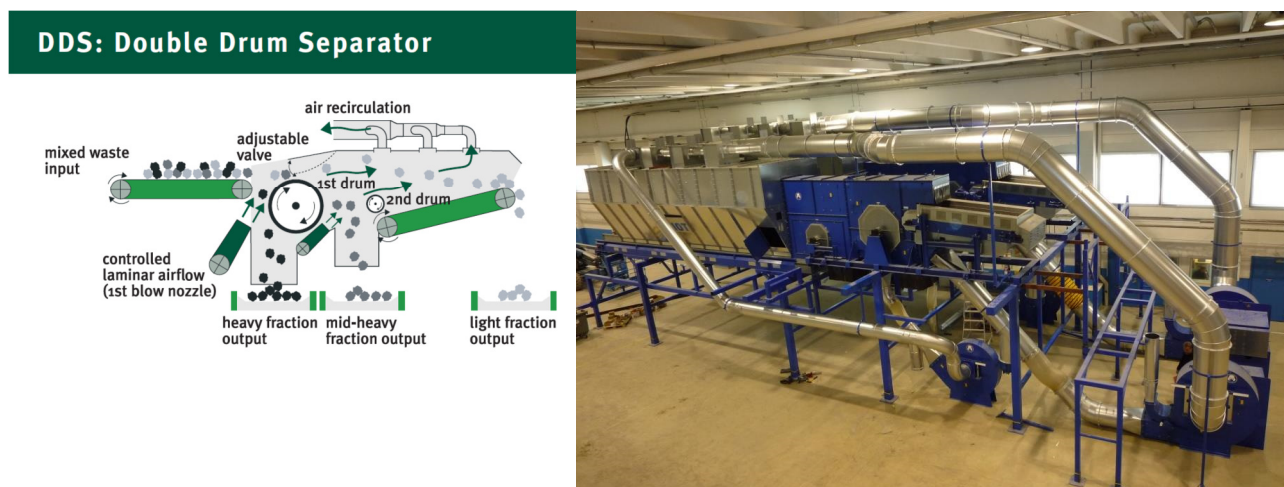
Just as screens use rotating disks and rubber fingers to push flat materials up an incline, ballistic separators use floor paddles connected to cam shafts to walk flat materials forward up an incline. With both types of machines, three dimensional material bounces or rolls downward and both types of machines allow small particles to fall through the surface that the flat material is riding on. With ballistic separators, though, there are no exposed rotating shafts for film to wrap around – it simply travels up and over the top with the paper materials where it can be manually or optically sorted from paper. RSE believes that over 15 MRFs in the U.S. had ballistic separators at the time of this report, up from none only five years ago.

5.2.3. Air Separators

Air separation equipment of different designs that uses combinations of air flow and mechanical equipment are used in MRFs in North America, including by Bollegraaf Recycling Solutions (PaperMagnet), CP Manufacturing (Air Drum Separator), Green Machine® (Ballistic Belt Separator), and Machinex Recycling (Flat & Light Separator). All of these air separators are designed to take the containers stream after paper/containers screening has occurred and further clean as a quality control measure the containers stream of residual paper and film plastic. They are not designed to replace screens and perform initial separation of paper and film from containers. However, they could be used in dual stream systems to separate film from rigid containers if the film is included and collected in the container stream.

A different type of air separator is offered by Bulk Handling Systems (BHS), which sells Nihot Recycling Technology's equipment in North America. Nihot's air separators were developed in and are used extensively in Europe for high-volume separation of recyclable materials of different densities using air flow, rotating drums, and conveyors. BHS acquired Nihot and now Nihot is a wholly-owned subsidiary of BHS. Nihot makes both single drum and double drum separators depending on whether two or three splits density splits of material are desired. Figure 20 shows Nihot's double drum unit.

Figure 20 – Nihot Double Drum Separator

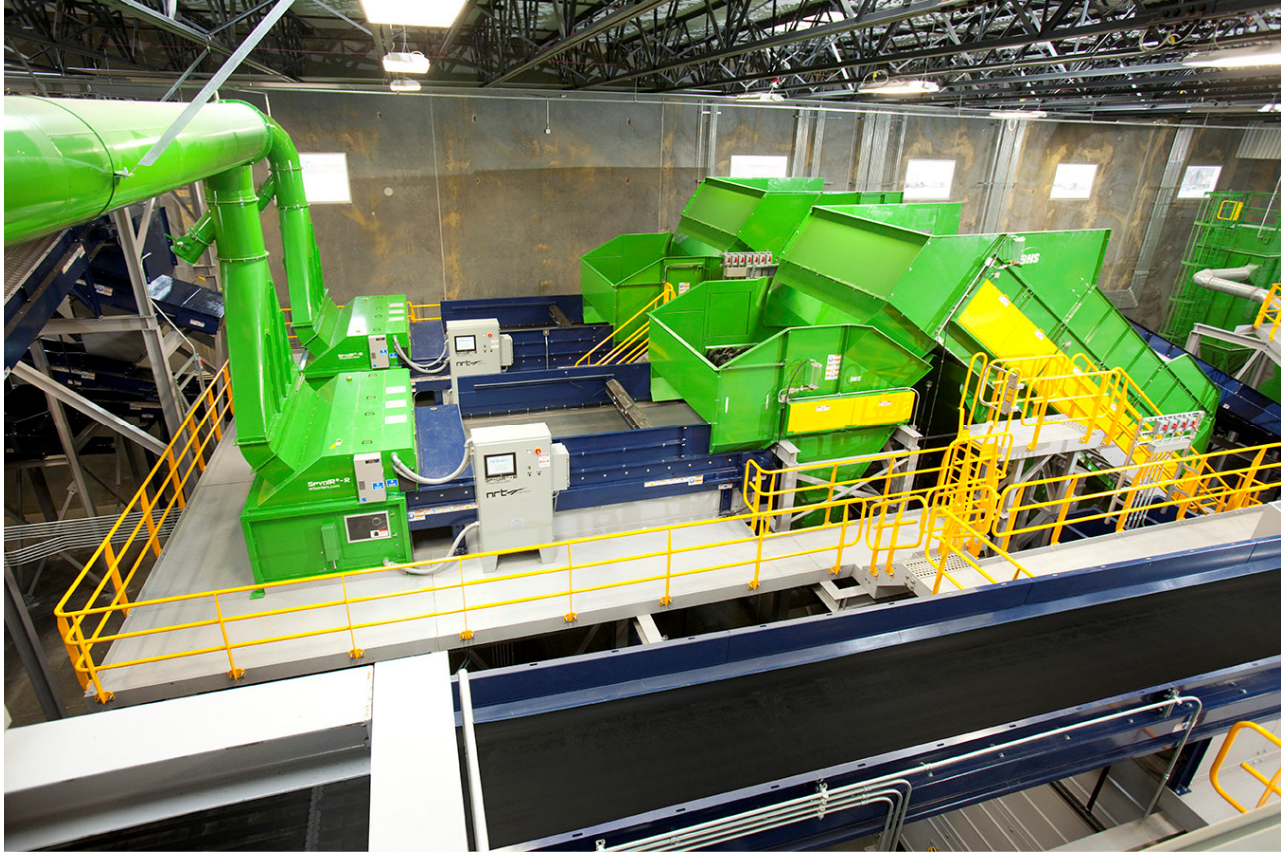


Photograph credit – Nihot Recycling Technology.

While some of Nihot's drum separators are used in North America for glass cleaning and separation, U.S. MRFs have not yet begun using Nihot drum separators for primary separation of light materials, such as film and paper, from heavier mixed incoming recyclables. There are a couple of atypical U.S. MRFs where film is separated from other recyclables using combinations of air and optical sorters (optical sorters are discussed later in this report). The most pertinent is the IREP Montgomery mixed waste processing MRF in Montgomery, Alabama, which opened in May of 2014 and closed due to financial problems in October of 2015.

The IREP MRF was designed by BHS to sort recyclables out of residential and commercial garbage. The facility design began with a presort station, followed by OCC and fines screens. Next was a Nihot single drum separator. The paper/plastic "light" fraction out of the separator was then sent over paper "polishing" screens to clean out lightweight three dimensional containers. The final step is where film separation from paper occurs – dedicated optical sorters at this point blow film up and out of the paper stream into vacuum hoods, which pneumatically conveys the film to a separate part of the plant. Figure 21 shows two parallel processing lines the plant – the optical sorters with pneumatic hoods are the units shown on the left of the photograph.

Figure 21 – BHS NRT Optical Sorters to Separate Film from Paper



Photograph credit – Waste360, Penton Media, July 2015. Optical sorters are on the left in the photograph.

5.2.4. Mechanical Separators

The flexible nature of film allows equipment designers to take advantage of this property to mechanically separate it from other rigid recyclables. Bollegraaf Recycling Solutions of the Netherlands (represented in the U.S. by VAN DYK Recycling Solutions) makes a piece of equipment called the Film Grabber. This piece of equipment was originally designed for use in Europe where paper and glass are collected separately from the “lightweight packaging” remainder, which includes plastic and metal containers and film plastic. This would be analogous to collecting film in the container stream in a U.S. dual-stream system. The Film Grabber is shown in Figure 22.

Figure 22 – Bollegraaf Film Grabber



Photograph credit – Bollegraaf Recycling Solutions

The Film Grabber is mounted over a conveyor belt and mixed recyclables pass underneath. The machine consists of a rotating drum with rods that are extended on the bottom half of its rotation so that they can snag highly flexible film from the surface of the recyclables and lift it to the top of the machine. At the top of the machine the rods retract and release the film into a vacuum hood that pneumatically conveys the film to a storage cage until it is ready to be baled. Air is also used in this device to blow film toward the surface of the recyclables so that it can be snagged by the rods.

As was mentioned previously, the Film Grabber was not designed for use in single-stream MRFs. Recyclables are piled on top of each other at the start of the MRF sorting process and the majority of film would not be accessible to be snagged by the rotating rods. RSE is aware of one MRF in North America that uses a Film Grabber. It is a dual-stream that collects film in its containers bin. In that MRF, the machine was able to remove approximately half of the film from the stream (the other half must be removed manually). For the Film Grabber to work, film must be flexible enough to drape over the rods and be lifted off the belt. This technology works well for individualized plastic bags and other very thin and highly flexible materials, but it is not effective in separating bags-in-bags, cereal box liners, chip bags, and laminated film plastic packaging. From this perspective it would be able to assist in sorting highly flexible polyethylene films from PP and multilayer films, which would remain with the mixed recyclables stream for the most part. When this technology is used on a fiber or single-stream line this system also captures some paper, especially thin and highly flexible newspaper, and some aluminum foil that would need to be manually separated later, and so it really only lends itself to being used in dual-stream systems where film is included with the containers stream.

A single-stream MRF in Edmonton, England also uses Film Grabber technology. That MRF sorts recyclables that are collected in many programs using a film blue-bag approach rather than bins or carts (including some programs that accept packaging film). The MRF uses two Film Grabbers located at the front of the sort line just after debagging equipment. These film grabbers were installed primarily to capture the large bags that recyclables had been set out in from which recyclables had been emptied. In that MRF the Film Grabbers are effective in capturing up to half of the plastic film out of the single-stream material—it is believed that much of this film is the large blue bags themselves, which would be easier for the Film Grabber to snag, than smaller sized packaging film that may have been the mixed recyclables. Labor is still required after the Film Grabbers to sort the film that the Film Grabber fails to capture. Generally speaking,

Film Grabbers are not effective enough to replace manual labor in U.S. MRFs, and so this equipment is not used for separating and sorting film in this country.

Bollegraaf is also testing and evaluating a totally different mechanical design to separate film from other recyclables that it calls a “String Stripper.” This equipment would function similar to the film grabber and would focus on separating highly flexible thin polyethylene film bags and wraps (as well as wires and strings) found in the mixed materials stream. As with the Film Grabber, manual and optical sorters would still be required for the removal of less flexible materials like flexible packaging bags and pouches. This equipment was developmental at the time of this report and not yet commercially available.

5.2.5. Robotics

Companies are working on developing robots that can use optical recognition technologies (discussed in the next section) to sort recyclables from a moving conveyor belt. To date, only one company, Bollegraaf, is known to offer this technology commercially – its technology is shown below in Figure 23.

Figure 23 – RoBB – Robotics by Bollegraaf Quality Control Sorter



Photograph credit – Bollegraaf Recycling Solutions

Bollegraaf represents its sorter as being for quality control after other means of primary sorting has already been performed (i.e., picking occasional pieces, and not for high-speed primary sorting of film). As the figure shows, the equipment is quite sizeable and likely costly.

In the United States, AMP Robotics is in an early stage of development of a much smaller-footprint robot that it hopes will be much less expensive than what is offered by Bollegraaf. However, the vision systems, computerized identification system, and mechanism for grabbing and lifting different types of films require more development. To date, AMP Robotics has focused on sorting of rigid plastic containers and paper, also as a supplement to but not replacement for other sorting systems already used in MRFs, with a focus also on replacing people with machines.

5.3. Sorting Technologies

5.3.1. Sorting Categories

Once classes of materials have been separated from each other, sorting is also generally needed to prepare materials to market grades (e.g., sort polyethylene film from other multilayer or non-polyethylene films). The prior subsections discussed technologies for separating film from mixed recyclables using a combination of

equipment and manual labor. This subsection discusses technologies for sorting film into different resin types and color streams to meet buyers' specifications. These technologies can be employed either at MRFs, at film PRFs (no film PRFs currently exist in the U.S.), or at plastics reclaimers who may produce more than one grade of recycled resins, or if integrated, may recycle some film types into products and resell the remainder either as non-recycled sorted film, or as recycled resins. Where to employ such technologies is a question of equipment cost and scale. There are over 630 residential MRFs in the U.S., 21 film plastics reclaimers, and no plastics recovery facilities to sort mixed plastics films (there are six such facilities for rigid plastic containers though). More costly sorting technologies may only be able to be employed downstream of MRFs.

This project has divided film into three major categories:

- Category 1: single PE resins or blends of compatible PE resins
- Category 2: polypropylene films or blends
- Category 3: Other resins or blends

If majority polypropylene multilayer films and if other films are to be collected mixed with polyethylene films, they will need to be sorted at a minimum into polyethylene versus Other, and potentially into the three categories listed above.

5.3.2. Sorting Technologies

Manual Sorting

Currently, all film that is recycled in North America is separated by the source into the market grades of polyethylene listed in Table 2 above, or manually sorted by a MRF into a polyethylene-only MRF grade. Film reclaimers also perform a manual quality control pick to remove any non-polyethylene film or other contaminants prior to recycling the film. Film is very thin and lightweight – RSE estimates that it takes over 100,000 pieces of residential film to make one ton. If each piece of film must be individually picked up and sorted by hand by paid U.S. manual sorting staff, the cost of sorting would quickly exceed the value of the material even before any of the cost-adding reclamation steps are performed. Currently, film that goes through manual sorting for color sorting or resin separation reasons is exported to Asia where low-cost labor is used to perform the sorting since manual film sorting in the U.S. is cost-prohibitive.

Optical Sorters

Optical sorters are used to identify and sort plastics by resin type. There are approximately twelve companies that offer optical sorters for sale for sorting rigid plastics, and optical sorters for rigid plastics are considered to be a widely commercialized technology that is used extensively by large MRFs, PRFs, and rigid plastic container reclaimers to sort plastics by resin type. A few recycling equipment companies are working on optical sorting machines that can sort film by resin type. These companies and the equipment they are developing are described later in this subsection. Optical film sorting equipment has only been developed in the last year or two, and has been adapted from rigid plastic container sorting equipment, or paper quality control sorting equipment. These machines will likely require new designs or design refinements to improve film sorting cost-effectiveness.

Optical sorters are composed of three main systems—a feed-regulating conveyor system, a lamp/camera/computer system to identify the plastic material and/or color, and a sortation system to sort one type of desired plastic material out from a mixture of other plastics types. Problems with optical sorting of film occurs mainly in the feed-regulating presentation of film.

The first system of an optical sorter, the feed-regulating conveyor system, is designed to singulate plastic

items on a conveyor belt so that no two items are on top of each other, and ideally there is some space all around each item. To do this, items to be sorted are deposited from slower moving conveyor belt onto a very high speed acceleration conveyor, which spreads materials out. Acceleration conveyor belts for rigid containers are also designed with features to help them remain in place for detection and sorting. Singulating very thin film is much more difficult than singulating rigid containers because the light weight of film leaves it more susceptible to air currents and less able to be held in place by friction on a conveyor belt in comparison to rigid plastic containers. Furthermore, film, since it is often flat, may remain on top of a second piece of film or may stick to other materials. Equipment manufacturers have focused on redesigns for the feed-regulating conveyor systems of rigid container optical sorters to adapt them for sorting film. To date, the redesigns have included using laminar air flows.

The second system of an optical sorter is the lamp/camera/computer system. This system works by:

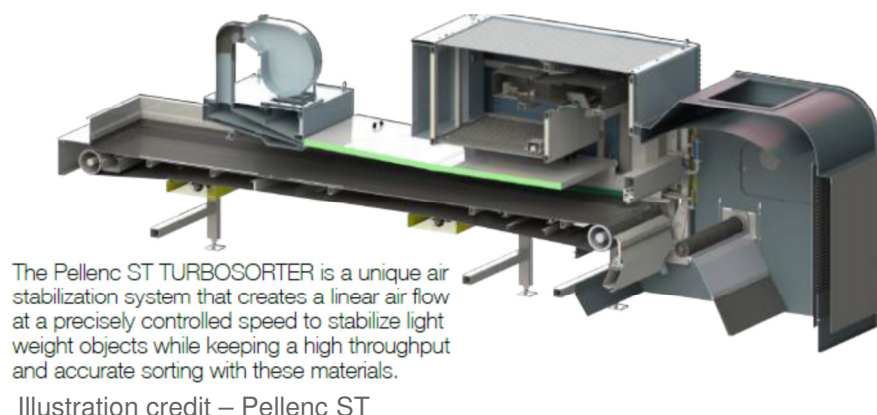
- 1) Illuminating the material to be sorted by an intense light;
- 2) Imaging and measuring the spectrum of light that is reflected back from the surface of items to be sorted;
- 3) Comparing the spectrum from an item to a library of reference spectra in a computer database, and based on a computer algorithm, make a determination of the resin type, and for some machines, the color of the plastic product.

Near infrared (NIR) light provides information about the chemical makeup of the plastic product to be sorted. Systems that measure NIR can distinguish between PE, PP, PET, and other resins because they have different spectra in the NIR range. Existing optical sorters measure reflected NIR light. The surface resin gives the strongest reflected signal back, and interior layers generally are not detectable by NIR because the light is absorbed and the intensity of the return signal is very weak compared to the signal of the surface resin. Because the majority resin of a multilayer bag or pouch is typically on the outside layer, film optical sorters can be used to sort film into PE, PP, and Other film categories (the categories separately used to describe film in this report).

The third system of an optical sorter is the sortation system. Once the item to be sorted is characterized, air jets are typically used to blow one resin type of item down a chute once it reaches the end of the acceleration conveyor belt. If more than one sort for film is needed, a second optical sorter in series with the first would be needed to further sort film into a third stream. Optical sorting machines are 91-98 percent effective in identifying resin types and sorting out materials. Additional optical sorters that use visible light instead of NIR can be used to sort clear from colored (or heavily printed) film.

Figure 24 shows an illustration of the design of a film NIR optical sorter sold by Pellenc ST of France. RTT Steinert GmbH of Germany also sells an optical sorter specifically designed to sort film into different market grades. Other optical sorter companies also will note that their equipment has the ability to perform the same type of sorting as Pellenc's and Steinert's film optical equipment; however, these other companies have not yet developed and patented the feed-regulating and sorting systems parts necessary for a dedicated film optical sorter like Pellenc and Steinert have done. The expense of optical sorters designed specifically to sort film by resin type make it likely that such equipment, when it is eventually installed in the U.S., will likely be installed downstream of all but the very largest of MRFs, primarily at film PRFs (should they ever be developed) or film reclaimers.

Figure 24 – Pellenc ST Film Turbosorter



As discussed earlier in this subsection, one of the drawbacks of NIR is that it is only useful for identifying surface layer resin composition. Some researchers are investigating whether light from the terahertz versus the NIR part of the spectrum can be used to identify whether plastics are single-layer versus multi-layer. Light around the terahertz part of the spectrum penetrates more deeply than does NIR light (this is the same technology used to see through clothing in airport security screening areas). A Canadian company, TeTechS, has developed its Rigel™ technology on a lab scale, but is looking for a venture capital partner to invest in the technology for commercial scale use for plastics sorting.

5.4. Reclamation Technologies

Once film has been sorted into market grades, it needs to be processed by a plastics reclaimer to return it to a plastic form suitable for recycled content manufacturing. This processing may include additional color sorting (depending on the recycled product application), cleaning, screening out of paper and higher melting point film layers, and repelletizing (or direct recycled product manufacturing by companies that both reclaim and manufacture recycled content plastic products). Film reclaimers must decide whether to use a dry recycling approach or a wet recycling approach, where film is washed in water. The dry approach is significantly less costly than the wet approach and is therefore used for high-quality recovered film that is not dirty. The wet approach is used where either the film is dirty, or the reclaimer wants to put the film back into a very demanding application, such as back into blown film manufacturing, and very high quality of the recycled resin is needed. Washing can also help to remove surface-printed inks that otherwise may remain with the film when it is recycled using the dry approach (washing does not remove inks that are reverse printed on the inside of multi-layer laminated bags and pouches). The following two subsections discuss the similarities and differences between the two approaches.

5.4.1. Dry Approach

Figure 25 is a depiction of the dry recycling approach. Not all film reclaimers use all of the steps or exact sequence shown below – it depends greatly on the quality and cleanliness of the film that they purchase for recycling. Cleaner film that is suitable for the dry recycling approach of course carries a price premium over that of dirtier film as shown earlier in this report in Figure 13, because less cost need be invested in reclaiming and cleaning clean film compared to dirty film. There is not a lot of capital equipment required by film recyclers for the dry approach, especially for very clean film, so smaller scale facilities can enter the business and be competitive with larger scale businesses. There is not a large economy-of-scale advantage for larger dry film recyclers compared smaller dry film recyclers.

Figure 25 – Typical Dry Film Recycling Process



A disadvantage of the dry approach is that inks are not removed, so any printing on film results in impurities in and discoloration of the recycled resin produced from the film. Contaminants, including dirt and tapes, if not removed manually, magnetically, or by air classification can usually be removed by screening at the end of the process. Film recycled through a dry process either needs to be very clean to start with, or needs to go to non-film recycled content products. Film to be recycled through the dry process still requires careful manual quality control on the front end to remove non-polyethylene materials and in some cases perform color sorts.

In addition to the dry approach for relatively clean films discussed above, some overseas film plastics recyclers have developed dry cleaning processes in which shredded plastic film is mechanically beaten by high speed rotating paddles within a confined space and/or subjected to frictional cleaning in which one piece of film is rubbed against another piece of film. Dirt and paper are liberated from the film and screened out. The advantage of this process is that it eliminates the use of water or chemical agents for cleaning and does not have the liquid waste disposal issues and associated costs of the wet approach described below. Dry cleaning will remove 80-90 percent of contamination.²¹

²¹ "Collection and Recycling of Household Plastic Film Packaging," Waste & Resources Action Programme (UK), September 2013.

5.4.2. Wet Approach

Figure 26 is a depiction of the wet recycling approach. The pre-wash step is usually a wet-shredding step that serves to wash away some of the dirt while also providing for an initial size-reduction of the film.

Figure 26 – Typical Wet Film Recycling Process



Washing film is very costly, adding an additional 10-20 cents per pound to the cost of recycling compared to the dry approach. Much of this additional cost comes from the energy required to dry the film, which on a cost per pound basis is constant, meaning that the cost does not go down as larger volumes are processed by bigger facilities. Some film recycling equipment suppliers have designed integrated film recycling lines that do not require separate pieces of equipment for drying, densifying, and extruding film. For example, EREMA makes an integrated piece of film recycling equipment that can accept film with 12 percent residual moisture, which the equipment then dries, densifies, and extrudes (energy is still required by this piece of equipment to evaporate the residual moisture).

In addition to higher energy costs associated with the wet approach compared to the dry approach, the wet approach also has a much greater capital equipment cost. However, unlike energy costs which are fixed cents per pound regardless of plant size, the capital equipment cost and associated labor cost per pound will decrease as film is recycled in larger volume throughput facilities. This means that unlike dry recycling facilities, there are cost advantages to large film wash facilities compared to small ones.

As shown earlier in this report in Figure 13, dirty curbside baled film that requires washing has a value

approximately 20 cents per pound less than baled clean clear film that does not require washing. While some portion of this lesser value is due to curbside film including colored film, which limits its recycled content product uses, the majority comes from the additional expense of washing the film.

5.4.3. Special Reclamation Approaches for Multilayer Films

The fact that multilayer films are made of dissimilar plastic resins that are incompatible with each other, and in some cases include aluminum foil layers, makes them challenging to economically recycle and may require added recycling steps in addition to the wet and dry approaches described above, or specialty processing unique to multilayer films may be required. If they are to be recycled into higher-value applications, they will likely require washing since a significant percentage of multilayer films are food contact bags, bar wraps, and pouches and so come with food contamination. For them to be recycled, therefore, a decision needs to be made whether to wash them for higher-value applications, or to not wash them and have the recycled resin go into low-value products that can tolerate the contamination.

Only an extremely small amount of these materials are currently being recycled. The limited recycling of these materials that does occur generally falls within five approaches:

- Dilution;
- Compatibilizers;
- Solid-state shear pulverization;
- Feedstock recovery; and
- Niche recycling.

Each of these approaches is described below. In addition to these in-practice approaches, experimental laboratory work has been performed where the materials from the different layers may be able to be separated through a series of processing steps that may include selective dissolution using organic solvents (e.g., to dissolve the outside PET layer of a pouch), depolymerization²² of outside PET layers or nylon layers from pouches, and melt filtration whereby polyethylene and polypropylene are molten but PET and nylon are still solid and can be physically filtered out. This research is only experimental and not commercially used anywhere to RSE's knowledge.

Dilution

Dilution is the most common way in which multilayer films are recycled. In dilution, multilayer films are blended in with other rigid or flexible plastics being recycled so that the non-compatible portion becomes a small percentage (usually less than ten percent) of the final recycled resin or product. Examples where this is done is for products with forgiving performance or aesthetic requirements, such as some lower tier plastic lumber that is produced. Unmelted PET, nylon, and aluminum flakes become solid inclusions in thick section products that are primarily polyethylene. Polypropylene and other resins that melt at

Figure 27 – Product Examples of Diluted Incompatible Resins



²² Depolymerization is the process of chemically breaking a plastic down into its original building blocks, allowing it to be purified and made back into a polymer. Depolymerization only works for certain classes of polymers such as PET, nylons, and PLA. It does not work for polyethylene, polypropylene, or polystyrene.

temperatures near to that of polyethylene fill in microscopic void spaces in the main polyethylene matrix.

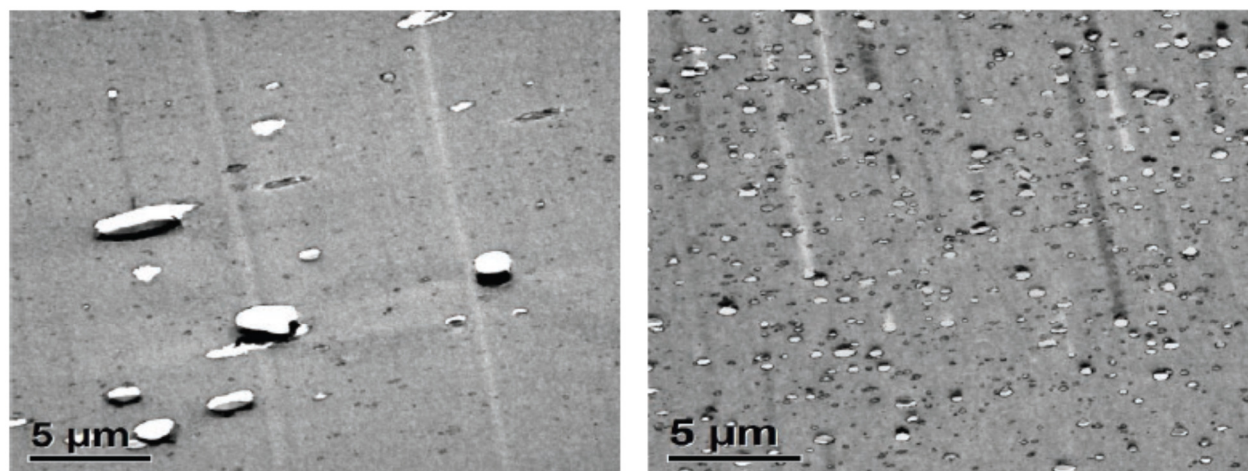
Likewise, majority PP chip bags can be blended into other recycled polypropylene streams to dilute the LLDPE portion. This need not be done to simply dilute (hide) impurities in the majority polymer matrix. Sometimes careful blends of incompatible resins can enhance performance of the majority resin. For example, one drawback of polypropylene is its low impact strength, particularly at low temperatures – this would be a concern for a manufacturer of plastic (PP) resin chairs, for example, who would like to ensure the chairs don't crack if used in cold weather. If LLDPE (such as from PP/LLDPE chip bags) is blended into PP at the right levels, it can improve the impact strength of the PP. A variety of researchers have examined PP/LLDPE blends and found that LLDPE loadings of up to 30 percent may be desired depending on the application and other performance requirements. Merchant recyclers who provide compounded PP resins could recycle significant quantities of recycled chip bag material as part of impact PP grades that they sell.

Compatibilizers

Compatibilizers are specialty additives that are added to blends of dissimilar plastics in order to evenly disperse the smaller percentage plastic type into the primary resin and tie together the different resins so that the resulting blend doesn't have large flaws and can still meet performance specifications. Several compatibilizers are commercially available and if used correctly allow a non-compatible material to blend with PE without negative effects. Compatibilizers essentially have part of the molecule made from one polymer, PP for example, and the other part of the molecule made from a different polymer, LLDPE for example. Compatibilizers coat the surface of the boundary between the two resins, bridging the gap between the separated resin zones, tying them together.

The drawback to compatibilizers is that they are expensive; however, they need not be used in large quantities to be effective. Compatibilizers only work when the different resins that need to be compatibilized are both molten, so they work best with resins that can be processed at similar temperatures (e.g., blends of PP, PE, and EVOH or nylon barrier layer polymers, rather than blends with PET which melts and is processed at significantly higher temperatures). Figure 28 shows how compatibilizers work to allow incompatible layers to be recycled together.

Figure 28 – Effect of Compatibilizer Additive on Recycled Multilayer Film Resin



Photograph credit – The Dow Chemical Company. The photograph on the left has no compatibilizer and has large EVOH domains. The photograph on the right shows how Dow's Retain™ compatibilizer has dispersed and homogenized the EVOH domains into the polyethylene matrix.

Solid-state Shear Pulverization

Solid state shear pulverization is a process in which mixed dissimilar plastics, or multilayer films, are sheared together at temperatures below their melting points. The shearing process causes the plastics and any food residues to break down into micro to nano-sized particles. This process literally tears molecules in half, and the loose ends reconnect, often with a loose end from a dissimilar plastic, linking dissimilar plastics together and compatibilizing them. This results in a well-mixed and homogenized general purpose resin that has properties between those of the individual component resins. Any impurities become small particle fillers in the blended resin that is produced. This process is a mechanical rather than a chemical approach to compatibilizing dissimilar resins. Because it is done below the melting temperature of any polymer, it can also compatibilize multilayer structures that include PET. Because of variation in the incoming materials stream composition and the fact that contaminants are not removed in the recycling process, the recycled resin that is produced would not be suitable for closed loop recycling back into film products, which is a high-precision demanding application.

Zzyzx Polymers is an example of a company that offers this technology. Zzyzx Polymers has a 1.2 million pound per year demonstration-scale facility in Pennsylvania and is seeking to license its technology to existing plastics recyclers who offer a variety of compounded resin lines for sale. Zzyzx Polymers received a Closed Loop Foundation grant in 2016 to develop a commercial scale processing line with a capacity of up to 8.7 million pounds per year. This technology is easily scalable – one only needs to add multiple solid state shear extruders at one site to increase the production capacity. Because the recycled resins that are produced are low-value, and would likely be competing against inexpensive recycled extrusion grades of polyethylene, it is not likely that manufacturers of recycled resins produced through this process would be able to afford to offer much if any scrap value to MRFs, nor could they afford to truck materials more than a few hundred miles. This technology could best be used in the following recycling applications:

- Integrated recycler-manufacturers of polyethylene MRF film to take film materials they otherwise would dispose as contaminants (i.e., chip/snack bags, bar wraps, stand up pouches) and allow them to process them into a form that could potentially be blended into their recycled content products, depending on the application, or sold as a lost cost general purpose recycled resin.²³
- Recycling of pre-consumer multilayer film manufacturing scrap.
- Recycling of post-consumer snack bags and bar wraps (separated from non-PP pouches). These PP/PE films, if washed and processed using this technology, could be sold for a premium price as a compatibilizer for recycled cap material from PET bottle recycling facilities, or as a compatibilizer for recycled pigmented HDPE bottle resin that has high levels of PP cap material. This same resin could be sold to custom compounders as a carrier resin for pigments and other additives they compound for sale to virgin PP product manufacturers.
- Production of low-priced general extrusion grade resins as described in the paragraph above.

Feedstock Recovery

Feedstock recovery is a general term that includes technologies such as gasification and pyrolysis. These technologies use very high heat in low oxygen environments to break down plastics into synthetic gas and diesel-like oils. The gas is suitable for combustion and the oils can either be combusted or sent to a refinery for further processing into industrial chemicals.

As of the beginning of 2016, U.S. crude oil prices were at lows not been seen in over a decade and natural gas likewise was priced low. While prices are likely to increase in the next couple of years, RSE does not

²³ Zzyzx has performed a test of 50 pounds of such MRF reject material (primarily a mix of chip bags and pouches) and found the recycled resin produced could be used to mold certain forgiving plastic products.

believe that the prices forecasted by the U.S. Energy Information Administration will provide for the financial viability of merchant pyrolysis and gasification plants during that time period. Only if such plants function as alternative disposal facilities to landfills, and charge a disposal fee for plastics delivered to them, are they likely to be financially viable for the next several years.

RSE is aware of three gasification units that are currently being operated at commercial scale by recyclers as minor side operations to their primary businesses. These are used to gasify waste materials the companies otherwise cannot recycle and the gas they produce is combusted for energy. The recyclers are:

- Pratt Recycling, Conyers, GA. This gasifier is located at Pratt's paper recycling mill. Its primary purpose is to gasify plastic found in Pratt's incoming paper, as well as residue from its co-located residential recyclables MRF, which would also include film plastic. The gasifier also accepts wood, carpet, and tire waste from outside sources.
- Shaw Industries, Dalton, GA. This gasifier processes post-consumer carpet (carpet fibers and backing are made from plastics) and pre-consumer carpet scrap. Shaw is a major carpet manufacturer.
- Ultra-Poly Corporation, Portland, PA. This gasifier is located at a large merchant plastics recycler and compounder. Plastics that Ultra-Poly cannot otherwise recycle are gasified and converted to electricity.

Apart from the advanced feedstock technologies discussed above, film plastic that is otherwise not able to be recycled can be processed into a fuel and combusted at cement kilns. A number of U.S. kilns take these materials, primarily from pre-consumer manufacturing scrap sources, and combust them. This is also the primary disposition of non-polyethylene film and flexible packaging that is collected in European residential recycling systems.

Niche Recycling

Niche recycling is when companies offer recycling as a cost-based service that otherwise would not be profitable or commercially viable on its own, usually only for their own branded packaging. A good example of a niche recycling company is TerraCycle. TerraCycle either contracts with major brands to offer a recycling service on their behalf, or charges dedicated consumers a service fee. The materials recycled by TerraCycle are materials that otherwise are not accepted in residential curbside collection programs or drop-off programs, and include PP-based snack bags and multilayer pouches. Generators must fill a box and then schedule UPS to pick up the box from their location. Specific branded materials that TerraCycle will recycle are:

- PP-based snack bags, pillow pouches, and bar wraps:
 - Bear Naked brand energy bar wrappers;
 - Hain Celestial's family of snack brands (Sensible Portions, TERRA Chips, and Garden of Eatin');;
 - Clif Bar brand of bar wraps;
 - Entenmann's Little Bites pillow pouches; and
 - LÄRABAR® and Cascadian Farm energy bar wrappers.
- Multi-layer pouches:
 - Bear Naked brand granola;

**Figure 29 – TerraCycle
Capri Sun Tote Bag**



Image downloaded from DwellSmart, the Official Online Retailer for TerraCycle, on March 23, 2016 from <http://www.dwellsmart.com/TerraCycle>

- Ella's Kitchen brand of baby food;
- GoGo squeeZ® brand of pureed snacks;
- GU brand of energy gel;
- Hain Celestial's Earth's Best brand of baby food;
- Honest Kids brand of drink pouches; and
- Kraft Foods' Capri Sun brand of drink pouches.
- Monolayer polyethylene:
 - Glad brand food storage products, including zip top bags and rigid plastic food storage containers.

TerraCycle recycles multi-layer pouches into the totes shown in Figure 29, or otherwise has relations with recyclers who recycle them in ways discussed above in this section.

6. Summary of Obstacles

Earlier in this report obstacles to increased recovery of film plastics were introduced as value chains were discussed. This section compiles those obstacles, classifies them by type, identifies existing groups and initiatives focused on different recycling value chain levels and obstacles, and identifies actions and investments that other entities, the investment community, and the Closed Loop Fund can take to help film plastics recycling advance in the United States. Table 8 summarizes obstacles to film plastics recycling and gives examples of initiatives already underway to address the obstacles. Each of these is discussed in greater detail below.

Table 8 – Summary of Film Obstacles and Existing Initiatives to Overcome Them

Obstacles	Existing Initiatives										
	WRAP	How2Recycle label	CPIA Best Practices	U.K. WRAP/ REFLEX	MRFF	Equipment Mfg. R&D	California Policies	APR DfR	Compatibilizers/Solid State Shear Pulverization	Energy Bag/Bale	Wal-Mart Sandwich Bale
PE Film											
Residential Retail Return Collection Obstacles											
1. Lack of a retail recycling habit	X										
2. Few retail return sites accept PE wraps for recycling	X										
3. Consumer lack of awareness of the recyclability of film wraps	X	X									
4. Inconsistent bin placement and signage	X										
5. Store employee lack of program understanding	X										
6. Difficulties for consumers in identifying flexible packaging accepted in recycling programs	X	X									
Residential Curbside Collection Obstacles											
1. Difficulties for consumers in identifying recyclable flexible packaging	X										

Obstacles	Existing Initiatives										
	WRAP	How2Recycle label	CPIA Best Practices	U.K. WRAP/ REFLEX	MRFF	Equipment Mfrg. R&D	California Policies	APR DfR	Compatibilizers/Solid State Shear Pulverization	Energy Bag/Bale	Wal-Mart Sandwich Bale
2. Curbside film picks up contamination in curbside collection systems			X								
3. Curbside film has low and in some cases no value (cost exceeds compensation)											
4. Very few MRFs accept curbside film			X		X						
MRF/Sorting Obstacles											
1. MRFs have not been designed to sort film					X						
2. MRF equipment adapted for film sorting does not yet achieve industry effectiveness standards				X		X					
3. Manual sorting of film is very costly						X					
4. Lack of markets				X							
Polyethylene Film Market Obstacles											
1. Cost of washing											
2. Lack of reclamation markets for MRF film											
3. Low cost alternative virgin and recycled resins								X			
4. Low end-user demand for film-to-film recycling				X			X				
Non-PE Film											
Collection obstacles											
1. Lack of MRFs that accept majority PP bags and multilayer pouches				X	X						
2. Recycling program participant confusion over acceptable films for recycling collection											
MRF/Sorting Obstacles											
1. MRFs have not been designed to sort film					X	X					
2. MRF equipment adapted for film sorting does not yet achieve industry effectiveness standards						X					
3. Manual sorting of film is very costly						X					
4. Low market value and market demand for non-recycled flexible packaging										X	
Market obstacles											
1. No markets				X							
2. No automated film sorting by resin/type in North America				X	X	X					
3. Incompatibility of dissimilar resins				X				X	X		

Obstacles	Existing Initiatives										
	WRAP	How2Recycle label	CPIA Best Practices	U.K. WRAP/REFLEX	MRFF	Equipment Mfr. R&D	California Policies	APR DfR	Compatibilizers/Solid State Shear Pulverization	Energy Bag/Bale	Wal-Mart Sandwich Bale
4. Low market value and market demand for non-recycled flexible packaging										X	
ICI Film Recycling Obstacles											
1. Low generation volumes of film at most individual generators	X										X
2. Lack of data on which generators recycle film and which do not											
3. Commercial recyclers not interested in handling film	X										
4. Training and motivating employees											
5. Mandatory commercial recycling programs (ICI single-stream)											

A review of the initiatives listed above shows that there is duplication of efforts with respect to certain obstacles, whereas other obstacles are not being addressed at all. The obstacles and initiatives listed in Table 8 are further described in the sections that follow.

7. Polyethylene Film Obstacles

7.1. Collection Obstacles

7.1.1. Residential Collection Obstacles and Existing Initiatives to Address Them

Residential Return to Retail Collection Obstacles

1. *Lack of a retail recycling habit.* While return to retail collection cannot be strictly called inconvenient, since literally every family must visit grocery stores regularly, consumers have not developed a recycling habit connected to their grocery store. While nearly two thirds of Americans say they recycle on a “regular basis,” only 32 percent say they have returned plastic shopping bags to stores for recycling.
2. *Few retail return sites accept PE wraps for recycling.* While ACC reports that over 90 percent of U.S. households have retail drop-off recycling access for polyethylene film bags, less than ten percent of those retail sites officially accept polyethylene wraps. Reasons for the reluctance to accept a broader array of polyethylene film vary, but may include:
 - Only feeling responsible for the use of disposable carryout bags the retailer gives out, but not feeling responsible for general use film packaging for the products sold on the shelves;
 - Concern over higher levels of contamination that may occur from accepting a broader stream;
 - Concern over sanitary conditions if film that has been in contact with food is placed in recycling collection containers; and
 - Potential for more labor cost associated with emptying film collection containers more frequently.

3. *Consumer lack of awareness of the recyclability of film wraps.* Consumers are generally aware that film bags are recyclable if returned to retail sites; however, they are often unaware that polyethylene wraps are recyclable as well. A survey done by ACC's Flexible Film Recycling Group (see discussion below) found that 82% of the public didn't know plastic wraps other than retail carry-out bags could be recycled at the store, and 54% didn't know that plastic bags and film generally should NOT be in curbside bins. The broadening of collection programs to accept other clean and dry polyethylene wraps only began in earnest after the Flexible Film Recycling Group began promoting the recycling of wraps in 2012.
4. *Inconsistent recycling bin placement and instructional signage.* Recycling bins at different retail locations are typically inconsistent in where they are placed and the signage they have, which may result in confusion and deter participation. While some local government recycling web sites and other instructional materials mention retail take back for plastic bags and films, few actively promote it.
5. *Store employees' own lack of understanding of whether bags and film are recyclable in their stores.* Phone calls were made to twenty retail stores listed on www.plasticsrecycling.org under "Find a Drop-off Location". Calls were made to the first 20 stores listed under a search for Greenville, South Carolina. The person who answered the phone was asked if their store accepted additional flexible plastics for recycling, such as newspaper and bread bags or if they only accepted shopping bags. Nine stores replied that they only accepted shopping bags, seven said that they thought other bags were OK but they weren't really sure, two said they accepted all kinds of plastics, including other bags and bottles, because their bin sign said "plastic". One person was not sure and said to bring it in and she would find someone who knew, and one store had no recycling bin.
6. *Difficulties for consumers in identifying flexible packaging accepted in recycling programs.* Currently, a majority of films and flexible packaging found in households is primarily PE, comprising HDPE shopping bags along with LDPE or LLDPE bread bags, newspaper bags, air pillows, and other types of wraps. However, the mix of materials is changing and is certain to become more challenging in the future. Already polypropylene fruit bags are common, and the use of multi-layer or laminated bags and pouches is growing rapidly. Consumers presently have very little guidance as to how to tell the different polymers apart, and in fact it is almost impossible. The Resin Identification Code (RIC), required by 39 states to label rigid plastic containers but not film packages, as flawed and problematic as it was, at least provided consumers with some information about which rigid plastic containers could be placed in the recycling bin. The RIC has been used inconsistently on some flexible packaging such as retail shopping bags, but has never been required by law. Therefore the consumer cannot distinguish identical packages made from PP and PE, or a single-resin plastic bag from a pouch or chip bag containing layers of different polymers along with adhesives and non-plastic components.

Initiatives Underway to Address Obstacles

1. *Wrap Recycling Action Program*

The American Chemistry Council's (ACC) Flexible Film Recycling Group (FFRG) was formed in 2012 by a small group of ACC members who wanted focused efforts to increase the recycling rate for film plastics and improving consumer awareness about recyclability of this material. This group now includes resin makers, brand companies, intermediate processors and reclaimers, end users, and retailers.

In 2013, the FFRG began a 3-year pilot partnership with the Sustainable Packaging Coalition and the State of Wisconsin to increase plastic film recycling through: (a) increased awareness of the recyclability of film beyond bags; and (b) increased access to commercial film recycling for businesses. The Wrap Recycling Action Program (WRAP) was developed from the State of Wisconsin pilot. WRAP has its own consumer-facing website at www.PlasticFilmRecycling.org. The site offers tools such drop-off and recycler directories, downloadable posters, tip sheets, frequently asked questions, and more.

The WRAP campaign is a national, multi-stakeholder public education and outreach initiative with the goal of doubling the 1 billion pounds of film recycled in 2013 by 2020. WRAP seeks to forge partnerships with motivated stakeholders like state/local governments, retailers, non-profits, brand companies and recycling service providers.

Because of the broad spectrum of stakeholders, the purpose of WRAP is multi-faceted:

- Provide accurate educational material to consumers and businesses about what, where and how to recycle plastic bags and film;
- Improve access for small and midsize businesses to recycle this material through improved infrastructure;
- Motivate retailers and brand companies to encourage consumers to bring material back to stores for recycling; and
- Track programs to map national participation and progress.

WRAP has two levels of recognition - Champion and Partner - to allow participation at the level that fits the needs and resources of the stakeholder.

Communities that elect to participate as Champions choose activities from the following list of options:

- Review local listings in the Drop-off Directory for accuracy and/or omissions.
- Encourage local retailers to use WRAP posters with film packaging images.
- Include a link to PlasticFilmRecycling.org on the local website.
- Encourage local recycling service providers to list in the Film Recycler Directory.
- Provide information to residents/businesses via mailers, emails, blogs, etc.
- Use a digital badge on their website to instruct residents not to put film in curbside bins.

WRAP Partners complete many of the tasks listed above and then move beyond education into efforts such as facilitating new collection programs or testing specific outreach strategies with particular focus on data collection to share with other communities.

Potentially useful data include tracking the impact of education to residents about what and where to recycle film and bags – i.e. directing them to retail return programs – in reducing film

WRAP Results in Vancouver Washington

Vancouver was experiencing high contamination rates of 19 percent in its curbside recycling collection program. Even though film was not accepted in the city's program, many residents were placing film in their recycling carts, as well as other items they should not be placing in the carts.

WRAP worked with the city on a "Recycling Done Right" consumer education campaign, inspecting carts and sending a mailer to all single-family homes. The outreach campaign was effective, reducing film bags and wraps from 1.2 percent to 0.68 percent by weight of the cart contents, a 43 percent reduction in film bags and wraps received by the City's MRF.

In parallel to the curbside contamination reduction initiative, WRAP worked with the city and local grocery stores to promote return to retail as the appropriate was to recycle bags and wraps. This included improved signage and collection containers at grocery film bag and wrap collection points, providing shopping list note-pads that included film bag and wrap recyclability messaging in the margins, utility bill inserts, and other outreach events.

Retail collection of polyethylene film bags and wraps after the campaign was implemented more than doubled, increasing by 125 percent over the pre-campaign collection quantities. With respect to awareness of non-bag wrap recycling, wraps were 1.75 percent of film returned to retail before the education and outreach program began, which increased to 9 percent after the campaign. This significant increase came with a small yet manageable increase in contamination from 1.75 to 3.7 percent of the total materials placed in the retail film collection bins.

contamination in the curbside stream and MRFs. Retail collection bin audits and MRF bale audits can be used to measure the impact. The sidebar illustrates the impact that WRAP has had in a recent Vancouver Washington campaign.

Participating in WRAP does not preclude involvement in or with other plastic film recycling programs; WRAP can be a complement to other programs.

2. *How2Recycle Label*

The How2Recycle label is an initiative developed by the Sustainable Packaging Coalition (SPC), a program of GreenBlue, that attempts to address consumer confusion about the recyclability of all types of household packaging. Program sponsors and supporters include consumer brand companies and retailers such as Target, Clorox, Kellogg's, McDonalds, ConAgra Foods and more.

The How2Recycle label provides information about the type of material, the format of the material (i.e. a bottle or a bag), how to prepare it for recycling, and locational instructions as to whether the package can be recycled traditionally or only through special means.

For flexible plastic film, bags and wraps, the How2Recycle label specifies "store drop-off". SPC has partnered with the FFRG and WRAP to feature the How2Recycle label on educational and promotional materials provided for WRAP campaigns.



Residential Curbside Collection Obstacles

1. *Consumer difficulty in identifying recyclable flexible packaging.* This same obstacle applies to film returned to retail for collection and was discussed previously under the retail return section above. In addition to the WRAP education materials and the How2Recycle label approaches, there is the possibility to simply let consumers place all film materials in their curbside collection containers and sort it at MRFs or other downstream recyclers into market grades with the remainder being disposed or sent for energy recovery. Very few U.S. MRFs, however, send their residue to be prepared into an engineered fuel product and MRFs are challenged to do any film sorting by resin type.
2. *Curbside film picks up contamination in curbside collection systems.* Loose film that is collected curbside picks up contamination from the residues of rigid containers that are collected curbside, as well as from bits of glass from containers that break in the collection and sorting process. Furthermore, loads of collected recyclables are dumped from collection vehicles onto concrete floors and may pick up additional dirt and contamination from these floors or from the collection vehicles themselves if the collection vehicles are also used on alternate days to collect disposed waste. Small pieces of paper, bottle caps, dirt, grease, and other contaminants are also picked up during the MRF sorting/processing steps. All of the contaminants picked up from curbside collection and MRF sorting either requires costly cleaning of the film not required of retail drop-off film, or limits the recycling of the film to low-value recycled applications where clean recycled resin is not required.
3. *Curbside film has low and in some cases no value.* The contamination discussed in the prior obstacle results in less market value for curbside film compared to retail drop-off film. This low value means that

MRFs must charge municipal recycling program sponsors an additional processing fee to accept it because the cost of sorting it far exceeds its value in the marketplace.

4. *Very few MRFs accept curbside film.* Very few MRFs accept film because of the cost to processing it and lack of markets for curbside film.

Initiatives Underway to Address Obstacles

1. *Wrap Recycling Action Program.* Although this initiative is focused on return to retail drop-off, it can assist consumer understanding of which PE films are accepted in curbside recycling programs.
2. *Canadian Plastics Industry Association (CPIA) best practices.* It is fairly common for polyethylene bags and in some cases wraps to be collected curbside in certain Canadian provinces. The Canadian Plastics Industry Association has developed residential program educational materials and best practices to reduce sorting cost and attempt to preserve film quality. This is done by encouraging curbside recycling program participants to place their PE film into one film bag and then tie off that bag to keep the PE film unitized into a film ball. This improves the cost-effectiveness of manual sorting and preserves the cleanliness of the film inside the outer bag, and helps prevent film from clogging MRF screens and contaminating other commodities.

7.2. MRF/Sorting Obstacles

MRF/Sorting Obstacles

1. *MRFs have not been designed to sort film, so film is excluded from the primary supply chain for plastic recyclers of residentially-generated materials: the curbside recycling collection system.*
 - Sorting at the MRF is problematic for bags and film material due to the effort needed to manually sort it, and the difficulty in knowing where to place automated sorters to capture it effectively. For manual labor, if a plastic bottle weighs 20 grams and a plastic bag weighs 2 grams, ten times the effort is required to sort the same amount by weight of plastic film than that of the bottle. Automated plastic sorting machines, which identify objects by polymer type, may not effectively distinguish between a bottle and a bag made of the same polymer. Additionally, getting the lightweight bags and films to “stay put” on a conveyor belt, against unpredictable air currents, is challenging.
 - Plastic bags and some film types wrap around screen shafts, rendering them ineffective and causing downtime and worker risk to clean them regularly. While theoretically screens with larger-diameter shafts resist the wrapping action, MRF managers have reported anecdotally that the larger shafts reduce the effectiveness of the screens, which are designed to allow heavier, three-dimensional containers to separate from lighter paper streams by gravity.
 - The plastic film material invades and contaminates virtually all other commodity streams, potentially reducing their value.
2. *MRF equipment adapted for film sorting does not yet achieve industry effectiveness standards.* Mechanical equipment used in MRFs generally needs to be approximately 90 percent effective in separating one material from other materials in order for widespread use. Existing equipment used in MRFs is not capable of this degree of sorting effectiveness. As a result, film sorted and recycled by U.S. MRFs is almost exclusively sorted by hand.

The mechanical similarities between paper/cardboard and film (i.e. thin, flat, light two-dimensional materials) make automatic separation difficult. Screens using rotating shafts and fingers are able to direct from 80-90 percent of film to paper quality control lines where further film sorting is possible.

However, much of the film also winds up on container sorting lines where it (along with small paper) must be removed and redirected to paper quality control lines. Ballistic separators, an equipment technology that performs a similar function using a different approach, may be more effective in sorting film with paper than screens, while also avoiding thin polyethylene bags wrapping around screen axles. Attempts to sort film from paper using NIR sorters is further hampered by materials overlapping on the paper processing belt, resulting in film that is missed and is shipped out as part of paper bales, or excessive amounts of paper that are accidentally sorted with film.

Purchasers of sorted materials from MRFs typically require that the product they are purchasing have from 90-96 percent of the commodity that they are intending to purchase (i.e., be 90-96 percent pure – the higher limit being for high-value commodities such as aluminum cans), with only single digits of moisture and other contaminant materials. Film that is mechanically sorted is not this pure and must be further sorted by hand or by additional downstream optical sorters to meet market specifications.

Optical sortation machines have proven to reliably identify and sort rigid plastic containers. These machines can similarly work well for flexible packaging, with three important caveats:

- The flexible packages must be presented to the machines in a way that allows accurate high-speed identification and sorting – existing designs use lamellar air flow to assist with this presentation.
- The identification of the film resin is not blocked by coatings, dark pigments or attachments.
- The outer layer of the package, which is the only layer that current technology auto-sortation machines can identify with consistent accuracy, is comprised of the primary resin type called for in the market specification.

3. *Manual sorting of film is very costly.* The cost of sorting film manually is highly dependent on whether and the degree to which curbside recycling program participants place film inside of one film bag and tie it off. For example, one film bag containing 20 pieces of film has only 5 percent of the direct manual sorting cost of film set out for recycling as individual pieces. Even when film is bagged, collection truck compaction and metering equipment at the MRF can cause bags to break open and their contents to be scattered. The cost of manually sorting film is a minimum of \$150 per ton, not including the cost that film adds to additional quality control (to remove stray film) from other product grades and the cost of removing film from screens. MRF film scrap value is far less than the cost to sort and bale it.
4. *Lack of Markets.* There are only two film reclaimers that buy and recycle North American MRF film on an ongoing basis, one in Canada and one in the United States. The capacity of these two reclaimers to wash MRF film is far less than the amount of PE film that enters North American MRFs currently, let alone the capacity that would be required if film were to be officially accepted in U.S. curbside collection programs. This lack of markets is the primary reason that U.S. MRFs are only able to market approximately 3 percent of the film that enters U.S. MRFs each year.

Initiatives Underway to Address Obstacles

1. *United Kingdom REFLEX project film recycling research.* The REFLEX (Recycling of Flexible Packaging) Project is a collaborative research and development project co-funded by Innovate UK (U.K.'s economic development agency) and collaboration partners Amcor Ltd, Dow Chemical Company Ltd, Interflex Group, Nestlé UK Ltd, SUEZ Environment (former SITA UK), TOMRA Sorting Ltd and Unilever UK Central Resources Ltd.. The project goal is to create a circular economy for flexible packaging by targeting each step in the supply chain – package design, manufacture, sorting and reprocessing. Axion Consulting Ltd is the lead consultant on the project. The project spans a two-year period from October 2014 to September 2016.

This project builds upon other work that Axion was involved in since 2010 that was funded primarily by the Waste and Resources Action Programme (operating as WRAP) in the U.K. The learnings from the

WRAP research are included in the discussion in this section along with current REFLEX project results. In the U.K., plastic packaging is composed of roughly 1/3 bottles, 1/3 tubs and thermoforms, and 1/3 film/flexible packaging. Residential recycling collection is approximately 40 percent single-stream, 30 percent dual-stream, and 30 percent multi-stream (more than two streams). Based on sorting flexible packaging found in MRFs, Axion believes that the relative material compositions are approximately 39 percent polyethylene, 40 percent polypropylene (both mono-layer and multilayer), and 22 percent other multilayer pouches. Like in the United States, film of any type – PE or otherwise – is not generally accepted in U.K. curbside recycling programs, primarily because of lack of markets. There is only one film reclaimer with a wash line in the U.K. for cleaning MRF film, PlasRecycle. PlasRecycle is a relatively new company and only accepts PE film for recycling.

In order to work toward the ability to more comprehensively collect film curbside in the U.K., the REFLEX project tested near infrared (NIR) optical sorters for their ability to detect and separate mixed polyolefin (PP and PE) packaging from multilayer packages made from other materials, such as those made from PET or nylon, or films made from other materials such as PVC or PLA. Two types of NIR sorting tests were performed – one using a flat/round screen to separate a film/fiber mix, followed by optical sorting,²⁴ and a second test as would be used by a film reclaimer (or as a second step in a MRF) to further sort film by material type.

Sorting film out of a paper stream, (as could occur if film were included in single-stream recycling program and was sorted onto the fiber line using flat/round separation technology, followed by sorting by a single optical sorter) proved problematic. The paper/film stream that was produced by the screen had approximately 6 percent film and 94 percent paper, and when the film was ejected using a NIR optical sorter, a lot of paper was carried with the film, so that the “film” was 84 percent paper and only approximately 16 percent film. This test showed that optically sorting film from fiber in MRFs would likely require at least two optical sorters in series to allow a MRF to produce bales of at least 90 percent purity that reclaimers would require.

When sorting one type of film from mixed film, as would be performed by a film reclaimer, the optical sorter tested was effective – capturing approximately 85 percent of PE/PP film (i.e., positively sorting 85 percent of the PE/PP out of a mixed film stream), and achieving nearly 90 percent purity (i.e., approximately 10 percent of non-PE/PP materials were accidentally sorted into the PE/PP stream). These sorting effectiveness parameters are only a little less than that of the same type of NIR equipment when sorting rigid plastic containers.

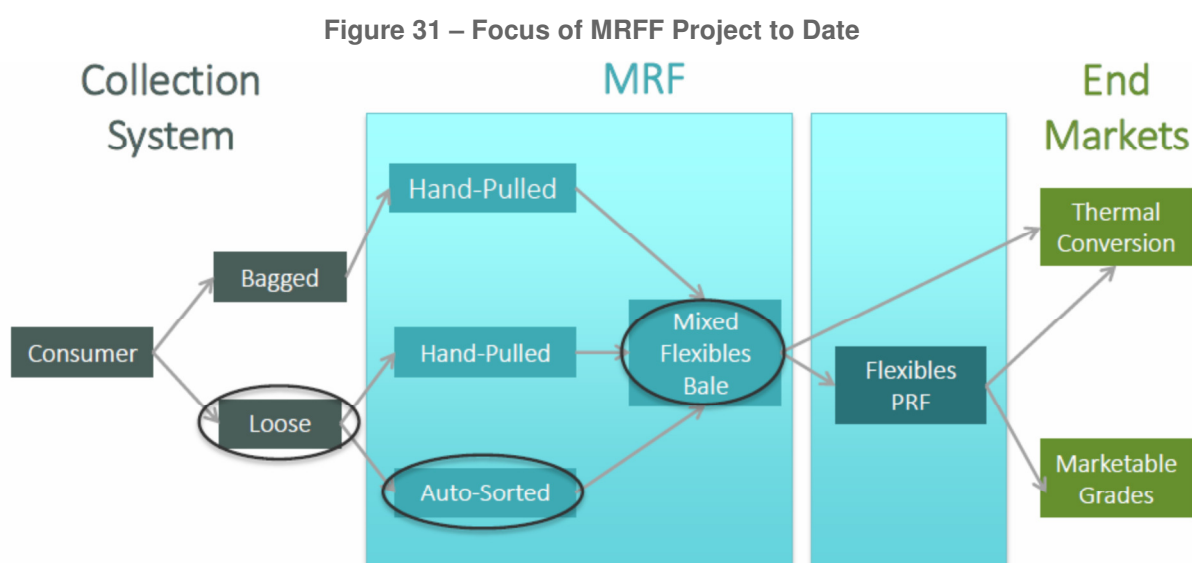
An economic assessment suggests that using NIR sorters of the type tested in the REFLEX project (i.e., adapted for film sorting) in MRFs processing household plastic film from co-mingled curbside collection programs may be preferred over hand sorting. This conclusion is attributable primarily to the significantly reduced operating cost of the NIR sorters compared to manual labor cost. This indicative analysis is useful for MRF operators who are currently using hand picking and are seeking to replace this operation with NIR sorters, as well as for informing the initial design of new MRFs where film is to be part of the incoming stream. However, Axion cautions that its economic assessment assumed that suitable buyers for all of the material produced can be secured (i.e., that multilayer chip bags and bar wraps could be left mixed and marketed with PE MRF films). This assumption is not yet valid in either the U.S. or the U.K.²⁵

²⁴ This type of a test has also been performed in the United States as part of the MRFF project described elsewhere in this report.

²⁵ “Processing Trials for Post-consumer Film Waste,”(IMT006-004), Waste Reduction Action Programme, September 2013.

2. *Material Recovery for the Future Project.* Materials Recovery for the Future (MRFF) is a project of the American Chemistry Council (ACC) Foundation for Chemistry Research and Initiatives, a 501(c)(3) tax-exempt organization. MRFF is a collaboration of brand owners and trade associations²⁶ to undertake research to determine how flexible packaging of all types (i.e., not just polyethylene) can be collected in curbside recycling programs and sorted by material recovery facilities. The increased convenience of curbside recycling collection offers the possibility for much higher recycling rates than is found in retail return programs.

Figure 31 depicts the focus of the research from the MRFF project, which to date has focused on testing the ability of mechanical equipment and optical sorters to separate film from mixed residential recyclables.



The MRFF project sought to confirm the conclusions of the REFLEX project for the U.S. residential recycling materials stream, and to better understand how film might flow to residue or adversely impact other commodity streams. The initial U.S. research was conducted at one single-stream MRF. Tests at this MRF indicated that 88 percent of loose flexible packaging flowed to the fiber lines, and that optical sorters on the fiber lines were able to extract a “relatively clean” stream of mixed flexible packaging from the paper. However, screens (to separate flexible packaging and paper from containers) and optical sorters were overwhelmed by the higher amount of flexible packaging presented to them and an unacceptable percentage of flexible packaging was missed and not sorted with existing equipment and existing sorting system design. Like the U.K. project results before it, the project found that MRFs would require equipment upgrades and redesign if mixed flexibles were to be added to collection programs.

The MRFF Project hopes to continue its research in 2016/2017, including:

- Exploring the financial feasibility of an intermediate flexibles plastics recovery facility (PRF) that could serve as a regional sorting facility for flexible packaging into market grades (e.g., PE and potentially PP), and materials for energy recovery/chemical conversion.

²⁶ Partners include the Society of the Plastics Industry, the Association of Plastic Recyclers, the Flexible Packaging Association, Amcor, Dow, Nestle Purina, P&G, PepsiCo, SC Johnson, and Sealed Air.

- Performing lab testing of screens and optical sorters to identify the extent to which equipment can be optimized through design changes, as well as determining equipment size/ratings for streams that include flexible packaging. Additional (redundant) or larger screens/optical sorters may be required to adequately process the stream.
 - Identifying and testing end-use products that might be produced from the recycling of different types of flexible film (including multi-layer and laminate film packaging), such as mixed plastic lumber.
3. *Equipment Manufacturers' Research and Development (R&D) Efforts.* Individually, optical sorting equipment manufacturers and MRF equipment manufacturers are researching ways to separate film from other materials in MRFs and to sort film by resin type in a cost-effective way. MRF equipment manufacturer BHS summarizes the challenge as follows:

“The optical method is difficult when you have a high fiber to film ratio as the amount of fiber lost in the process proves unacceptable to most users. As such, this method has not caught on in single-stream recycling applications.”

While BHS is investigating other innovative film sorting solutions, the consultants behind the REFLEX and MRFF projects both hope to find ways for equipment manufacturers to adapt existing paper/containers separation equipment and optical sorters to cost-effectively separate film to fiber lines and then sort it out optically, as described above.

7.3. Polyethylene Film Market Obstacles

Market Obstacles

1. *Cost of washing.* Washing and drying film to get it clean enough for high-value recycled content uses adds ten to twenty cents per pound (\$200 to \$400/ton) to the cost of reclaiming it compared to retail return film that does not need to be washed and dried.
2. *Lack of reclamation markets for MRF film.* There are only two film reclaimers that buy and recycle North American MRF film on an ongoing basis, one in Canada and one in the United States. The capacity of these two reclaimers to wash MRF film is far less than the amount of PE film that enters North American MRFs currently, let alone the capacity that would be required if film were to be officially accepted in U.S. curbside collection programs. This lack of markets is the primary reason that U.S. MRFs are only able to market approximately 3 percent of the film that enters U.S. MRFs each year.
3. *Low cost alternative virgin and recycled resins.* End users are hesitant to absorb the costs and risks of using MRF-derived polyethylene film when less expensive and less risky materials are available. This sensitivity varies based on the product being made from recycled material. Blown film recycled applications are much more sensitive to variation of properties that can come from recycled resins, and loss of productivity or need to limit the amount of recycled resin used for process control reasons can make the use of recycled PE film unattractive in comparison to virgin resin. Alternatively, recycled polyethylene from rigid plastic bottles can be produced for \$200 per ton less than recycled polyethylene from film if the film needs to be washed.
4. *Low end-user demand for film-to-film recycling.* Successful recycling requires balanced supply side (collect and recycle) and demand side (use in recycled products) activities. The best value is often obtained by recycling materials closed-loop – film recycled back into film. U.S. PET bottles contain on average 7 percent recycled content, and pigmented HDPE bottles contain on average 13 percent recycled content, and recycling of these materials is supported by brand commitments to use recycled content in their packaging.

Approximately 200 million pounds of polyethylene film is recycled back into film products in the U.S. each year. A majority of film that is recycled back into film goes into recycled content trash bags, which RSE estimates to have an average of 6 percent post-consumer recycled content. A lesser amount goes into recycled content retail carryout sacks, which RSE estimates to have an average post-consumer recycled content of 3 percent. Virtually no recycled film goes back into film packaging for branded consumer packaged goods made with polyethylene and polypropylene (i.e., snack pouches, bar wraps, and multilayer pouches). Commitment by brands to incorporate some level of recycled content, especially in inner core layers of their packaging, is needed to significantly grow collection and reclamation of those materials. Incorporating this recycled content will likely be difficult due to technical challenges of producing multilayer films, optical property requirements (need for clear or white film substrates for printing), and need to obtain U.S. Food and Drug Administration letters of no objection to use recycled content in food packaging applications.

Initiatives Underway to Address Obstacles

1. *California Policy Initiatives.* California in the past has supported film market development through policy action requiring trash bag recycled content. California in Chapter 5.3 (commencing with Section 42280) to Part 3 of Division 30 of the Public Resources Code, which was enacted as Senate Bill 270 in 2014, also imposes single-use bag fees and transitions the state to a ban on single-use plastic bags, which are to be replaced by paper and reusable plastic bags. The legislation also requires reusable plastic bags to be made from a minimum of 20 percent postconsumer recycled material by January 1, 2016 and a minimum of 40 percent postconsumer recycled material by January 1, 2020. This law also appropriates \$2 million for loans to California companies that manufacture plastic reusable grocery bags with recycled content. Implementation of this law is currently on hold pending a referendum to repeal the law to be voted on by California voters in November of 2016.

If the bag law is not repealed, RSE estimates that 20-40 million pounds per year of increased end market demand for recycled PE film may be created by the law. This would be a 10-20 percent increase over the current amount of PE film recycled back into film nationally. The current reclamation and retail bag manufacturing infrastructure for film would require additional investment and new sources of supply of film to meet this increase in demand. The amount of California loan funding to be made available is not sufficient for the equipment changes needed. Also, the law should not divert film currently being recycled into some other product (e.g., return-to-retail bags and wraps currently being recycled into composite lumber) into recycled content reusable retail sacks – additional film recovery/reclamation is needed. Potential sources of the additional film would be MRF film that is currently being disposed (which would need to be washed), or film that has been collected and is currently being exported for recycling.

California also is considering how to best invest funds it generates from its climate change policies in recycling so that recycling can assist with reducing greenhouse gas emissions. However, CalRecycle seems to be focusing first on directing funds to organics management and there is no guarantee that its funding will be directed toward film market development.

2. *APR's Design for Recycling.*

The Association of Plastic Recyclers (APR, formerly the Association of Postconsumer Plastic Recyclers) is a trade association comprised of companies involved in the production, use, and recycling of plastic packages. Members include brand owners, package manufacturers, and plastic reclaimers.

APR has historically helped plastics recyclers by providing guidance on package design to brand companies. The APR Design® Guide for Plastics Recyclability is a published resource providing package designers and engineers with evaluations of package design elements and innovations in

terms of recyclability criteria provided by APR member companies. The APR Design® Guide is data-driven and based on several levels of testing that determine the compatibility of package design elements with typical plastic reclaiming systems. The latest version of the APR Design® Guide also considers the performance of plastic packages in MRFs. APR's Critical Guidance Recognition, based on the Design® Guide, enables brand companies to demonstrate the recyclability of package designs through rigorous peer-reviewed test protocols.

APR is in the final review stages of a revision to the film and flexible packaging Design® Guide. Film package design elements earn the following ratings based on test data and/or surveys of MRFs and reclaimers where test data is lacking:

- APR Preferred
- Detrimental to Recycling
- Renders Unrecyclable
- Needs Further Testing

APR recognizes that its guidance for film is not complete, as the procedures for developing test methods and then testing innovations take time and some innovations have been introduced to the market so recently that APR has not had time to develop guidance. However, the APR Film Reclamation Committee is aware of the urgency of developing technical guidance to keep up with new package innovations and plans to assign a Continuous Improvement Subcommittee with the task of prioritizing testing needs and developing a plan and timeline to address them in the second half of 2016 and in 2017.

As a practical matter, the composition of many laminated, multi-material flexible pouches and other packages would most likely be characterized by APR as “detrimental” or “renders unrecyclable”. The Film Design® Guide is currently undergoing revisions, but is expected to be published on the APR web site in the summer of 2016. This initiative is primarily focused on helping existing reclaimers of polyethylene film reduce their cost of dealing with problematic film and flexible packaging so that they can cost-effectively compete with virgin and alternative recycled sources of polyethylene resin.

8. Non-polyethylene Film Obstacles

8.1. Collection Obstacles

Collection Obstacles

1. *Lack of MRFs that accept majority PP bags and multilayer pouches.* There are no markets for baled PP bags and multilayer pouches so MRFs do not accept these materials for recycling.
2. *Recycling program participant confusion over acceptable films for recycling collection.* Current film recycling messaging for PE films focuses on product types/uses (e.g. plastic carrier bags) because few film products are labeled for recycling. If film recycling is expanded beyond PE bags and wraps, such as accepting PP bags, all types of film may need to be collected, as something in between is likely to confuse users of recycling services.

Initiatives to Overcome Obstacles

The below initiatives were discussed previously. They are simply listed again here.

1. *REFLEX United Kingdom film recycling research*

2. *MRFF project*

8.2. MRF/Sorting Obstacles

MRF/Sorting Obstacles

Obstacles to MRFs accepting non-polyethylene films are similar to those of accepting polyethylene film, with some notable differences.

1. *MRFs have not been designed to recycle film, so film is excluded from the primary supply chain for plastic recyclers.* This same obstacle was cited under the polyethylene film discussion section and most of the comments similarly apply to non-polyethylene flexible packaging. A notable exception is that flexible packaging is generally thicker than thin polyethylene bags and sacks and thus does not tend to wrap around the axle of screens like those polyethylene products do.
2. *MRF equipment adapted for film sorting does not yet achieve industry effectiveness standards.* This obstacle was discussed previously for PE film and applies equally to non-PE film. Existing equipment used in MRFs is not capable of meeting MRF industry sorting effectiveness standards. When non-polyethylene film is added to U.S. MRFs, hand sorting can be used to remove film from material streams, however, additional sorting would be required, likely downstream of MRFs, to further sort the film into PE, PP, and Other (energy) grades. Optical sorting by resin type is needed since it is very difficult for manual sorters to distinguish between PE, PP, and Other types at speed or scale.
3. *Manual sorting of film is very costly.* This same obstacle for PE film remains for the other types of film that could also be included in curbside recycling collection programs.
4. *Low market value and market demand for non-recycled flexible packaging.* At the time this report was prepared, especially when the price of coal, oil, and natural gas were at lows in the first half of 2016 not seen for years, the value and demand for non-recycled plastics for energy and pyrolysis was significantly reduced. This presents an obstacle to collecting and sorting all film types and being able to market a “non-recyclable” fraction and avoid incurring disposal costs for that fraction.

Initiatives to Overcome Obstacles

The below initiatives were discussed previously. They are simply listed again here.

1. *MRFF project*
2. *Equipment manufacturer research and development*

8.3. Market Obstacles

Market Obstacles

1. *There are no current large-scale markets for non-polyethylene flexible packaging.* Generally speaking, value-added polyethylene film markets have strict specifications against the very types of materials expected to become more prevalent in flexible packaging, particularly in the residential stream, such as polypropylene, EVOH, PET, nylon, and metal foil. The commercial/industrial film mix is not expected to change as much. Traditional markets for polyethylene film are back into bags and film, or into composite lumber products. Current PE end use is split almost evenly between these two markets. Recycling film back to film is very challenging with low tolerance for impurities. Most of the film recycled back into film

products comes from industrial, commercial, and institutional (ICI) PE recycling programs.

Most residential film is collected through return to retail programs and from there directed to composite lumber, a more forgiving end use that does not require washing the film, largely because of the clean collection approach. Composite lumber absolutely requires certain stiffness and strength specifications, and although some companies co-extrude a thin layer of virgin plastic over the composite board that covers up surface imperfections and impurities, non-polyethylene materials are not accepted. This is because the composite decking market is selling a premium product in comparison to treated wood lumber, and because of past product warranty issues related to quality control. For these reasons, this market is not generally willing to consider accepting non-PE films into their recycled plastic mix.

Alternatively, unsorted mixed PE and non-PE films may be sent to recycled applications where appearance and strength are unimportant, such as parking lot car stops. However the market for such products is currently small and likely to remain so, even with additional market development.

Advancing the collection and recycling of these non-polyethylene materials will likely be best served by further sorting film into PE, PP, and Other multilayer grades. This will require sorting improvements as discussed above to sort polyethylene from non-polyethylene films, and development of recycling markets not currently in existence for the non-polyethylene materials.

2. *There is no automated film sorting by resin/type in North America.* Although the percentage increase by weight of these other non-polyethylene materials if included in the postconsumer recycling stream processed by MRFs would be extremely small, the percentage increase by number of packages is more significant, which drives up sorting cost. Without market demand/depth and a clear financial value offered by markets, MRFs will resist adding flexible packaging to their facilities beyond PE film, even if PE MRF film markets were to be further developed. As discussed previously under the U.K. REFLEX and the US MRFF projects, at least two optical sorters in series would be required to produce a mixed film bale of sufficient quality to be marketable. Additional sorting of the mixed films into PE and PP grades would then be needed, either at the MRF, PRF, or plastics film reclaimer level, with a mixed energy grade remaining. These sorting infrastructures do not currently exist in North America.
3. *Incompatibility of dissimilar resins.* PP bags and bar wraps include heat seal layers (often of polyethylene) and barrier layers. Other pouches may be made from various layers of PET, nylon, EVOH, and aluminum foil. All of these materials are incompatible with each other, and once laminated together, there is no existing commercial technology to separate them for recycling into higher-value recycled products. Existing solutions include diluting incompatible materials by blending, and compatibilization to link the otherwise incompatible materials together.
4. *Low market value and market demand for non-recycled flexible packaging.* Markets downstream of MRFs would need to offer a value that covers MRF (and potentially downstream film PRF) sorting costs. Pyrolysis or alternative fuel plants that offer to take non-recycled materials for no value (the current business plan and market status for such plants), would not provide sufficient market demand for MRFs/PRFs to consider allowing non-PE flexible packaging into the curbside recycling system if they represent any sizeable percentage of the mixed film stream accepted.

Initiatives to Overcome Obstacles

Consumers' expectations are that packages will be recyclable, and the consequent pressure placed on consumer brand companies, and their packaging suppliers, is to deliver recyclable packages. As flexible pouches are replacing rigid plastic containers for many household products (for example, when liquid detergent in bottles is being replaced by detergent pods in flexible pouches), it makes little sense to consumers that the pouch package cannot be recycled after they have been taught that they should recycle

the bottle. The consumer brand companies are caught in the cross-hairs between beginning of life and end of life for their packages. This tension is providing some impetus for consumer packaged goods companies to request their flexible packaging suppliers work on flexible packaging design innovations so that they are recyclable within existing polyethylene film recycling systems. The first two initiatives below focus on minimizing the non-recyclable fraction of film packaging by design for recycling.

1. *REFLEX United Kingdom Film Recycling Research.* Work by the REFLEX Project and related WRAP U.K. research focused on optical sorting of film from mixed recyclables streams was described previously. The REFLEX project has also focused on exploring and evaluating alternatives to previously difficult to recycle multilayer films. These alternatives are potentially more suitable for recycling and yet still deliver the performance requirements and technical properties needed for products ranging from confectionery to detergent. Research began with investigating design-for-recycling features that could make previously non-recyclable multilayer packages recyclable. These investigations have concluded with the following design recommendations for multilayer packaging users, if the package performance requirements allow:
 - Replace PET and nylon layers with polyethylene or polypropylene layers;
 - Use ethylene vinyl alcohol or silicon oxide for oxygen barrier layers over oxygen barriers from other materials;
 - Use metallized PP as a barrier versus an aluminum foil layer; and
 - Minimize printing and make ink choices that lessen the discoloring of the reclaimed resin when processed through wash and dry-processing reclamation technologies.

At the time this report was prepared, the REFLEX Project was continuing to focus on recycled content product applications and plastic product manufacturing techniques that could be produced from separately sorted and reclaimed PE and PP film bags, as well as products that could accept the mixed PE and PP film material for blending with other resins or for the production of non-demanding applications such as parking stops and blocks.

The REFLEX Project believes that with design for recycling, the vast majority of film and flexible packaging can be produced from PE and PP mono or multilayer packaging, which can be recycled, and that there needs to be only small amounts of multilayer packaging that is PET or nylon based packages. This shift to design-for-recycling of film packaging may minimize optical sorting expense (especially at MRFs) to provide for large enough yields of commodities with value (PE and PP films, versus film that only has an energy market), to make residential film recycling financially viable through curbside recycling systems. Axion believes that it is possible for flexible packaging to follow a similar model to that for plastic bottle recycling, and take ten years to mature to a point at which large quantities of flexible packaging are diverted from the waste stream through the curbside recycling system.

2. *Use of Compatibilizers.* Multilayer blown or extruded film packages that are mostly PE-based, but may contain some EVOH and tie layers to bind the PE and EVOH, are more adaptable to the recycling stream than multilayer laminated constructions of PE with PP, PET, or metal foil, in which the layers are glued together with adhesives.

Technologies for chemically compatibilizing different resins are available in the marketplace and are used by olefin recyclers, mostly to address PE contamination in PP or vice versa. However, the cost is high and borne by the recyclers.

Compatibilizers for PE and EVOH are under development, including a product by Dow Chemical branded RETAIN™, a compatibilizer built into the PE resin itself (this offers an advantage to the recycler as the brand company bears the cost of the compatibilizer up front as opposed to the recycler downstream). Some of the tie layers that bind PE to EVOH are actually formulations of PE and most

likely recycling compatible without further need for compatibilizers of the tie layer material themselves.

However, no chemistry is available to compatibilize PE with PET, or PE with metal foil, or PE with some of the adhesives. If the value of these packages is to be recovered, two options must be investigated:

- Developing new compounding technologies that combine physical and chemical methods to blend these materials together into feedstocks that can be used to manufacture products, along with market development efforts.
 - Exploring collection for energy recovery by conversion to fuel products.
3. *Solid-state Shear Pulverization.* Solid state shear pulverization is a mechanical compatibilization process in which mixed dissimilar plastics, or multilayer films, are sheared together at temperatures below their melting points, resulting in a compatibilized resin with properties similar to that of the primary components. Zzyzx Polymers is an example of a company that offers this technology. Zzyzx Polymers has a 1.2 million pound per year demonstration-scale facility in Pennsylvania and is seeking to license its technology to existing plastics recyclers who offer a variety of compounded resin lines for sale. This technology is easily scalable – one needs only to add multiple solid state shear extruders at one site to increase the production capacity. Because the recycled resins that are produced are low-value, and would likely be competing against inexpensive recycled extrusion grades of polyethylene, it is not likely that manufacturers of recycled resins produced through this process would be able to afford to offer much if any scrap value to MRFs, nor could they afford to truck materials more than a few hundred miles. This technology could best be used in the following recycling applications:
- Integrated recycler-manufacturers of polyethylene MRF film to take film materials they otherwise would dispose as contaminants (i.e., chip/snack bags, bar wraps, stand up pouches) and allow them to process them into a form that could potentially be blended into their recycled content products, depending on the application, or sold as a lost cost general purpose recycled resin.²⁷
 - Recycling of pre-consumer multilayer film manufacturing scrap.
 - Recycling of post-consumer snack bags and bar wraps (separated from non-PP pouches). These PP/PE films, if washed and processed using this technology, could be sold for a premium price as a compatibilizer for recycled cap material from PET bottle recycling facilities, or as a compatibilizer for recycled pigmented HDPE bottle resin that has high levels of PP cap material. This same resin could be sold to custom compounders as a carrier resin for pigments and other additives they compound for sale to virgin PP product manufacturers.
 - Production of low-priced general extrusion grade resins as described in the paragraph above.
4. *MRFF project.* As discussed previously, the MRFF project is investigating the cost of optically sorting film. It is expected that the project will also consider the cost of sorting film by resin type (at least PE and PP/Other). This information can inform identifying where sorting by resins should occur for the least cost to the system – MRF, PRF, or reclaimer.
5. *The “Energy Bag” Pilot Project.* In the summer of 2014, a coalition of stakeholders tested the concept of collecting films and flexible packaging from consumer households via their single-stream recycling program, and then separating the material at the MRF and sending it to an energy conversion company to be recycled into a fuel product. The group included Dow Chemical, Republic Services, The Flexible Packaging Association, Reynolds Consumer Products, the city of Citrus Heights, California and Agilyx, the energy conversion company.

²⁷ Zzyzx has performed a test of 50 pounds of such MRF reject material (primarily a mix of chip bags and pouches) and found the recycled resin produced could be used to mold certain forgiving plastic products.

During the June through August pilot, residents were provided with distinctive polyethylene bags, bright purple and 8-gallon in size, and instructed to place all of their “non-recycled plastics” or NRP (the term used by the project) into this bag and then place the bag in their curbside cart. The NRP include all flexible packaging and also plastic utensils, straws, and foam cups. A total of 26,000 households participated. Arrangements were made at the MRF to manually sort out these bags on the incoming pre-sort line, facilitated by the bright purple color.

The trial concluded with the following observations:

- One-third of the targeted households participated in the program at least once, resulting in about 8,000 energy bags being collected, totaling approximately 3 tons of material.
- Manually pulling bags at pre-sort in the MRF was effective, and no energy bags were found wrapped around the screens.
- Ten percent of the bags were randomly collected for auditing each day, resulting in a total of 13.7 percent of the collected material by weight being audited for contamination over the course of the pilot. The contamination rate was calculated at 16.5 percent, typical of the average encountered at that facility during normal operations.
- Dedicated sorters were employed to pick the bags. It was found that each sorter could pick between 40 and 50 Energy Bags per minute, or 6.3 tons of material in an 8-hour shift.
- Overall, some 58 percent of the materials collected were film plastic, including 33 percent non-polyethylene bags/pouches, 19 percent polyethylene bags and wraps (which could have been returned to retail for recycling), and the energy bags themselves, which represented 6 percent of all materials collected. Excluding non-plastic contamination, which was approximately 16 percent of the total material collected, approximately 2/3 of the plastics collected were film plastic.
- The plastics were sent to a pyrolysis plant for conversion to oil. Pyrolysis oil yields were approximately 75-80 percent that of the normal feedstock that the pyrolysis plant would produce. The reason for the lower yield was attributed to there being elevated proportions of rigid PET and PVC thermoform packaging and bottles.

While considering the project a success, participants also conceded that the affordability of such programs could be problematic if the concept were widely adopted with extensive quantities of materials placed in bags for energy recovery. The corporate sponsorship, along with the research nature of the pilot, enabled long planning timeframes, attention to detail, and immediate trouble-shooting. The communications and advertising materials were top-notch. The bags were provided to residents at no cost, and while acknowledging that the unusual color and size were one of the keys to the pilot success, there was also concern about long-term affordability and who would pay for the expense of the program on an ongoing basis since the value of recovered plastic being used for pyrolysis or energy applications is essentially “no value” with the market perhaps paying the cost of shipping and fuel processing.

9. Industrial, Commercial, and Institutional Film Collection and Processing Obstacles and Existing Initiatives to Address Them

9.1. Obstacles

1. *Low generation volumes of film at individual businesses.* Low generation volumes of film at many different types of generators that make it cost-prohibitive for them to separate and bale their own film or even to provide them with mini-balers. Tactics for combining the material from small-quantity generators to obtain sufficient quantities to interest local recycling collector/processors and reclaimers are not well developed. In malls or shopping centers, different stores almost certainly have different decision-making structures for authorizing recycling programs, a range of storage issues, and different inventories of scrap. Additionally, transporting small quantities from a number of generators to consolidation points on-

site must be addressed. Outside of malls, many film generating establishments are located in multi-tenant buildings, and building management, which arranges for waste and recycling service for all of the building tenants, often doesn't offer recycling service for film plastics, or recycling services at all.

2. *Identification of companies not recycling film.* It is difficult to identify large generators that are currently not recycling their film and then to determine the best way to approach them and convince them to take action. The larger film reclaimers have carefully guarded sole supplier relationships with the larger generators, and no database exists of companies that already are, or are not, recycling film plastics. The relationships may exist at the corporate level, the regional level, or the individual store level, depending on the chain.
3. *Commercial recyclers not interested in handling film.* While the opportunity to combine commercial film collection with existing long-standing cardboard (OCC) recovery programs is promising, OCC collectors may still be reluctant to handle a material with which they are not familiar and do not have market relationships. Handling film may require them to make additional trips, require more space at their facilities to sort and store processed recyclables, and deal with new markets and specifications.
4. *Training and motivating employees to separate film for recycling and keep it clean, especially when disposal is easier or less time-consuming.* While much industrial, commercial, and institutional film packaging is solely polyethylene, commercial generators are also likely to use polypropylene, or film laminated to paper, or other non-compatible materials. On-site identification and sorting is necessary as these materials generally cannot be baled together, and that requires the recycler to provide training and feedback to the generator. Employee turnover can make quality and consistency a challenge.
5. *Mandatory commercial recycling programs.* This obstacle is counter-intuitive. In many jurisdictions where it is mandated that commercial businesses recycle, there has been a tendency for waste management companies with commercial waste collection accounts to offer recycling collection programs for mixed commercial recyclables, collecting those materials in single-stream collection containers and delivering them for sorting at facilities with single-stream processing equipment. Many of these programs exclude film from the recycling program and instruct businesses to dispose of the film rather than recycle it. In these instances, businesses are more likely to dispose of film than recycle it with a different recycling partner, or recycle it as a separate film stream.

9.2. Initiatives to Overcome Obstacles

1. *Wrap Recycling Action Program.* The WRAP program has researched approaches to increase access to commercial film recycling for businesses, beginning with a Wisconsin initiative. Existing networks can be provided with technical assistance to collect and process ICI polyethylene film from the increasing number of businesses seeking recovery options for shrink film and transport packaging in an innovative and efficient manner. Examples include distributors who can backhaul from smaller customers (e.g., dry cleaners), less than truckload common carriers, co-collection with OCC by existing local OCC processors.
2. *Wal-Mart Stores Inc. Sandwich Bale™ and Super Sandwich™ Bale.* An innovative approach to overcome these challenges was developed and patented by Rocky Mountain Recycling and licensed to Wal-Mart Stores Inc. This approach, known as the Super Sandwich Bale™ or the Wal-Mart Plastic Sandwich Bale™ includes baling different recyclables together at the point of commercial generation using inexpensive downstroke balers, which are common throughout the retail industry and other large generators, and are primarily used to bale old corrugated containers (OCC). The innovation was to include other materials as a distinct layer in the bale and have the bales hauled by back-haul to a central warehouse and distribution center, at which point they could be broken apart, manually separated, and rebaled as separate materials, or sent to a recycling facility equipped for more efficient

sorting and baling. There are two varieties of the bales used by Walmart and Sam's Club locations – the Sandwich Bale in which clear pallet stretch wrap and protective clothing bags are baled as a middle layer in an OCC bale, and the Super Sandwich Bale in which 32 different materials, including aluminum cans, front of store plastic bags, plastic bottles, office paper and paperback books, are baled together. Figure 32 shows photographs of these innovative approaches.

Figure 32 – Super Sandwich Bale™ and Sandwich Bale™ Approaches Used by Wal-Mart Stores Inc.



Left photograph downloaded on March 24, 2016 from http://corporate.walmart.com/_news_/media-library/photos/environmental-sustainability/recycling-super-sandwich-bale.

Right photograph downloaded on March 24, 2016 from <http://www.packworld.com/sites/default/files/styles/lightbox/public/images/issues/08.05/images/Features/DSC00380.jpg?itok=x7HBrnPL>

While the Sandwich Bale™ and similar efforts are promising, store associate training programs, ongoing supervision, and downstream processor feedback on proper material preparation and quality must be provided to avoid “aspirational recycling,” or more troubling, the mentality that pushing responsibility for quality downstream is appropriate (i.e. “just get rid of it”).

10. Emerging Companies in Film Plastics Recycling

There are a number of established plastics recycling companies and recycling equipment companies such as BHS, Pellenc ST, RTT Steinert GmbH, and TOMRA Sorting Recycling (formerly TiTech) whose innovations and technology solutions were discussed earlier. The purpose of this report section is to provide a summary of a number of small and emerging companies around the world that the Closed Loop Fund may have become aware of that may benefit from investment. These companies are attempting to carve out a niche in film plastics recycling and are found around the world. Many of these companies are looking for investors to fund their continuing research and development efforts and/or finance their growth and expansion plans. Often these emerging companies are not able to access capital from traditional sources of financing and instead work diligently to obtain media coverage of their innovative company, in the hopes of attracting the notice of venture capital firms, social investment funds, and angel investors. A selection of emerging companies include:

- **Ambercycle** – U.S. R&D company that is investigating the development of genetically engineered bacteria to produce enzymes that can depolymerize certain plastics used in textiles, as well as in flexible packaging, such as PET. Some types of plastics can be broken back down to the chemicals that were used to make them in the first place (“depolymerization”), including PET and nylon, which are used in many multilayer pouches. Depolymerization does not work for other plastics including polyethylene or polypropylene. Depolymerization would allow the separation of nylon and PET layers from polyethylene layers in multilayer structures. Chemical depolymerization has been around for years and is a proven technology; however, because of its cost, is not currently used to recycle post-consumer plastics in the U.S. at a large scale.²⁸ Ambercycle hopes to find a more cost-effective alternative approach to depolymerization that could also separate PET feedstock chemicals from other composite structure materials.
- **AMP Robotics** – U.S. early stage technology development company for robotic sorting of recyclables. AMP Robotics believes it can develop a much smaller-footprint and less expensive robot than that of offered by Bollegraaf. However, the vision systems, computerized identification system, and mechanism for grabbing and lifting different types of films would require development. To date, AMP Robotics has focused on sorting of rigid plastic containers and paper, also as a supplement to but not replacement for other sorting systems already used in MRFs, with a focus also on replacing quality control people with machines.
- **Drought Diet Products** – U.S. early stage manufacturing company that intends to develop agricultural irrigation products made from recycled polyethylene MRF film. Drought Diet Products received a grant from the Closed Loop Foundation in 2016 to characterize and test recycling of MRF film, manufacture extrusion dies for production of its products, and develop a solution for joining separate lengths of its polyethylene irrigation products.
- **EcoGlobal** – U.S. holding company that hopes to develop an operational company currently in the concept state that potentially would be called Ekopolimer. Concept is based on a company with a similar concept launched overseas a couple of years ago. Products would be forgiving products made primarily from LDPE film plastics with up to 30 percent impurities from other plastics including

²⁸ The largest depolymerization plant in the U.S. was permanently closed by its owner, carpet and flooring company Shaw Industries, September 1, 2015. In a press release, Shaw stated “the equipment for depolymerization is old and inefficient, and lower oil prices have made the process less economically viable” than mechanical recycling processes. The plant had a capacity to depolymerize over 100 million pounds per year of nylon 6 from post-consumer carpets. It was not designed to process PET carpets, which was an additional reason cited for the plant closure, or materials from packaging. Shaw is replacing the depolymerization facility with a mechanical recycling facility.

HDPE and PP or non-plastic materials. The manufacturing process would be a compression molding or low pressure intrusion molding approach to making large thick plastic products. This company still needs to prove its concept, including settling on product lines and evaluating market penetration forecasts, and develop company financial forecasts for a go-forward business plan.

- **Enval** – U.K. company started by university researchers to commercialize and license the technology for a microwave induced pyrolysis process that they invented. Enval has a small demonstration-scale plant that is used to show potential licensees its technology. Enval's process is designed for plastic pouches that have aluminum foil layers (e.g., the Capri Sun pouch). The economics of its process depend on aluminum foil recovery as well as the sale of pyrolysis fuel oils. Enval does not represent its technology as a solution for metallized film (e.g., potato chip bags) because the aluminum is too small to be recovered, and it has not positioned itself as another one of many technology vendors seeking to license general plastics pyrolysis technologies. RSE believes Enval's technology is best suited for processing pre-consumer pouch manufacturing scrap, rather than serving as a solution for post-consumer multilayer pouches sorted out from other films and pouches. RSE makes this assessment because pouches made with foil are estimated to be less than five percent of PP and multilayer pouches sold, and detecting and sorting out such a small fraction is not believed to be cost-effective.
- **Green Mantra Technologies** – Canadian company that utilizes a patented proprietary catalytic pyrolysis process to cost-effectively transform hard-to-recycle polyolefin plastics such as grocery bags, shrink wrap, bottle caps, milk jugs and shampoo bottles into high-value waxes, greases, lubricants and other specialty chemicals. The company states that its wax products include “drop in” replacements as well as novel waxes that are cost and performance competitive with waxes made from traditional petroleum-based feedstocks. These wax products have a broad range of applications in the asphalt roofing and paving, inks, coatings, plastics, plastic color masterbatch, adhesives, and rubber industries. The company recently completed construction of a new full-scale manufacturing plant with an annual capacity of 5,000 metric tons. The company has been through several rounds of obtaining venture capital financing. The company is somewhat selective in the raw materials it sources, preferring separately sorted polyethylene and polypropylene streams.
- **Loop Industries Inc.** – U.S. research and development company that has developed in the laboratory a low-energy process to depolymerize PET. As described above under Ambercycle, depolymerization could allow the recycling of multilayer pouches made in part from PET. Loop Industries is looking for investment funds for further R&D.
- **NBF Plastics LLC** – U.S. company whose principals sell plastic products currently produced by others (not necessarily made from recycled plastic) into niche markets that they know well. This company would like to develop new products and internalize manufacturing, recycling polyethylene film in a large part molding process. NBF has conducted R&D and demonstration-scale manufacturing and now needs financing to scale up to an operating manufacturing business.
- **PlasRecycle** – U.K. start-up polyethylene film reclamation company that opened in September 2013 that sorts, washes, and repelletizes polyethylene film bags and wraps. Pellets are marketed to trash bag manufacturing, drainage pipe, and panel manufacturers. Around 40 percent of the company's £10.7 million startup costs were financed by government loans (City of London and WRAP nonprofit using federal government DEFRA funds). The company has undergone several additional infusions of venture capital since startup. Investment reports from the fall of 2015 seem to indicate that PlasRecycle has yet to turn a profit.²⁹ The company does not have proprietary equipment and is not fundamentally different or more innovative than North American film reclaimer

²⁹ Based on RSE's review of Foresight Investments PCC Limited investment reports, downloaded on June 3, 2016 from <http://www.cisx.com/listedsecuritynewsitems.php?companyID=3955>

EFS.

- **Plastic Forests Pty Ltd** – Australian company that performs dry recycling of polyethylene films, mostly from industrial and agricultural film sources. Plastic Forests sells recycled pellets and manufactures “forgiving” products including landscape edging. The company is investigating the ability to manufacture a more-demanding product, trash bags. There are several U.S. companies that make forgiving products out of dry recycling film processes including Greenpath Recovery (cornerboard), Mondo Polymer (guard-rail offset blocks), and Ply Gem (plastic roofing shakes). Other US companies make landscape edging out of recycled HDPE bottle resin (Epic Plastics and Master Mark Products) instead of recycling film.
- **TeTechS Inc.** – Canadian company conducting R&D for the use of terahertz frequency light for optically sorting plastics. This light is found in the far infrared part of the spectrum, versus the near infrared and visible light spectrum that is currently used by optical sorters to sort plastics. This different part of the spectrum may allow for the sorting of black plastics, and can identify that there are multiple layers in film plastics. While lab scale research has been done, it is not yet proven whether this equipment can identify different polymer resin types used in film packaging at the speed and manner in which film would be presented for optical sorting at commercial scale.
- **Zzyzx Polymers** – U.S. company started by university researchers to commercialize and license the technology for solid state shear pulverization of mixed multilayer bags and pouches that otherwise would not be recycled. The company has a demonstration facility to show its technology to potential licensees. The technology uses a chilled high-shear compounding extruder to make compatibilized resins from unwashed mixed plastics, resulting in a well-mixed and homogenized general purpose resin that has properties between those of the individual component resins. Any impurities become small particle fillers in the blended resin that is produced. This process is a mechanical rather than a chemical approach to compatibilizing dissimilar resins. Because it is done below the melting temperature of any polymer, it can also compatibilize multilayer structures that include PET.

Variation in the composition of incoming materials streams processed using the Zzyzx approach results in varying properties for the recycled resins that are produced, which means they are best suited for forgiving applications and would not be suitable for closed loop recycling back into film products, which is a high-precision demanding application. Furthermore, because food packaging film would not have been washed to remove contaminants prior to the recycling process, the recycled resin that is produced would have an odor that may limit its recycling uses.

11. Opportunities to Overcome Obstacles

11.1. Types of Obstacles and the Right Strategies to Overcome Them

The prior discussions went through the film recycling value chains and identified obstacles to higher levels of recovery. Existing efforts by other groups to overcome those obstacles were also discussed, in order to draw upon lessons learned by others as well as to evaluate where additional investment by the Closed Loop Fund or other investors may be duplicative or unnecessary. This section classifies the obstacles by type (shown in Table 9), and identifies strategies to overcome each type of obstacle. While certain strategies are able to be employed by the investment community (such as loans), other strategies such as research and development grants are more appropriate for other entities to provide.

General obstacle types and strategies to overcome those types of obstacles are:

- **Behavioral.** This obstacle means that generators choose to not recycle a particular material, or choose

not to participate in recycling at all, despite being aware that a material is recyclable. This behavior arises when generators assign a higher value to a non-conforming behavior than the conforming behavior (e.g., they perceive their time as being of more value than the additional time required to recycle). A contributing factor could also be a knowledge barrier, where if they were better informed of the value of the proper behavior, they would then conform. Strategies to overcome behavioral barriers include:

- Incentives – i.e., increasing the value of the behavior by approaches such as deposit-return systems, financial payments, reward points, recognition, etc.
 - Financial penalties – i.e., increasing the cost of the non-conforming behavior by assessing fines or fees or not collecting waste from businesses that are not recycling.
 - Convenience – i.e., reducing the “cost” of compliance by making the desired behavior more convenient or easier than the existing program requires.
 - Prohibitions and mandates – i.e. disposal bans, mandatory recycling requirements.
 - Promotion/education – this addresses instances with specific individuals where knowledge barriers are contributing factors.
- **Knowledge.** This obstacle means that generators legitimately don’t know that a material should be recycled, or are unsure (and have been instructed “when in doubt, leave it out”). It can also apply to other tiers of the recycling value chain where markets are not well-developed and recycling of certain materials is not mature. Strategies to overcome knowledge barriers include:
 - Information dissemination/education.
 - Signage at recycling collection containers.
 - Material labelling.
 - Market directories, market price indices.
 - **Financial.** This obstacle means that the cost associated with recycling exceeds that of not recycling for a specific participant in the recycling value chain. Sometimes costs resulting from disposal are not assigned to disposal, therefore it’s the true cost of disposal is not reflected (e.g., funding residential waste collection from general fund taxes rather than user fees). Other times the value of an external cost or benefit is not monetized for the current recycling system (e.g., climate change benefits associated with recycling, or the future value of scarce resources). Often environmental or social costs are not monetized, resulting in decisions that may be made purely on a financial basis. Of course, sometimes financial costs clearly outweigh benefits, financial and otherwise, and in those cases there is little justification for recycling. Strategies to overcome financial barriers include:
 - Ongoing subsidies.
 - Tax surcharges (e.g., disposal tip fee surcharges), and/or tax credits (e.g., for recycling equipment).
 - Disposal bans, which creates a level playing field for all generators, and drives recycling regardless of the cost.³⁰
 - Establishing larger scale facilities and equipment so they have better economies of scale.
 - More distributed facilities, usually when transportation costs are a significant component of costs.
 - Capital grants and below market capital loans.
 - Mandatory recycled content policies to increase market demand.
 - **Infrastructure.** This obstacle means one or more links in the recycling value chain are lacking (e.g., there are no U.S. reclaimers who produce recycled PP from residential bags and bar wraps) or where there are infrastructure links whose capacity is greatly less than the need of the system. This can be because of other fundamental obstacles that are the root cause (e.g., financial). It can come from lack of sources of capital, particularly under “chicken or egg” scenarios where capital markets won’t provide

³⁰ If not properly structured, disposal bans can increase cost if they result in contamination of recycling streams.

financing to recycling markets because collection is insignificant or doesn't exist, and generators won't invest in collection and sorting capital because markets are inadequate or don't exist. Strategies to overcome infrastructure barriers include:

- Government policies, such as disposal bans, mandatory recycling, mandatory recycled content, and environmentally preferable procurement to create a need for infrastructure.
 - Capital grants to new and existing facilities.
 - End use recycled product development, testing, and process design grants.
 - Venture capital investment.
 - New equipment loans.
 - Loan guarantees.
- **Institutional.** This obstacle is closely related to and may come from or may further reinforce infrastructure obstacles. Institutional obstacles occur when something is not historic standard industry practice and there is a resistance to change. Institutional obstacles often come from industries where catastrophic failure can have large financial implications and/or loss of life. It can also occur when decision-makers are risk-adverse. In some cases, standards may specify “virgin only,” insurers may not insure products manufactured with recycled content, or government regulators may require a higher standard of care than required. Strategies to overcome institutional barriers include:
 - Grant-funded demonstration projects.
 - Pilot projects.
 - Technical assistance, to better ensure first-time success rather than failure.
 - Development of standards and specifications.
 - **Operational.** This obstacle means a choice of operational parameters at one level of the recycling value chain that impacts the whole chain. For example, aggressively promoting bagging of film in curbside single-stream systems results in cleaner material, potentially avoiding the need for costly washing, and greatly reduces sorting costs. Not insisting on this fundamental participation/operational practice can result in financial obstacles, which in turn can result in infrastructure obstacles. Likewise, choosing convenient curbside collection over retail return can overcome one barrier and increase collection quantities, but result in new financial barriers to downstream entities of the value chain. Strategies to overcome operational barriers include:
 - Development and promotion of best practices.
 - Training of generators on material sorting and preparation.
 - Consideration of separate collection infrastructures, such as alternate day collection, separately bagged material, or special collection/handling of hard to recycle materials.
 - **Technological.** This obstacle is multifaceted and includes instances where enabling technology is current lacking (e.g., sorting equipment is not cost-effective), or areas where technological innovations not yet commercialized can unlock current barriers. For example, the U.S. Food and Drug Administration is responsible for ensuring packaging in contact with food does not leach hazardous chemicals into the food. Film plastics not intended for contact with food, such as polyethylene tissue overwrap, need not be made to the same purity standards as polyethylene film sealant layers used in food packaging that is in contact with food. Absent a technological solution to identify and sort the less expensive non-food-grade PE from the food-grade PE, legitimate health and safety considerations prohibit the use of recycled polyethylene in food packages where it is in direct contact with food.
 - Research and development.
 - Venture capital investment.
 - Design competitions and awards programs.

11.2. Assessment of Other Initiatives

The other initiatives discussed previously were included in this report so that the CLF could understand where other initiatives are already being directed toward overcoming obstacles, and where the investment community could best act in concert with those other initiatives to affect a comprehensive solution to overcoming film obstacles, especially those that are chained. All of the initiatives are steps in the right direction; however, they are not coordinated and in many cases they are not sufficiently resourced to enable obstacles to be overcome. A tentative summary assessment by RSE of the initiatives is as follows (it would be beneficial to solicit and incorporate stakeholder input into this assessment for the final project report):

- FFRG WRAP is providing measurable improvements in expanding the effectiveness of the existing retail return infrastructure to recover non-bag PE film. RSE's opinion is that this program is under-resourced to fully overcome the obstacles being targeted. RSE also believes, however, that collecting PE film through retail return will limit PE film capture effectiveness due to consumer preference for and availability of curbside recycling collection for other recyclables (which send the message that film is "not recyclable" in their programs). Furthermore, FFRG's commitment to retail return of PE film as the preferred approach (because it collects "recycle-ready" PE film without additional need for further sorting or cleaning) may provide an impediment to the recycling of non-PE films in the future, since those films would likely not be accepted in a return to retail environment.
- How2Recycle label provides an excellent consumer interface and encourages design for recycling. Its drawback is that its use is voluntary, and as a result, few packages use it, especially if packages cannot be labeled with an unqualified "recyclable."
- CPIA's best practices for curbside collection of MRF film can be very effective in reducing sorting cost; however, practical experience has shown that sizable percentages of film collected in residential curbside collection systems will not be placed in an outer bag. RSE is aware of some Ontario Canada communities that are considering dropping film from their curbside collection programs because the manual sorting cost is still high, even when best practices are employed.
- UK WRAP/REFLEX project has been performing cutting-edge research for several years. The lessons learned from this work (need for design for recycling, need for market development/promising recycled content product areas, limitations of current optical sorting equipment) apply equally to the U.S. In its own words, work to implement project learnings and recommendations may "take ten years to mature to a point at which large quantities of flexible packaging are diverted from the waste stream through the curbside recycling system."
- The MRFF study sought to confirm UK WRAP/REFLEX learnings under the U.S. film and MRF processing parameters. While full study results have not yet been released, it would appear that optical sorting effectiveness and affordability concerns identified by REFLEX were confirmed here as well. RSE's understanding is that the MRFF study has identified the need for more equipment research and development in the hopes of identifying a solution for overcoming the barriers that were being targeted.
- Equipment manufacturer R&D is not focused on developing systems to sort film by resin and type because the list of who potentially would buy such equipment (i.e., dedicated film plastics sorting facilities and reclaimers) is very small, and a large R&D and product development investment is not justified. Potential demand for such equipment is therefore met by modifying existing designs for rigid plastics optical sorters at minimal development cost. Equipment manufacturers are not likely to invest in truly innovative designs for film resin sorting without grants. Alternatively, equipment manufacturers are willing to invest in equipment technology for use by MRFs since the potential sales market is quite large. Equipment solutions that have been developed by equipment manufacturers to date have proven to be too costly for MRFs to purchase. Equipment

manufacturers may need incentives to continue their R&D in this area, and MRFs may need financial aid to acquire film separation equipment for equipment manufacturer R&D to be successful.

- California policies to require post-consumer recycled content in trash bags and reusable plastic grocery carryout sacks have and will continue to support film recycling chains by providing a “demand-pull.” The impacts have supported ICI film recycling chains, however, and not residential film recycling. If California’s single-use bag ban is not repealed in 2016, the law is likely to have the unintended consequence of many California grocery stores eliminating their return to retail recycling programs for retail carryout sacks, losing the recycling infrastructure for non-bag wraps as well, leading to a decrease in residential film recycling quantities. At 12 percent of the U.S. population, California policies have some but not a large impact on the national film recycling infrastructure.
- APR’s film design for recycling work provides a voluntary process for multilayer package developers to market packages as recyclable through the current retail return system for PE film, especially when paired with the on-package How2Recycle label (the APR design for recycling process is entirely dependent on consumers being told whether they should recycle a particular film package or not). Dow is an early beneficiary of the process. This program is expected to help with shifting to more recyclable bags, wraps, and pouches in the years to come.
- Energy bag/bale research is in an early stage of development. Additional research and financial support is needed on ways to reduce the cost of such programs to supply non-recycled materials to recovery markets, and find ways to financially support such programs.
- Compatibilizer development faces an uphill battle; however, it is more promising now than it was before APR’s film design for recycling work. Only when compatibilizers are embedded in the original package and reflected in that package’s cost (e.g., such as Dow’s development of a recyclable multilayer pouch) and the package is recognized and treated as recycled, will these developments prove useful. Otherwise, compatibilizers don’t address design for recycling, and their added cost when incorporated during the recycling process typically erases the additional value that the recycled resins that are produced have.
- Wal-Mart’s sandwich bale concept is innovative and has been around for several years now. However, it has not moved forward to being used more widely to overcome the obstacles discussed in this report.

11.3. Investment Community Funding Opportunities

Actions that private sector entities can take include loans, venture capital investment in early-stage innovation companies, and grants for research and development and commercialization/demonstration of new technologies.

Loans can validate unproven business models and technologies (at higher-risk companies). Low cost loans can also be focused on improving the economics of established film recycling companies, especially at the reclamation and end-use stages of the recycling value chains, by investing in equipment that is more energy efficient or allows companies to operate more efficiently through mechanization or greater economies of scale.

Venture capital investments can assist in the commercialization of technologies and the growth and success of start-up companies that otherwise struggle to obtain financing from traditional sources of capita.

Alternatively, grants are more appropriately utilized for:

- Research and development, which may ultimately lead to solutions for overcoming technology barriers;

- Developing new/additional demand for recycled products and resins from film, to overcome infrastructure gaps and obstacles, from existing virgin companies or early stage companies committed to using recycled material in their products; and
- Pilot projects and ongoing demonstration programs, which allow wary individuals to visit sites, question operators, and review program data, which have the potential to assist in moving emerging technologies forward.

Table 9 summarizes the obstacles discussed previously, identifies which ones are being addressed by other initiatives or private companies (such as equipment manufacturers), and identifies obstacles that could be effectively addressed by the investment community. As can be seen from the summary in the table, the opportunity for the CLF and other members of the investment community³¹ to take action is focused on the MRF/sorting and reclamation/product manufacturing links of the recycling chains.

Table 9 – Summary of Film Obstacles with Investment Needs and Types

Obstacles	Obstacle Type	Existing Initiative?	Investment types ¹
PE Film			
Residential Retail Return Collection Obstacles			
1. Lack of a retail recycling habit	Behavioral	X	
2. Few retail return sites accept PE wraps for recycling	Infrastructure (root: Institutional)	X	
3. Consumer lack of awareness of the recyclability of film wraps	Knowledge	X	
4. Inconsistent bins, bin placement, and signage	Infrastructure	X	G
5. Store employee lack of program understanding	Knowledge	X	
6. Difficulties for consumers in identifying flexible packaging accepted in recycling programs	Knowledge	X	
Residential Curbside Collection Obstacles			
1. Difficulties for consumers in identifying recyclable flexible packaging	Knowledge	X	
2. Curbside film picks up contamination in curbside collection systems	Operational	X	
3. Curbside film has low and in some cases no value (cost exceeds compensation)	Financial (root: Operational)		
4. Very few MRFs accept curbside film	Infrastructure (root: Financial, Institutional)	X	
MRF/Sorting Obstacles			
1. MRFs have not been designed to sort film	Infrastructure	X	G, L

³¹ The Closed Loop Fund is part of this broader community, with the goal that its activities leverage additional capital from the broader investment community. The Closed Loop Fund's primary focus is to make loans, mostly for capital investments, which will provide an immediate return-on-investment (business case) that supports repaying the loans over a period of up to five years. The Closed Loop Fund accepts applications focused on collection, processing, and communication projects that are intended to increase recycling access and rates. There is also a related Closed Loop Foundation that may make selected grants. The founders of the Closed Loop Fund are also investigating the suitability of a venture capital fund focused on film recycling.

Obstacles	Obstacle Type	Existing Initiative?	Investment types ¹
2. MRF equipment adapted for film sorting does not yet achieve industry effectiveness standards	Technological	X	
3. Manual sorting of film is very costly	Financial, Operational	X	G
4. Lack of markets	Infrastructure	X	
Polyethylene Film Market Obstacles			
1. Cost of washing (MRF film)	Financial		G, L
2. Lack of reclamation markets for MRF film	Infrastructure, Financial		G, L
3. Low cost alternative virgin and recycled resins	Financial	X	G, L
4. Low end-user demand for film-to-film recycling	Varies by use: Institutional, Technical, Financial	X	G, L
Non-PE Film			
Collection obstacles			
1. Lack of MRFs that accept majority PP bags and multilayer pouches	Infrastructure (Root: Financial)	X	
2. Recycling program participant confusion over acceptable films for recycling collection	Knowledge		
MRF/Sorting Obstacles			
1. MRFs have not been designed to sort film	Infrastructure	X	G, L
2. MRF equipment adapted for film sorting does not yet achieve industry effectiveness standards	Technological	X	
3. Manual sorting of film is very costly	Financial, Operational	X	G
4. Low market value and market demand for non-recycled flexible packaging	Financial, Infrastructure	X	
Market obstacles			
1. No markets	Infrastructure, Financial, Technological	X	VC, G, L
2. No automated film sorting by resin/type in NA	Infrastructure	X	VC, G, L
3. Incompatibility of dissimilar resins	Technological, Financial	X	VC, G, L
4. Low market value and market demand for non-recycled flexible packaging	Financial, Infrastructure	X	G, L
ICI Film Recycling Obstacles			
1. Low generation volumes of film at most individual generators	Infrastructure, Operational, Institutional	X	
2. Lack of data on which generators recycle film and which do not	Knowledge		
3. Commercial recyclers not interested in handling film	Institutional	X	
4. Training and motivating employees	Knowledge, Behavioral		
5. Mandatory commercial recycling programs (ICI single-stream)	Financial, Operational		G, L

1. Investment types include grants (G), loans (L), and venture capital (VC).

The obstacles that the investment community is in a position to address, and types of investments that may be most effective, are further discussed in the following paragraphs.

- 1) **Inconsistent bins, bin placement, and signage for collecting polyethylene retail return film.** This can be considered similar to the single-stream cart loans that the CLF has made, or recycling cart grants made by companies through environmental organizations (e.g., Coca Cola, Recycling Partnership, Keep America Beautiful), except that in this case it would be focused on retail grocery chains that desire to begin collecting PE film at their stores, or expand existing collection of bags only to include PE wraps as well. The FFRG WRAP program provides technical assistance and best practices in this area, but does not have a bin grant program in place. FFRG could partner with CLF and other funders to establish such a program as part of a broader initiative to expand non-bag wraps recovery through the existing return-to-retail infrastructure. WRAP pilots have shown PE film collection increases of up to 125 percent when new bins are paired with an effective collection program.
- 2) **MRFs have not been designed to sort film.** Even if recycling program participants have been instructed to place film together in a tied-off outer bag, a large percentage will still place individual pieces of film directly in their recycling containers. If film is officially accepted in curbside collection programs, even more loose film will be received than the current quantities they receive when not asking for it. MRFs that will accept curbside film therefore will need to be designed to sort bagged (if promoted, which is currently considered the best practice) as well as loose film. This infrastructure obstacle may be overcome by providing grants and loans to residential MRFs to install equipment for film recycling. In new construction single-stream MRFs, ballistic separators may be preferred over screens for separating paper and film from rigid containers (RSE is not aware of a study or evaluation that specifically compared the two types of equipment specifically with respect to film handling implications in MRFs). Other less costly pieces of capital equipment that could also be considered for existing as well as new construction MRFs include pneumatic conveying systems and dedicated film balers. If flexible packaging beyond PE film is to be included in residential curbside collection programs, additional film-specific equipment that may be funded could include optical sorters to separate (and potentially sort at the MRF level) from the fiber stream, and possibly a manual film sorting line to sort PE from other types of film. The depreciation life for MRF equipment is generally considered to be ten years, and loans, if offered, should be for a ten year term. Because MRFs are a low-risk industry and are able to obtain commercial loans without the need for assistance, and have chosen to not install such equipment, grants for demonstration MRFs designed for film recycling could demonstrate the feasibility, or industry-wide partial assistance grants may be needed to improve sorting economics to catalyze acceptance of film in MRFs.
- 3) **Manual sorting of film is very costly.** This infrastructure obstacle is not likely to be overcome solely with low-interest loans to residential MRFs, since MRFs are already able to obtain commercial loans, existing technology is quite expensive and not highly effective, and new technology development is not normally financed with short/mid-term loans. However, combinations of loans and grants to install optical sorting equipment to separate film from other streams, such as paper, have the potential to reduce the sorting cost barrier, especially at large MRFs.

Current equipment to replace manual sorting is focused on using optical sorters, which have a high capital cost. This means optical sorters only makes economic sense for large-volume MRFs. For example, only MRFs that currently sort over 15 tons per hour of recyclables typically have any optical sorter at all in their MRFs (usually used to sort out PET). Only a dozen or so North American MRFs currently have optical sorters on their paper quality control lines. Until the MRFF project provides learnings from its research to better inform a size-threshold cutoff for optically sorting film, RSE estimates that only MRFs processing at least 30 tons per hour of mixed single-stream recyclables will likely be able to justify the capital cost of optical sorters on their fiber lines, unless grant funds are made available to lower the threshold. MRFs of this scale only account for approximately half the residential recycling tonnage processed in the United States. For the other half of families served with recycling collection access, film would either need to be separated by hand in MRFs (at high cost), or not included in programs at all.

If in the future mixed films are to be collected, a second step of sorting mixed film into different grades would be needed. If this step were to be performed in MRFs, even more cost would be added, and therefore would be a consideration by only the very largest of MRFs. Sorting of mixed films by resin requires a separate film sorting conveyor and the following additional steps:

- Open bagged film so each piece of film is individualized;
- Positively sort out bags and film that is obviously only polyethylene into a one grade, either manually or by an additional film optical sorter;
- Leave all remaining film, and potentially miss-sorted fiber, as a mixed resin/laminate grade that could be sent for energy recovery.

RSE believes that resin sorting of mixed curbside-collected film, if its collection and recycling is to occur in the future, would be better performed by a film reclaimer that operates at the higher scale required by the sorting equipment, allowing a variety of sizes of MRFs (not just large ones) the option of collecting more than just PE film. This is only likely if non-recycled film is reduced through design for recycling, markets are developed for recycled PP film, and recovery or other low-value markets are developed for the remaining residue fraction.

- 4) **Cost of washing film is expensive.** This financial obstacle has the potential to be reduced but not eliminated through combinations of grants and below-market loans to film reclaimers for them to increase the capacity of their plants for washing and drying MRF film. Essentially, the cost per pound recycled can be reduced by: (1) distributing fixed costs over more pounds; and (2) installing larger scale and more efficient equipment, but only up to a point. Once that point is reached, parallel wash lines would be required, which would no longer provide operational efficiencies, but would still allow fixed costs to be spread over more pounds. The average polyethylene film reclaimer wash capacity in North America is less than 20 million pounds per year. By comparison the average North American polyethylene bottle reclaimer wash capacity is approximately 60 million pounds per year, and this larger scale provided competitive advantages for supplying recycled polyethylene into recycled product markets for bottle recyclers in comparison to film recyclers. RSE estimates that the following relative proportions of film types would be contaminated by their contents:

- PE film: approximately 10 percent of film. This film, if collected, would need to be washed for high-value uses. If contaminated by the collection/recovery method (e.g., single stream collection, not bagged), an additional amount may need to be washed.
- PP film: over 75 percent of film. Broad collection of PP film would mean washing nearly all collected.
- Other film: approximately half of film/flexible packaging. This type of film cannot go to high-value uses and does not need to be washed.

One of the greatest costs of recycling film is the cost of drying the film after it has been washed. Shreds of film tend to trap and sandwich water between the sheets, unlike bottle flakes which are rigid and more easily shed water droplets. This makes drying film harder and more costly than drying rigid plastics. The area of equipment manufacturer drying technologies and reclaimer operating practices for drying film could benefit from additional research and development; however, that is a different strategy than the scaling-up strategy discussed above.

- 5) **Lack of reclamation markets for MRF film.** Only two North American film reclaimers purchase MRF polyethylene film on an ongoing basis. Combinations of grants and loans to companies interesting in entering the business of purchasing and washing MRF film have the potential to assist in overcoming this obstacle, provided there is sufficient end user demand to accompany the increased recycled resin produced. Ideally a new market entrant would have the desire to recover and wash PP film it receives as well. Without more market depth and diversity, MRFs and local collection programs are reluctant to

consider officially adding film to their programs. Furthermore, over 95 percent of PE film currently received by MRFs is disposed rather than marketed, in part due to wash capacity being less than the supply of film that MRFs have, regardless of whether they officially accept it or not. Wash capacity can be added by either increasing the scale of existing recyclers, or adding additional reclaimers to the recycling value chain, and preferably both. Furthermore, the more geographically distributed reclamation markets for MRF film are, the better the ability to save on transportation costs. The two current North American markets for MRF film are located in Indiana and Ontario, less than 500 miles from each other.

- 6) **Low cost alternative virgin and recycled resins.** Investors in recycling cannot influence the price of alternative virgin and recycled PE resins, nor can private sector investors implement the government policies that can be applied to this obstacle, so what remains is for the investment community to make combinations of grants and loans that have the potential to reduce the cost of the entire recycled PE film resin value chain. These areas include more and larger scale film reclamation facilities (discussed above under 4 and 5), and lower financing costs for collection, MRF, and reclamation equipment used for film provided by grants and below market capital loans. Outright equipment grants have a higher potential to help recycled PE film be even more cost-competitive than do below market loans.
- 7) **Low end-user demand for film-to-film recycling.** This obstacle is multi-faceted. Depending on the plastic product application, the root cause may be an institutional barrier (not able to be overcome with loans), a technical barrier (such as inability to sort film by food grade versus non-food grade types, also not able to be overcome with loans), or an economic barrier, which may be able to be partially overcome with below market loans (refer to the above discussion on items 3-6). Technical assistance grants and grants for product development testing would be effective in overcoming this barrier at smaller manufacturers. Combinations of grants and loans for converting processing lines to use recycled content may also be needed.
- 8) **Lack of markets for non-polyethylene consumer films.** This obstacle has both infrastructure and financial elements associated with it. A reason why existing MRFs and markets only accept PE films is the lack of markets for non-polyethylene films. Without addressing markets for non-polyethylene films, the cost of collecting and then disposing of non-polyethylene films prevents mixed film collection programs. Loans and grants may partially address the financial aspect of this obstacle, focusing specifically on instances where it is difficult for companies to obtain financing due to the lack of market data and lack of collection (chicken-egg scenario). Infrastructure obstacles associated with the lack of end use of recycled resins (e.g., for the recycling of PP bags and bar wraps) are better addressed through grant programs. Because of the risk of developing a new type of business, venture capital investment may be required for this obstacle.
- 9) **No automated film sorting by resin/type.** An obstacle to further developing markets for non-polyethylene materials, such as for PP bags and bar wraps, is the infrastructure gap of having no optical sorting equipment for the sorting mixed film materials by type in North America. Existing film recyclers of retail return film, and particularly film recyclers who accept curbside film, could benefit from having optical film sorters. As discussed above, RSE does not believe that optically sorting film by resin in MRFs would be cost-effective; also, the transportation expense of a film PRF that does not further reclaim film or prepare a fuel product from the unmarketable fraction would only add cost and not help the system economics in RSE's opinion. Therefore, this equipment would best be employed by helping existing film reclaimers to reduce manual sorting/quality control costs and ensure a better separation of films into PE and PP streams for recycling, and other types for energy recovery markets. RSE considers this type of equipment to be necessary for the further development and recycling of PP film materials, and loans can be part of a financial assistance package that may include grant funds and other forms of assistance. Venture capital could play a role in overcoming this obstacle if a new reclaimer that intends to accept all films and sort and reclaim the different components is receptive to

venture capital financing.

- 10) **Incompatibility of dissimilar resins.** This obstacle has both technological and financial aspects associated with it. The technological aspects are best addressed through venture capital investment and research and development grants. The financial aspects may also be addressed by offering loans for equipment to blend in compatibilizers or process mixed dissimilar film packaging by solid state shear pulverization. This turns materials that otherwise can go into only very low value applications into materials that can go into moderate-value applications, helping to improve the financial viability of collecting, sorting, and processing mixed films. Loans can also be made to large reclaimers of film to purchase solid state shear pulverization equipment so that non-recycled materials currently being disposed at a cost can instead be processed into a low-value yet salable resin.
- 11) **Low market value and market demand for non-recycled flexible packaging.** Root causes that result in this obstacle are financial obstacles (low value of fuel products) and infrastructure (few facilities with approved governmental permits to thermally treat non-recycled plastics). Non-recycling markets for non-polyethylene films include depolymerization, pyrolysis, gasification, and engineered fuel production. Regarding infrastructure, RSE does not believe that there are any plastics depolymerization or pyrolysis facilities operating at commercial scale³² for post-consumer plastics in the U.S. at the current time under current energy pricing conditions. RSE is aware of one gasification facility for non-recycled paper and plastics (it is a private facility that is not known to accept outside tons). Alternatively, RSE believes that there are approximately 25 cement and lime kilns in the U.S. that have equipment that enables them to combust non-recycled plastics and other alternative fuels; however, at the present time, RSE believes that less than ten are likely accepting and combusting non-recycled film plastics, mostly sourced from ICI generators. Such few markets present a financial obstacle to most MRFs, as discussed in the following paragraph.

The financial obstacle arises from the fact that non-recycling markets typically offer no value for non-recycled plastics sourced from MRFs. While no value is better than paying a landfill disposal fee, lack of value doesn't offset MRF sorting costs and offers no incentive to collect and process these other materials. Furthermore, there is not much ability for markets to offer much value for non-recycled plastics because the value of fossil energy sources caps its value. If the value of coal, which is the primary cement industry fuel source, is assumed to be \$60 per ton (note that current average pricing is less than this), the value of plastics processed into fuel would have a value of approximately 4.5 cents per pound (after adjusting for relative BTU content). This value needs to also internalize the cost of freight from MRF to fuel preparation site and the cost of fuel preparation, which includes shredding and blending, leaving no value or at most a penny or two per pound that fuel processors could offer once energy prices increase over current summer of 2016 levels.

In order for energy markets to be an option to help support options for non-PE plastics, more geographically dispersed markets are needed (to reduce the average freight cost). It would be appropriate for the investment community to support the development of additional engineered fuel processors through capital loans, particularly those who supply cement kilns and other such fuel customers, for the non-recycled fraction. The alternative is for communities that are willing to add all films to their collection programs to finance the costs of collection and MRF processing to produce a no/low value commodity grade from the non-recycled residue. The financial impact of this on MRFs and collection programs can also be minimized by reducing the generation quantity of non-recycled film packaging through design for recycling initiatives such as are being acted on by APR, U.K. REFLEX, and private companies such as Dow.

³² RSE defines commercial scale to be at least 5,000 tons per year capacity with plant operations of at least one shift per day and at least 250 operating days per year.

- 12) **Mandatory commercial recycling programs (ICI single-stream).** Root causes that result in this obstacle are financial and operational obstacles. In areas where state or local government policy requires ICI recycling, waste haulers and recycling service providers need to offer services that can accommodate the variety of compositions of materials and volumes of recyclables generated by businesses of all types. Often this includes a transition to ICI single-stream collection and processing rather than customized recycling solutions for individual businesses. ICI single-stream processing lines may share equipment with residential single-stream MRFs, in which case film sorting problems and diminishment of sorted material value are the same as for residential film. Where there are dedicated processing lines, they tend to be more manual and less mechanized, and focused on paper, OCC, and beverage container sorting. For these reasons film is often not included by service providers in ICI single-stream programs. Operational obstacles have the potential to be overcome through education programs to encourage placing all film in large clear bags (commercial film is for the most part clear, and black trash bags would diminish its value). Financial obstacles can be overcome by maintaining ICI film's value, and the investment community can offer grants and low cost loans for early separation at pre-sort stations (sorting positions and bunkers for film), quality control lines (for sorting into a clear film fraction), and dedicated film balers.

11.4. Roadmap for Progress

The prior section discussed specific areas where the investment community may consider financing to overcome obstacles. However, offering financing at one link in the film recycling value chain (e.g., MRF film sorting equipment) without some party working to overcome obstacles at a different link (e.g., lack of sufficient MRF film markets) may not be effective in solving the obstacles faced by the entire recycling value chain. The lack of one or more links in a chain causes the whole chain to not work. A broader roadmap that includes stakeholder involvement in its development can provide a real and coordinated path forward, including using the “best tool from the toolbox” for each obstacle. A stakeholder involvement process was beyond the scope of RSE’s engagement for this project but should be considered as a next step. There is no guarantee that stakeholders will arrive at consensus for the roadmap, or commit to providing adequate programs and financing to implement it and overcome obstacles. For the time being, this section provides the outline of a potential general roadmap that the Closed Loop Fund and the broader investment community can use to guide investments in the film recycling industry.

Table 10 maps where various stakeholders can become involved in overcoming the obstacles identified in this report. Ideally, stakeholder discussions will occur and agreement will be obtained on which entity will establish programs, agree to funding levels, and make funding commitments. As a caveat, further opportunity-specific analysis may be needed to ensure that investment community financing will serve as a sufficient catalyst to overcome the obstacle as intended (e.g., below market loans may not provide sufficient financial savings or be appropriate for the stage a company is in). In addition, as discussed above, a multi-faceted strategy may be needed to work on overcoming other obstacles that will need to be addressed simultaneously within a recycling value chain.

Table 10 – Summary of Film Obstacles with Mapping of Potential Stakeholder Participation

Value chain link	Obstacles	Value chains				Potential Stakeholder Participation									
		Residential Retail Return PE	Residential Curbside PE	Residential Curbside Non-PE	ICI	Investment Loans	Private grants	Trade Association Programs	Value Chain Feedback	Retailers	Corporate R&D	Venture Capital	Brands/packaging Manufacturers	Government policy	Government grants
Collection	Difficulties for generators in identifying flexible packaging accepted in recycling programs (labeling)	X	X						X				X	X	
	Consumer lack of awareness of film wrap acceptance (confusion)	X						X		X		X			
	Inconsistent bins, bin placement, and signage	X				X	X	X		X				X	
	Lack of a recycling habit	X						X					X		
	Few retail return sites accept PE wraps for recycling	X						X		X		X		X	
	Few programs accept non-PE film for recycling	X	X	X	X			X		X				X	
	Store employee lack of program understanding							X	X	X					
	Contamination occurs from collection process							X	X						
	Film has low and in some cases no value		X					X							
	Very few MRFs accept film of this type		X	X	X	See below MRF obstacles									
	Low generation volumes of film at most individual generators				X			X	X				X	X	
	Lack of data on which generators recycle film and which do not				X			X					X		
	Commercial recyclers not interested in handling film				X			X	X				X	X	
	Training and motivating employees				X			X	X	X					
	Mandatory commercial recycling programs (ICI single-stream)				X	X			X				X		
MRF/Sorting	MRFs have not been designed to sort film		X	X	X	X	X						X	X	
	MRF equipment adapted for film sorting does not yet achieve industry effectiveness standards		X	X			X			X	X			X	
	Manual sorting of film is very costly		X	X	X	X		X		X				X	
	Lack of reclamation markets		X	X		See below reclamation obstacles									
	Low market value/demand for non-recycled flexible packaging			X		X		X			X	X	X	X	
Reclamation and end use	Cost of washing		X	X		X					X			X	
	Lack of reclamation markets		X	X		X					X		X	X	
	Low cost alternative virgin and recycled resins	X	X	X	X	X						X	X	X	
	Low end-user demand for film-to-film recycling		X	X		X	X				X	X	X	X	
	No automated film sorting by resin/type in NA		X	X		X	X							X	
	Incompatibility of dissimilar resins			X		X	X				X	X	X	X	

Based on the prior analysis, RSE recommends believes that private investment would be most effective if prioritized in the following areas, which are generally arranged in the order of what we feel would be most effective, with brief discussions of justification and dependencies on addressing other obstacles often by other entities:

- New wash plants for curbside polyethylene film.
 - Justification – U.S. MRFs receive approximately 300 million pounds per year of PE film (the vast majority unsolicited). Only approximately 10 million pounds is marketed to domestic and export markets – the remainder is disposed. The greatest obstacle to recycling this film, which already is collected and already is manually separated at MRFs to remove it from other MRF commodities, is quite simply the lack of markets to sell it to (i.e., those with wash capacity). New wash plants would reduce transportation distances, and freight costs, and provide additional market capacity. If the existing PE film collected were to be recycled rather than disposed, up to nearly 300 million pounds of additional residential film would be recycled, tripling the current amount of residential film recycled.
 - Dependencies – New plants, in order to succeed financially, should be scaled larger than existing film wash plants. Either higher virgin polyethylene resin prices (leading to higher recycled resin prices) or a combination of grants and loans to reduce the capital cost burden are needed to provide a business case for investment in curbside film wash capacity. Furthermore, the increase in recycled resin on the market may also require more end use markets to be developed in concert with expanded wash capacity.
- Equipment that increases the scale and efficiency of existing wash plants for curbside polyethylene film, including overall capacity expansions, equipment and silos that enable bulk shipment of reclaimed resin (applies to merchant reclaimers), blending and compounding equipment, and high efficiency dryers.
 - Justification – Recycling curbside film is not highly profitable for existing reclaimers who wash film. Improving their profit by helping them operate more cost-effectively, and enabling them to add value and expand market demand through compounding, may make expansion of curbside film processing of interest to these existing reclaimers.
 - Dependencies – Loans may not provide sufficient financial incentive for plant expansion – a combination of grants and loans to reduce the capital cost burden may be needed to provide a business case for investment in curbside film wash capacity. Furthermore, the increase in recycled resin on the market may also require more end use markets to be developed in concert with expanded wash capacity.
- Solid state shear pulverization equipment at reclaimers of curbside PE film.³³
 - Justification – APR model bale specifications limit non-PE films (PP film, multi-layer pouches) to less than 2 percent of incoming material. This is a difficult specification for MRFs to make, and much MRF film that is recycled rather than disposed is sold at downgrade prices. Solid state shear pulverization equipment would enable a reclaimer to sell a low-price recycled resin from PE recycling line rejects rather than dispose of it or send it to energy recovery.
 - Dependencies – This equipment only makes sense for film reclaimers who are interested in accepting for a discount contaminated MRF PE film that does not meet APR model bale specifications. The higher level of rejects would likely mean that this equipment should be paired with an optical sorter to minimize reclaimer sort labor cost. Ideally, the reclaimer

³³ The Zzyzx technology is very promising for a plastics reclaimer to use for recycling multilayer films it otherwise would discard or send to energy, or for an integrated reclaimer that manufactures forgiving plastic products (this would allow it to acquire mixed MRF film for a very low cost compared to purchasing prime MRF grades of sorted plastics).

would also be interested in examining market solutions for the PP fraction of films received as described above. This equipment also only makes sense at film reclaimers who would recycle at least twice the amount of PE curbside film that they currently have the capacity to reclaim.

- PP film recycled product development, including blending and compounding equipment (merchant reclaimers) or integrated product manufacturing.
 - Justification – Although industrial woven PP slit film products are currently recycled (e.g., industrial bulk sacks), residential PP films are not. PP film composes over 20 percent of all film generated, and RSE estimates that approximately 70 percent of it is generated in the residential sector. Most residential PP film is a multilayer package with an inner PE layer, and because it is used primarily for food contact applications, would need to be washed to be recycled, or go to thick gauge non-aesthetic part manufacturing.
 - Dependencies – Collecting and recycling PP residential film faces significant challenges, but it is the next logical step past PE-only film recycling. Food contamination provides an obstacle to retail return collection, which means collection would likely have to be through the curbside system. Residential curbside collection programs would not only collect PP film, they would need to collect all film types since the consumer cannot distinguish PP film from PE and multilayer pouches. MRFs are not able to sort mixed films by resin type, so a film reclaimer that has wash equipment and is willing to take and sort mixed films (preferably using optical sorters) would need to be established. Such a reclaimer would need a nearby energy market (or the ability for producing recycled solid state shear pulverization resin) for the non-recycled multilayer pouch portion it receives. In order for the reclaimer to have value-added outlets for ~75 percent of what it would receive (by reclaiming the PP), versus only ~55 percent of what it receives (by only washing PE, markets/recycled products for reclaimed PP would need to be developed. Testing should investigate whether it is better to co-recycle the PP film with PE film through dilution and the use of compatibilizers, or to sort out the PP film and blend it with other sources of recycled PP to dilute the PE layers. Unfortunately, recycled product development is best accomplished through grants and not loans. The groundwork for an eventual recycling chain needs to begin with end-product research and development before committing to investments in dedicated wash lines, residential collection programs, and sorting equipment at other levels in the recycling supply chain.
- End user silo, blending, and extrusion equipment to begin using film in currently virgin resin products.
 - Justification – Film product manufacturers who currently only make virgin/pre-consumer recycled plastic trash bags, and potentially in the near future, film retail carryout sacks, are prohibited from selling their products in California. These firms also may desire to broaden their sales offerings by producing green products lines in addition to their standard non-postconsumer products. These virgin product manufacturers, however, require additions of capital to do so. Increased end product demand for recycled PE film resin will trickle down the recycled film supply chain, with a focus on film recycled from ICI generators, which would not require washing.
 - Dependencies – Equipment loans alone may not be sufficient to provide the end use demand-pull to increase ICI PE film collection for recycling. Grants for technical and engineering assistance for process design changes (e.g., to change from mono-layer blown film production to three-layer co-extruded blown film production with the post-consumer recyclate in the inner layer) will also likely be required. Traditional sources of corporate financing are already available to these companies – CLF loans at below market rates may not fundamentally change the business case for them, and equipment grants may need to be offered in combination with loans to provide a sufficient financial driver for them to commit to using recycled PE. Even with additional demand, there are obstacles with

identifying additional sources/generators of ICI film and collecting/processing that film in a cost-effective manner that will require action by private film recyclers and groups such as FFRG to overcome.

- MRF film sorting and baling equipment.
 - Justification – MRFs will not agree to add film to curbside recycling programs if communities are not willing to increase their contracted compensation for the significant additional cost of handling film curbside, or unless their ongoing labor cost is reduced through grants of equipment to replace people. An initial demonstration MRF, probably funded primarily through grants, could help to objectively answer the question of cost-benefits of equipment. Once the benefit is proven, more widespread loans for retrofits (e.g., for ballistic separators, air separation, and fiber line optical sorters) may be justified.
 - Dependencies – The cost-benefit of MRF film sorting equipment is not yet established. Even if equipment improvements and reduced costs can be demonstrated (to overcome institutional obstacles), current market capacity is inadequate, and would need to be expanded in parallel with MRF equipment grants and loans.
- Equipment to expand the number of market outlets for non-recycled film, primarily for fuel preparation for cement kilns.
 - Justification – If film recycling programs are to progress past PE film, markets will be needed for non-recycled film to remove cost obstacles by avoiding disposal cost. Commercial pyrolysis, gasification, and depolymerization facilities are lacking or are in developmental phases. Cement kilns, alternatively, are well-distributed across the U.S. and are accustomed to using alternative fuel energy sources. A number already have the necessary governmental approvals to accept non-recycled plastics, though few currently do so. These kilns need assistance in identifying sources of supply, and equipment to process MRF residue into a form that the cement kilns can use, and/or feeding systems to feed the processed material into the kiln.
 - Dependencies – Fuel markets may be considered a bridging technology until recycling markets for PP are developed, or until solid state shear extrusion becomes available. Communities that are receptive to energy recovery over landfilling of non-recycled materials are a necessary part of collecting a broader set of materials curbside. Design for recycling changes to multilayer films are also needed to reduce the financial obstacle imposed by non-recycled films that need alternative solutions. The technology and cost of sorting films and other non-recycled paper and plastics from MRFs must also be addressed in concert with developing nearby local energy markets.

In addition to the focus areas listed above, grants are needed in the following areas:

- Development of MRF film separation/sorting equipment by MRF equipment companies and developmental technology companies.
- Research, development, and testing of multilayer pouches that are compatible with PE and PP film recycling systems.
- Research and development by film reclamation equipment companies for high efficiency dryers.
- Funding a demonstration single-stream MRF open for tours that is designed for mixed film separation.
- Research and development grants to develop new technologies to separate PET and nylon layers from multilayer pouches.
- Grocery store collection bin grants, possibly in partnership with FFRG's WRAP initiative.³⁴

³⁴ This recommendation can be considered lower priority because of the existing investments into this program and individual investments by retailers in collection containers for their own establishments.

11.5. Key Conclusions and Recommendations:

- There are a number of different organizations with initiatives underway attempting to improve film recycling, in some cases duplicating each other's efforts, whereas in other cases no one is addressing other obstacles. Furthermore, working to address one obstacle at one link in the film recycling value chain without some party working to overcome obstacles at a different link may prove ineffective. The lack of one or more links in a chain causes the whole chain to not work. It would be beneficial for stakeholders to meet and arrive at consensus for a coordinated way forward for film recycling, including roles and responsibilities and funding commitments.
- A film recycling loan fund can address some film recycling obstacles. Other obstacles would need grants or venture capital investments to overcome them. Examples include research and development to create new recycling technologies that do not exist today, or to demonstrate new technologies. State governments can also play a role in recycling market development and policies that support recycling collection of film.
- More than half of PE film collected in the U.S. for recycling is exported. The overwhelming majority of exported film goes to China with only small amounts going to other countries. Demand from China for recovered film has begun to decline and this is expected to be a long-term trend. Although some Southeast Asian nations are developing the capacity to reclaim film, they will not likely be able to replace the former capacity or the end-use demand that used to be in China for recovered plastics from the United States. Thus it is essential that the U.S. expand its infrastructure to sort, reclaim, and manufacturing products using recycled plastic PE film.
- Reclaimers and markets for PP film and Other film are virtually non-existent. The large combined total of PP-based film and Other film, together at 44 percent, makes it cost-prohibitive for film recycling programs to comprehensively collect "all film" and sort and dispose of nearly half of what would be collected. There is a need to develop a recycling infrastructure and recycling markets for at least the PP-based film portion, and potentially the Other film portion, in order for comprehensive film recycling to occur.
- It is important for film manufacturers to design film products and packages for recycling so that the economics of comprehensive film collection and recycling programs can improve. This includes designing products that are compatible with the PE recycling stream.
- There are a number of areas where investments by the investment community including the Closed Loop Fund and Foundation can help to improve film recycling in the U.S. These areas include expanding reclamation capacity and recycled content product manufacturing.

Appendices

Appendix A

This appendix includes a list of those U.S. and Canadian polyethylene film recyclers who routinely purchase U.S. post-consumer polyethylene film from ICI or residential generators. The list excludes companies whose focus is on recycling dirty agricultural films and those that primarily recycle pre-consumer film manufacturing scrap. These companies include:

AERT, Inc.
Berry Plastics Corporation
Cycle Tex
EFS-Plastics Inc.
Encore Recycling
Fiberon
FreshPak Corp.
Greenland Composites
Greenpath Recovery
Inteplast Bags and Films Corporation
Mondo Polymer Technologies
Nexcycle Plastics Inc.
Novolex
Petoskey Plastics
Ply Gem
Poly-America
Prime Plastic Products, Inc.
Trex Company, Inc.
Verdeco
Wisconsin Film & Bag