



Reclay StewardEdge
Product Stewardship Solutions





with



Analysis of Flexible Film Plastics Packaging Diversion Systems

Canadian Plastics Industry Association
Continuous Improvement Fund
Stewardship Ontario

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The purpose of this report is to provide a discussion of the current spectrum of flexible film packaging in Ontario and future trends to identify necessary approaches and actions to successfully manage all types of films at each stage of the diversion value chain.

Analysis of Flexible Film Plastics Packaging Diversion Systems

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Executive Summary

The purpose of this report is to explore and impartially report on the current flexible plastic film packaging trends and some of the opportunities, costs, and challenges associated with the diversion of all flexible films generated in the residential waste stream in Ontario. To this end, the Canadian Plastics Industry Association (CPIA), Continuous Improvement Fund, and Stewardship Ontario jointly sponsored this project. As well, this team had the volunteer support of the Pac Next organization that assisted with the project by providing advice and liaison coordination from its industry membership. This report was produced by a project team composed led by Reclay StewardEdge, with support from Resource Recovery Systems and Moore Recycling Associates, Inc.

According to Stewardship Ontario data, residential flexible film packaging makes up 6.2 percent of the mass of printed paper and packaging that is generated and subject to product stewardship in the Province.¹ Currently however, only six percent of residential film packaging is recycled.² Film plastic is not monolithic and comes in a number of varieties, including high and low density polyethylene film, biodegradable film, film made from other resins, and multi-laminate film that is composed of layers of different types of films. This complexity of films used in packaging, incompatibility of different plastics with each other, and differences in recyclability of and market demand for the different types of films all present challenges to increased recycling of film plastics.

This study researched film types and generation quantities, recycling market demand, and sorting technologies to help in identifying feasible approaches to increase the recycling and diversion of film from disposal. Based on this research, system approaches were identified and recovery models constructed to arrive at cost and recovery estimates for the different approaches. The approaches that were modeled in this study include residential curbside recycling collection, consumer drop-off at municipal and commercial return centers with on-site baling, and consumer drop-off at commercial return centers with the ability to take advantage of no-cost back-haul of loose film to a central baling facility.³ The approaches also considered producing two general market types of film – polyethylene (PE) film and all other non-polyethylene film. The cost estimates in this report are based on cost models that use certain key inputs including Ontario wage rates, and for curbside collection of film, the relative

¹ Based on quantities generated in 2011 as listed in Stewardship Ontario's "2013 Fee Calculation Tables" (2013_PIM_final_1_0.xls, <http://67.225.236.40/download/bb-fee-calculation-model-2013/>). This document also provides a fully allocated cost of recycling film in Ontario through the existing mix of municipal curbside and depot programs of \$8.9 million in 2011 with 4,742 tonnes recovered, or \$1,878 per tonne (commercial return center cost and recovery volumes are not included). It is important to note that these cost figures include an allocation of common collection, processing, capital, administrative, and promotion and education expenses to film, whereas the cost estimates in this report do not include these allocated costs.

² Reclay StewardEdge estimate derived from film recycling data from Stewardship Ontario for municipally-operated recycling programs and information reported by the Ontario Plastic Bag Reduction Task Group on the amount of retail bags returned to retail establishments for recycling.

³ This study considers return centers – both municipal and commercial – to be locations where consumers can deposit film into collection containers that are protected from the elements (i.e., dirt/moisture) and separate from other recyclables, and which are emptied by hand. Return centers can be located in municipal buildings, return sites for deposit containers (or other recyclables), retail locations, or a combination of such venues.

mix of two stream and single-stream materials recovery facilities in Ontario, to estimate costs. The extent to which other locations have labour cost or recovery infrastructure differences that differ from Ontario will limit the ability to use the per tonne cost figures in this report elsewhere, since they were developed specifically for the Ontario situation. As well, the quality of collected non-polyethylene film is a factor that could not be assessed given there are no practical diversion examples of this material stream in North American residential recycling programs.

There are a number of summary findings from the research conducted for this report including:

Film Collection and Sorting

- The project team did not find any technologies that would be expected to be commercially available now or in the near future that would have the ability to cost-effectively sort polyethylene film from non-polyethylene/multi-laminate films, or to sort non-polyethylene/multi-laminate films into different resin streams in materials recovery facilities or at re-processors;
- To promote greater recycling of flexible film, it is currently better to collect polyethylene film separately from non-polyethylene/multi-laminate films;
- It is not currently feasible to manually sort mixed residential non-polyethylene/multi-laminate films into different streams for recycling, as evidenced by the lack of even low labour cost export markets for such mixed films; however, those materials may be suitable for recovery markets in Canada or the United States that will convert them into energy or chemicals subject to the market specifications;
- Only one stream of film – polyethylene film or non-polyethylene/multi-laminate film – may be collected curbside if film is to be recycled at a moderate cost (recycling costs would be much higher than shown in this report if all types of film were collected mixed curbside);
- Polyethylene and non-polyethylene/multi-laminate film may both be collected through return centers; however, they must be collected and baled separately from each other since polyethylene film goes to recycling markets and non-polyethylene/multi-laminate film could go to a recovery market;
- Collecting film through commercial return centers that have free back-haul of loose film to central baling locations is the lowest-cost way to produce high-end market ready material at \$75 per tonne for polyethylene, and \$390 per tonne for non-polyethylene film;
- If free back-haul of loose film is not available, collecting and processing film through return centers where there is a cost associated with hauling away the film is more costly than curbside collection on average that is operated under best practices; however, the high market value of polyethylene film collected through return centers results in a lower net cost of recovery of \$225 per tonne for polyethylene film – the same is not the case for non-polyethylene film whose net cost is \$540 per tonne, and there is no financial advantage to collecting non-polyethylene film through return centers;
- Curbside recycling of moderate levels of film in Ontario using best practices is estimated to have a net cost of \$357 per tonne for polyethylene film and \$442 per tonne for non-polyethylene film; if higher recycling rates are desired, additional ongoing program promotion may be required, which can increase net costs to \$440 and \$505 per tonne respectively;
- The cost to manually sort film assumes best practices are utilized – specifically informing program participants are to place all their polyethylene film in bags and assuming they actually do so (failure to achieve a best-practice situation can result in curbside costs that are double that presented in this study); and

- Return center collection can approach the recovery of a moderate curbside collection program; however, it will not achieve the recovery rate potential of a high performing curbside program.

Film End Markets

- There is sufficient recycling market capacity to accept large increases in clean polyethylene film collection in Ontario;
- There is sufficient recovery market capacity to accept large increases in non-polyethylene/multi-laminate film collection in Ontario noting that each end user can have different material specifications;
- The recycling capacity in Ontario for curbside-collected film is growing and projected to increase by 7,500 tonnes by the fall of 2013;⁴ and
- With North American Curbside Film collection exceeding 18,000 tonnes and the shrinking export market for Curbside Film, there is a need for North American markets for such material to continue to develop and expand – an additional investment in film wash lines would be required, ranging from \$4 to \$8 million, depending on the additional quantity of film to be collected.

Design for Recycling

- From a general lifecycle assessment perspective flexible film packaging is a highly-efficient form of packaging – even when it is not able to be recycled, it typically results in less global warming potential, energy use, and quantity landfilled than recyclable rigid package alternatives; and
- There may be some limited opportunities to reduce the use of PVC/PVDC in certain packaging and redesign other multi-laminate packaging to be recyclable within the polyethylene film stream (e.g., frozen vegetables) based on discussions with a limited number of packaging companies, and a broader discussion with stakeholders to confirm these opportunities is recommended; however, these package types are a small percentage of the film packaging that presents challenges and these design changes will not change the conclusions of this report.

⁴ Source: Stewardship Ontario.

Comparative Evaluation

Table 1 provides a comparative evaluation of recovery models based on evaluation factors that the project sponsors considered most important for this study.

Table 1 Comparative Evaluation

Evaluation Factor	Curbside (moderate)	Curbside (high)	Return Center (on-site baling)	Return Center (no-cost hauling)
Market Considerations				
• Meets market quality specifications <ul style="list-style-type: none">○ Recycling○ Recovery	<ul style="list-style-type: none">○ Poor○ Acceptable		<ul style="list-style-type: none">○ Excellent○ Excellent	
• Current capacity in Ontario/Canada/ North America (tonnes/year) <ul style="list-style-type: none">○ Recycling○ Recovery	<ul style="list-style-type: none">○ ~5,000 (all N. America)○ ←-----150,000/150,000/1,500,000-----→ (recovery capacity is for pyrolysis, engineered fuel, and industrial uses – capacity of mixed waste gasification/EFW is in addition to these figures)		<ul style="list-style-type: none">○ ←----250,000 (all N. America) ----→	
• Market maturity/stability <ul style="list-style-type: none">○ Recycling○ Recovery	<ul style="list-style-type: none">○ Immature—few North American markets○ Growing—only a couple Ontario markets, but more extensive in U.S.		<ul style="list-style-type: none">○ Excellent	
Recovery projections				
• Recycling (polyethylene) amount and rate	10,084 tonnes ¹ (11%)	15,126 tonnes ² (17%)	10,084 tonnes ¹ (11%)	10,084 tonnes ¹ (11%)
• Recovery (non-polyethylene) amount and rate	10,084 tonnes ¹ (11%)	15,126 tonnes ² (17%)	10,084 tonnes ¹ (11%)	10,084 tonnes ¹ (11%)
• Combined potential recycling and recovery amount and rate	Not applicable ³	Not applicable ³	20,168 tonnes (23%)	20,168 tonnes (23%)
Cost Considerations				
• Annual net cost <ul style="list-style-type: none">○ Recycling of polyethylene film○ Recovery of non-polyethylene film	<ul style="list-style-type: none">○ \$3.6 million^{4,5}○ \$4.3 million^{5,9}	<ul style="list-style-type: none">○ \$6.7million^{4,5,6}○ \$7.6 million^{5,6,9}	<ul style="list-style-type: none">○ \$2.3 million^{7,8}○ \$5.4 million^{7,9}	<ul style="list-style-type: none">○ \$0.8 million^{7,8}○ \$3.9 million^{7,9}
• Other investments required <ul style="list-style-type: none">○ First year promotion/education○ Recycling market development (PE)○ Recovery market development (non-PE)	<ul style="list-style-type: none">○ None○ \$4 million¹¹○ None	<ul style="list-style-type: none">○ \$10.1 million¹⁰○ \$8 million¹²○ None	<ul style="list-style-type: none">○ None○ None○ None	<ul style="list-style-type: none">○ None○ None○ None
Impact on Existing Approaches				
• Consistency with existing approaches	Consistent with many Ontario programs		Convenient municipal return centers may be lacking in areas with curbside collection	Commercial return centers at select retail grocers currently only accept PE carryout sacks
• Single-stream versus dual-stream considerations	Potentially more costly in single-stream systems; some potential to partially use separation equipment and reduce costs in dual-stream MRFs		Not applicable	Not applicable

¹Assumes collection of 2 kilograms of film per household per year.

²Assumes an increased recovery level of 3 kilograms per household per year based on an ongoing enhanced education and awareness program.

³Assumes opaque carryout sacks are reused as bags for curbside film collection. Because sorters in a MRF will not be able to distinguish between a carryout sack of PE film and a carryout sack of non-PE film, only one material stream or the other, but not both, can be collected curbside.

⁴Net revenue of \$25 per tonne.

⁵Includes a combination of sorting costs and equipment capital and operating costs. Manual sorting costs are estimated at \$500 per tonne, which assumes that the vast majority of film received at MRFs is in bags. In two stream MRFs, air separation equipment is assumed to be used for film separation from rigid containers, at a cost of \$180 per tonne. The weighted average for Ontario is assumed to be 60 percent manually separated and 40 percent air separated film, for a weighted average separation cost of \$372 per tonne. Cost of capital upgrades needed to separate film that is collected curbside includes the addition of vacuum conveying systems in MRFs that handle over 10,000 tonnes per year of recyclables, and air separators in two stream MRFs. Total province-wide capital cost is estimated at \$5.5 million, financed over ten years at a 4 percent interest rate, which results in an annualized cost of \$0.7 million. This cost has been estimated based on a general understand of technology employed in Ontario MRFs – a detailed MRF-by-MRF assessment based on individual facility needs and costs may result in a different estimate of cost.

⁶Includes ongoing communications expense of \$0.25 per household per year to encourage high levels of film recycling and reinforce film set-out best practices by consumers (\$130 per tonne), in addition to a minor incremental base collection cost of \$10 per tonne (based on information from a film recycling pilot program in Langley, British Columbia).

⁷Includes an estimate of the cost of small-footprint downstroke balers needed to handle film at return centers, where each return center recovers on average 8.5 tonnes of PE film per year, which would mean there are nearly 1,200 return centers in Ontario under this scenario. Capital cost is estimated at \$10,000 per baler, or \$11.9 million, financed over ten years at a 4 percent interest rate, which results in an annualized cost of \$1.5 million. This cost would be doubled if both PE and non-PE film are accepted at return sites, because the two types of film need to be kept and baled separately from each other.

⁸Net materials revenue of \$275 per tonne for clean return center polyethylene film.

⁹Net cost of -\$40 per tonne to send to a recovery facility.

¹⁰Assumes a province-wide promotion and education campaign with a cost of \$2.00 per household to institutionalize the use of film best practices and promote the use of retail carryout sacks as collection bags (including the messages to place film in bags and tie the bags tightly to avoid spillage).

¹⁰Estimate of market development grant funding that may be needed to approximately double the reclamation capacity for curbside-collected film in Ontario (approximate cost estimate based on CIF/Stewardship Ontario funding expended for plastics market development in 2010/2011).

¹²Estimate of market development grant funding that may be needed to approximately triple the reclamation capacity for curbside-collected film in Ontario (approximate cost estimate based on CIF/Stewardship Ontario funding expended for plastics market development in 2010/2011).

The operating cost figures shown in Table 1 are additional incremental costs to recover greater quantities of film in Ontario, and are based on certain cost and recovery assumptions. The cost figures also assume that best practices for collecting film in bags are achieved (i.e., failure to collect film in bags can easily double the system costs). The cost figures shown in the table are not allocated system costs and so cannot be used to estimate fee rates or fees that producers of film packaging may be responsible for under provincial product stewardship policies. In summary, there are opportunities to increase the recovery of film packaging in Ontario and across Canada, both for recycling as well as recovery markets. Depending on the desired outcome in terms of recycling rate and willingness to divert film from disposal so that energy and resources can be recovered, different recovery models can be considered.

Next Steps

Next steps that can be considered to support increased flexible film plastics packaging recycling and diversion include:

- Continue investigating/monitoring film sorting technologies to effectively separate film resins from each other and from other recyclables;
- Pilot the collection of non-polyethylene film for recycling and recovery end markets;
- Investigate and promote design for recyclability options for non-polyethylene/multi-laminate film; and
- Foster the development of processing technologies to increase the recycling of all flexible film packaging.

Section 1: Introduction

Historically, the Blue Box curbside recycling system has been the predominant means of recovering recyclables from residents, offering the opportunity to recycle a variety of materials. With the growth in types of packaging and popularity of the Blue Box recycling system, program operators have gradually added more types of consumer packaging while simultaneously moving towards increased commingling of recyclables during collection. Given the changing mix of packaging and collection systems, there is a need to understand, the implications of film packaging trends on system costs, and identify opportunities for improved efficiency in the current curbside systems. To this end, the Canadian Plastics Industry Association (CPIA), Continuous Improvement Fund, and Stewardship Ontario jointly sponsored this project to explore the opportunities and costs of diverting flexible film packaging and the opportunities and challenges this class of plastics provides for material processing facilities and downstream plastic reprocessors to sort and classify the flexible film stream for maximum utilization. As well, this team had the volunteer support of the Pac Next organization that assisted with the project by providing advice and liaison coordination from its industry membership.

Flexible film plastics are a large component of both the consumer-packaging and industrial, commercial, and institutional discard streams. Flexible packaging is composed primarily of polyethylene (PE) based plastics, as well as a variety of other resins and laminated film plastics that can be more complex depending on the packaging application (i.e., can be composed of multiple layers of PE and non-PE elements). Currently, only PE based plastic film packaging is commonly recycled.

In Ontario PE film plastic bags and overwraps have typically been collected from residents through municipal curbside and municipal depot systems. Over the past few years, many large retailer chains have initiated and expanded return-to-retail collection programs for plastic carryout bags. Curbside and return center approaches each have strengths and weaknesses, and participation rates, recovery rates, and costs and revenue vary considerably among them. This study endeavors to objectively compare the various approaches of film diversion and processing to provide information for use in discussions regarding the future of film recycling in Ontario, and potentially more broadly in the rest of Canada.

This report:

- Discusses the amounts of various types of flexible film packaging generated in Ontario, identifies trends, and makes future quantity projections;
- Provides a comprehensive summary of recycling markets for recovered flexible film packaging to understand better what markets are currently available and what film types are currently recyclable by today's market standards and the issues in recycling flexible films at material recovery facilities and at plastics reprocessors;
- Provides a comprehensive summary of recovery markets that films can be directed to for conversion into energy or chemicals;
- Identifies available commercial and pre-commercial technologies for sorting a variety of film grades either at a materials recovery facility (MRF) or at a reprocessing operation; and
- Identifies various collection and processing methodologies, the pros and cons and cost drivers of each, and compares the associated capital and operating costs implications to collect film at curbside and return center sites.

Section 2: Flexible Packaging Generation and Trends

Categorization of Film

Plastic film is defined for the purposes of this report as plastic items with a thickness of less than 10 mils (i.e., 0.010" or 0.25 mm) and includes film and bags that are at least 85 percent (by weight) plastic with up to 15 percent other closely bonded or impregnated material. Film can be categorized into non-packaging and packaging film. Non-packaging film includes products such as garbage bags, trash can liners, freezer bags, and sandwich bags. This study focused on packaging film, further subdivided into the categories defined in Table 2.

Table 2 Definitions of Film Packaging Categories Included in this Report

Handling Fee/ Category	Description
Polyethylene film carryout bags	HDPE, LDPE, and LLDPE retail carry-out bags/sacks
Polyethylene film	Includes all other HDPE, LDPE, and LLDPE dry cleaning bags, bread bags, frozen food bags, milk bags, toilet paper and toweling, over-wrap, lawn seed, soil, peat moss, etc.
Biodegradable film	Film that will break down at significantly faster rates than traditional plastics. Includes film made from polymers synthesized from petrochemical or plant-derived precursors, including polylactic acid (PLA), polyhydroxycyanoates, and packaging resins derived from starch and cellulose. Includes traditional petrochemical resins that have been modified with degradability additives.
Plastic laminates - beverage	Includes flexible multi-layered and laminated plastic pouches and plastic bag-in-box liners for juice, wine and other alcoholic beverages.
Laminated/Other Plastic Film and Bags	Plastic film and bags that are at least 85% (by weight) plastic with up to 15% (by weight) other closely bonded or impregnated materials. This includes meat, poultry and fish wrap; vacuum sealed bacon bag; luncheon meat and cheese wrap; cereal liners; chip bags and other snack food bags; candy wraps; pasta bags; boil in a bag; plastic based food pouches; bubble wrap; cling wrap; some cookie bags, etc. Also includes monolayer films made from resins that don't fit in the other categories (e.g., polypropylene film).

Flexible Packaging Generation, Trends, and Future Growth Estimates

There have been a number of studies released in the past several years that forecast high growth rates for flexible packaging, at least for certain segments of that industry. Following are several examples:

- "Global industry growth [for stand-up pouches is projected] at over 11% per year" from 2012 to 2016;⁵
- "Demand for pouches in the US is projected to increase 5.1 percent per year to \$8.8 billion [US dollars] in 2016;"⁶
- "In unit volume terms demand for the North American region as a whole [for flexible packaging] is forecast at 2.0 – 2.5% per annum over the period [from 2011 to 2015]."⁷

⁵ "Stand-up Pouches 2012 to 2016," Allied Development, May 2012, as cited at http://www.packagingdigest.com/article/522096-Stand_up_pouch_sales_to_reach_4_billion_by_2016.php

⁶ "Pouches," The Freedonia Group, Inc., July 2012, as cited at http://www.packagingdigest.com/article/522197-U_S_demand_for_pouches_to_approach_9_billion_by_2016.php

Care should be taken when reading short claims about film packaging growth to consider whether they accurately characterize the overall film packaging marketplace in Canada. The first two bullets above illustrate the difference in package growth rates that market maturity makes for one specific flexible package format – stand-up pouches. While very high packaging growth is currently occurring in emerging markets in Asia, translating into a high global growth rate, the same is not the case in mature packaging markets like that of Canada, the United States, and Europe. Similarly, care should be taken not to presume that forecasted growth rates for certain small but growing package formats, like that of pouches, characterizes the growth rate for the entire film packaging market as a whole. This is illustrated in the third example where overall film packaging growth in North America (including Canada, Mexico, and the U.S.) is forecasted at much lower rates.

There are different growth rates for different package materials, formats, and contained products. For example, stand-up pouches are believed to represent a low percentage of the tonnage of flexible packaging in Ontario – even if this one package type has a high growth rate, it does not result in a high overall growth rate for all film packaging in the province. Furthermore, growth in some film packaging applications may result in a decline in other film categories. For example, if a brand-owner converts its packaging for raisins from a bag-in-box format, where a PE film bag is used inside of a paperboard box, to a stand-up pouch format, the growth in stand-up pouch tonnage is partially offset by a decline in the use of PE film for the bag-in-box format.

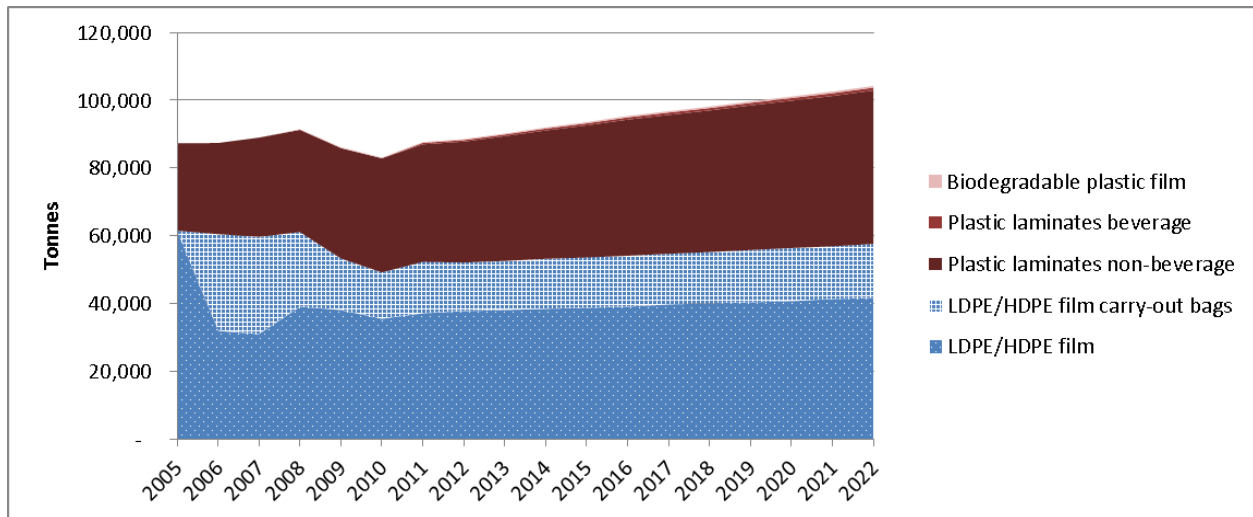
The project team conducted interviews with six leading companies that produce film packaging for the Canadian marketplace to better understand film plastics trends that are applicable in Canada. These interviews were informative and revealed the following:

- Film packing producers have been able to reduce the amount of film used to package products due to improvements in package production technology. In some cases they have substituted a stronger material such as polypropylene for polyethylene, allowing less plastic to be used through down-gauging while maintaining the same mechanical performance properties.
- Interest in biodegradable materials has moderated as many brand owners have concluded that biodegradable materials have recycling challenges and do not necessarily have a superior environmental profile compared traditional resins; however, consumers still generally believe that biodegradable materials are better for the environment than non-biodegradable materials.
- Brand owners have invested hundreds of millions of dollars in capital for North American package filling lines. Replacing these lines with new lines designed for flexible film packaging will occur slowly over time as the conversion is costly.
- The trend to replace rigid package formats with flexible multi-laminate package formats continues due to the superior performance and material reduction that can be achieved – most of the growth is for this type of packaging rather than single-resin films.

Figure 1 presents estimates for residential packaging film generated in Ontario in the past with projections for the future. Numerical estimates used to create Figure 1 and descriptions of growth assumptions for the estimates are contained in Appendix A.

⁷ “The North American Flexible Packaging Market to 2015,” PCI Films Consulting Ltd., December 2011 (summarized in mailer downloaded from <http://www.pcifilms.com/docs/N%20America%202011%20Mailer.pdf>).

Figure 1 Ontario Residential Packaging Film Historical Quantities and Future Growth Projections



Source: Reclay StewardEdge based on data and information from multiple sources.

According to data from the U.S. Environmental Protection Agency, plastic bags, sacks, and wraps as a percentage of U.S. municipal solid waste doubled from 1980 to 2000, and then leveled off. The same is believed to be true in Ontario through 2005. Since the time Stewardship Ontario began gathering data on Ontario residential film packaging generation, per capita consumption of film packaging has steadily declined from 4.92 kilograms per person in 2005⁸ to 3.89 kilograms per person in 2011.

Although Figure 1 seems to indicate a significant change in film carryout bags from 2005 to 2006, Reclay StewardEdge did not have information on which to base a separate 2005 film bag generation estimate, and so their generation quantity is included in the general LDPE/HDPE film category for that year. Much, but not all, of the decline in per capita film packaging usage in Ontario can be attributable to a reduction by half of the number of carry-out plastic bags distributed over the period from 2006 to 2010. This was the result of an initiative by the Ontario Plastic Bag Reduction Task Group, made up of the Canadian Council of Grocery Distributors (CCGD), the Canadian Federation of Independent Grocers (CFIG), the Canadian Plastics Industry Association (CPIA), the Recycling Council of Ontario (RCO), and Retail Council of Canada (RCC) in response to an Ontario government requirement that industry voluntarily reduce by half the number of carry-out bags distributed in Ontario by 2012. The reduction appears to have leveled off and for future forecasting this study assumed a constant per capita consumption of film bags.

Biodegradable film and multi-laminate beverage are nearly undetectable in Figure 1 because they are such a small portion of film packaging generated in the Ontario residential discard stream; even if they have higher than average growth rate than general flexible film packaging into the future, we do not expect them to become a significant component of packaging film generation in the next ten years. Multi-laminate film packaging (non-beverage) will continue to grow at a greater rate than PE films, but PE films will remain the dominant packaging material.

⁸ Primary sources for historical overall residential packaging film quantity estimates are fee-setting spreadsheet models that are publicly available from Stewardship Ontario's internet website. Although two additional years of initial data collection (2003 and 2004) are available, they are not considered reliable by the project team since they vary significantly from data for following years. Therefore, they have not been used in this study.

Section 3: Market Demand and Capacity

Overview of Existing Film Recycling

Table 3 shows estimates of the amount of Ontario residential film plastics that are collected for recycling and estimated recycling rates for each category of film. The table also shows combined estimates for Canada and the United States, including industrial, commercial, and institutional film plastics quantities.

Table 3 2011 Film Recycling in Ontario and North America

Film Type	Ontario Residential			North America (Residential & ICI)		
	Recycling (tonnes)	Generation (tonnes) ³	Recycling Rate	Recycling (tonnes) ⁴	Generation (tonnes) ⁵	Recycling Rate
Polyethylene carryout bags (recycle +reuse estimate)	2,400 ¹ (10,000) ²	14,900	16% (67%)	63,000	630,000	10%
Polyethylene film	2,800	37,400	7%	475,000	Unavailable	Unknown
Biodegradable film	negligible	250	0%	negligible	Unavailable	Unknown
Plastic laminates - beverage	negligible	440	0%	negligible	Unavailable	Unknown
Laminated/other film & bags	negligible	34,700	0%	negligible	Unavailable	Unknown

¹ Includes estimates of film carryout bags that are collected through return-to-retail programs and municipal programs as reported by the Ontario Plastic Bag Reduction Task Group and Stewardship Ontario.

² Includes bags collected for recycling plus bags not available for recycling because they are reused for trash can liners and other reuse applications (based on Stewardship Ontario waste audit data).

³ Reclay StewardEdge estimates derived from Stewardship Ontario data for polyethylene film and plastic laminates categories.

⁴ Reclay StewardEdge estimates derived from 2010 U.S. and 2011 Canadian film recycling data compiled by Moore Recycling Associates.

⁵ Based on 2011 U.S. resin use as reported in "2012 Resin Review," American Chemistry Council, increased by ten percent to provide an estimate for combined U.S. and Canadian consumption.

Table 3 appears to show a low recycling rate for PE carryout bags in Ontario if only the quantity of bags recycled is compared to generation quantities. In reality, some two-thirds of bags that are generated are estimated to be either recycled or reused for trash can liners, pet cleanup, or other uses, with only approximately one-third of carryout bags disposed as waste and available for additional recycling.⁹ If all remaining carryout bags that are disposed as waste in Ontario were collected for recycling, up to 5,000 additional tonnes would be recycled. The table also shows that there is much room for improvement for recycling greater quantities of other PE film packaging, and for potentially recovering other film types. The following subsections discuss recycling markets for film plastics and recovery markets,¹⁰ with a focus on Ontario markets first, and then more broadly on the Canadian and U.S. marketplace.

⁹ Estimates are based on a combination of Ontario Plastic Bag Reduction Task Group reports and Stewardship Ontario waste audit data.

¹⁰ Recovery markets are those where the plastic material is converted to chemicals or energy.

Recycling Markets

Overview

Approximately half of the film material collected for recycling in Canada in 2011 was processed domestically. Moore Recycling Associates estimates that Canadian reclaimers utilized about 38 percent of their processing capacity.¹¹ Below are the major commodities in the recycled film marketplace:

- Commercial Film - clean polyethylene film including stretch wrap and poly bags (no postconsumer bags;
- Mixed PE Film - mixed color, clean PE film including retail collected postconsumer bags, sacks, and wraps; and
- Curbside Film - mixed PE film generated at materials recovery facilities.

Nearly 60 percent of the reclamation capacity in Canada is in Ontario. The major end use for recycled film in Canada is to produce recycled content film and sheet products from Commercial, Mixed PE Film, and Curbside Film. Reclaimers in Ontario are unique in their ability to process Curbside Film into pellets suitable for film and sheet markets. In the United States, composite lumber is the primary end use for recycled film. Film and sheet markets sourced about sixteen percent of the available supply of recycled film in the U.S. in 2011. Additional end uses in Canada and the U.S. reported in 2011 were automotive applications, pipe, lawn and garden products and some injection molding articles. Table 4 shows the approximate market demand to recycle different film commodity grades in different market regions.

Table 4 Summary of Recycling Market Capacity

Commodity Grade	Approximate Market Capacity (Plastics tonnes/year)		
	Ontario	All Canada	Canada & U.S.
Commercial film (LDPE)	32,000	54,000	390,000
Mixed PE films	32,000	44,000	250,000
Curbside film	5,000	5,000	5,000
Other (for sorted single-resin streams)	0	0	5,000

Source: Moore Recycling Associates, Inc.

More than 95 percent of the U.S. and Canadian demand is limited to fairly high-quality material, generally Commercial and clean Mixed PE Film, which means that the material can bypass the wash phase at reclaimers¹², or the stream is single resin rather than a combination of HDPE and LDPE. Despite the jump in processing over the last several years, North American processing has not yet returned to the level seen in 2006, when strong housing and construction markets were creating higher levels of product demand for recycled content composite lumber.

The export market remains strong for the high value categories (Commercial and Mixed PE Film). Like North American markets, recycling interest in China, the dominant export market, is for monolayer

¹¹ Moore Recycling Associates gathered market data during an annual recycling survey and then did a round of interviews of companies that recently entered the market or provided limited processing data during the annual survey.

¹² The cost for the wash phase is highly variable depending on the type of washing but can be higher than \$440 cents per tonne.

films—primarily LDPE. Multi-laminates are considered contamination and are generally disposed or used as low value applications such as fishing floats depending the material and volume. The Chinese government at times becomes more restrictive with plastics imports, and this market is subject to disruptions particularly for the lower value categories such as Curbside Film. Therefore, a strong domestic reclamation infrastructure is necessary for future growth in recycling.

Recovered film enters the global market in different grades that have widely varying price points, depending on quality, with single resin bales of clear industrial film having the highest value, clean return center-collected mixed HDPE, LDPE, and LLDPE film having a moderate value, and curbside-collected mixed HDPE, LDPE, and LLDPE film having a far lower value. Film quantity is also important to the cost-effectiveness of film recycling programs. For this reason, many commercial return center recycling programs for residential film combine commercial polyethylene film (e.g., pallet wrap) that is generated on site to achieve the volume necessary to warrant a film collection program or investment in a baler. Likewise, other residential film recycling approaches may benefit from increased market demand due to increased quality and tonnage that comes from including industrial, commercial, and institutional film in residential film recycling programs.

Currently there is strong demand for bales containing a combination of polyethylene resins provided the material is clean and dry. Retail collection of film and bag material generally has the lowest collection cost of \$75 per tonne for large retailers with capabilities to backhaul scrap to distribution centers for consolidation) and the highest scrap value for post-consumer/household-generated material because of the efficiency gains through the combination of commercial film and postconsumer bag and wrap collection. Moore Recycling Associates estimates that the commercial sector generates well over twice as much film as the residential or consumer sector.

For more than 20 years, retail collection programs across North America have been producing bales with minimal contamination. Such programs have been able to generate revenue from both commercial and residential films, while reducing the retailer's waste and providing customers a recycling service. Retail collection is the predominant method of collection for postconsumer material in the U.S. and will likely continue to grow provided the stream continues to garner strong prices and bag bans do not result in retailers dismantling their collection program for postconsumer bags and other recyclable wrap. It should be noted that retail collection is more common in the U.S. compared to Canada (most likely because of Canadian MRFs' willingness to accept film and the available markets for curbside collected film in Ontario). Sorting film in MRFs is costly compared to the scrap value received and MRFs resist the addition without increased fees for service. U.S. retailers fill the need for recycling film and wrap and are mostly willing to do so voluntarily because the cost is negligible or in some cases revenue positive and provides economies of scale to assist with recycling their self-generated Commercial Film.

Commercial Grade LDPE

The highest value category of film consists of clean, clear L(L)DPE film and is often labeled Grade A. This category is generated in high volume and has very high market demand because it provides a fairly easy substitute for virgin feedstock in a wide variety of end products from film to composite decking. Currently demand far exceeds supply and this dynamic will likely continue for some time because additional incremental supply will likely come from small to medium generators who experience significant collection challenges. This film is found in nearly every business worldwide in large part because of light-weighting during shipping in an increasingly globalized society.

Although commercial film is not the subject of this study, it is important to consider its relationship to film markets because in North America the quantity of commercial film collected for recycling exceeds the amount of residential film collected for recycling and so it impacts markets. Residential film makes up less than twenty percent of the collected film.¹³ Furthermore, commercial return centers (including retail establishments) combine commercial and residential polyethylene for better program efficiency and economies of scale. This is further discussed in Mixed PE Films below.

Mixed PE Films

The category, Mixed PE Film, generally contains postconsumer bags and wrap with commercial film. Combining HDPE and LDPE of various colors usually lowers the scrap value but may create the volume needed to enable collection. Retailers throughout the United States have been collecting postconsumer bags and films for more than 20 years primarily because of the revenue from the scrap and the fact that it requires very little incremental labour and space, since most retailers already have a system in place for capturing their internally generated commercial film.

The key to understanding North American Mixed PE Film markets is to realize that while there are merchant reclaimers creating pellet, most of the reclamation capacity is for integrated recycling and manufacturing, where the reclaimer transforms the film into a specific product rather than reclaiming material into a general merchant resin for sale. The impact of this fact is that each film recycler may have different incoming material tolerances, specifications, and reclamation processes and equipment, designed around the product that they produce.

The largest North American purchasers of the mixed PE grade are U.S. composite lumber product companies including Trex Company and Advanced Environmental Recycling Technology (AERT). The products these companies make were created with support from virgin resin producers more than 20 years ago with the intent of creating demand for a particular combination of material now referred to as Mixed PE Film. The end product design was related to the feedstock supply. Even though the market was created through seed money, the concept of vertical integration is proven and can provide economic advantages. Vertically integrated companies are able to source bales of unprocessed scrap and directly produce an end product, saving on the cost of pelletizing and transportation of those pellets of recycled resin from merchant recyclers.

Another source of Mixed PE Film is single resin material that may require a wash phase. Examples include bags collected through a bottle redemption program. A growing number of bag manufacturers have become vertically integrated and purchase recovered film for recycling into bags. Most have chosen to source a single resin stream and put the material through a wash phase.

One of the conundrums in plastic film recycling is that in general, markets that are capable of handling fairly “dirty” material most often can only use one PE resin type (i.e., LDPE) and the markets that are capable of handling a mixture of PE resins (i.e., LDPE, LLDPE, and HDPE) cannot handle “dirty” material. The reason is that profit margins for reclamation are very tight;¹⁴ therefore, reclaimers must be selective in order to contain their processing costs (e.g., choosing either washing or sortation, but not both), and

¹³ 2011 Postconsumer Plastics Recycling in Canada, November 2012 and U.S. Film & Bag Recycling Report, Prepared by Moore Recycling Associates for the Canadian Plastics Industry Association and the American Chemistry Council.

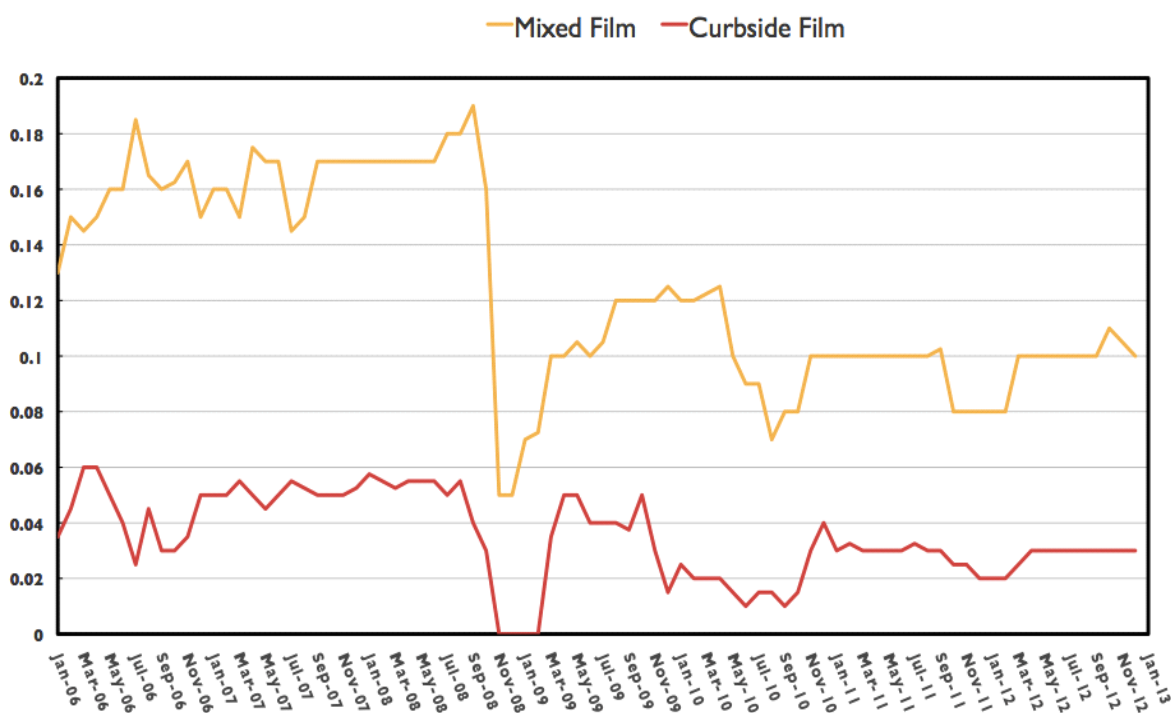
¹⁴ Data is limited on operating costs as reclaimers consider such information proprietary.

often they seek very specific grades of material. Infrastructure has developed the way it has to feed specific markets.

Curbside Film

Bales of Curbside Film have approximately one sixth the value of Mixed Film that comes from retail collection programs as shown in Figure 2 below, due to the contamination Curbside Film collects during collection and processing in MRFs.

Figure 2 Average North American Baled Film Price History for Return Center Mixed PE Film Compared to Curbside Mixed PE Film



Source: Moore Recycling Associates, Inc. Prices shown are in U.S. cents per pound.

Most end markets have very little tolerance for grit and general residue (non plastics, food, etc); the wear and tear on extruders makes washing MRF film a necessity. Washing is the most costly phase of recycling, at often more than \$440 per tonne. The total processing cost is dependent primarily on the quality of material coming (i.e., yield loss) and the cost of freight, both of which are highly variable. Major markets in North America have invested millions of dollars in wash lines over the years and have attempted to handle the material as efficiently as possible, but very few are used today (most have been dismantled) because, for most facilities, the cost to capitalize the washing lines plus the operating cost to process Curbside Film often exceeds its value in comparison to other sources of film.

Less than 3,000 tonnes of Curbside Film was purchased for recycling in Canada and the U.S. combined in 2011¹⁵, even though there was more than 5,000 tonnes of capacity. Not all markets are utilizing their

¹⁵ 2011 Postconsumer Plastics Recycling in Canada, November 2012, Prepared by Moore Recycling Associates for the Canadian Plastics Industry Association

wash capacity because, for many facilities, the cost to produce the pellet is higher than its sales value. Simply washing material does not guarantee a marketable product given the variation in material collected curbside. End markets with narrow specifications (e.g., blown film) may require extensive front-end sorting to achieve the correct melt flow. More forgiving markets such as composite lumber may be able to use unsorted curbside pellet, but they seldom do so because lower cost feedstock is available from Mixed PE Film bales that bypass the wash phase.

Other

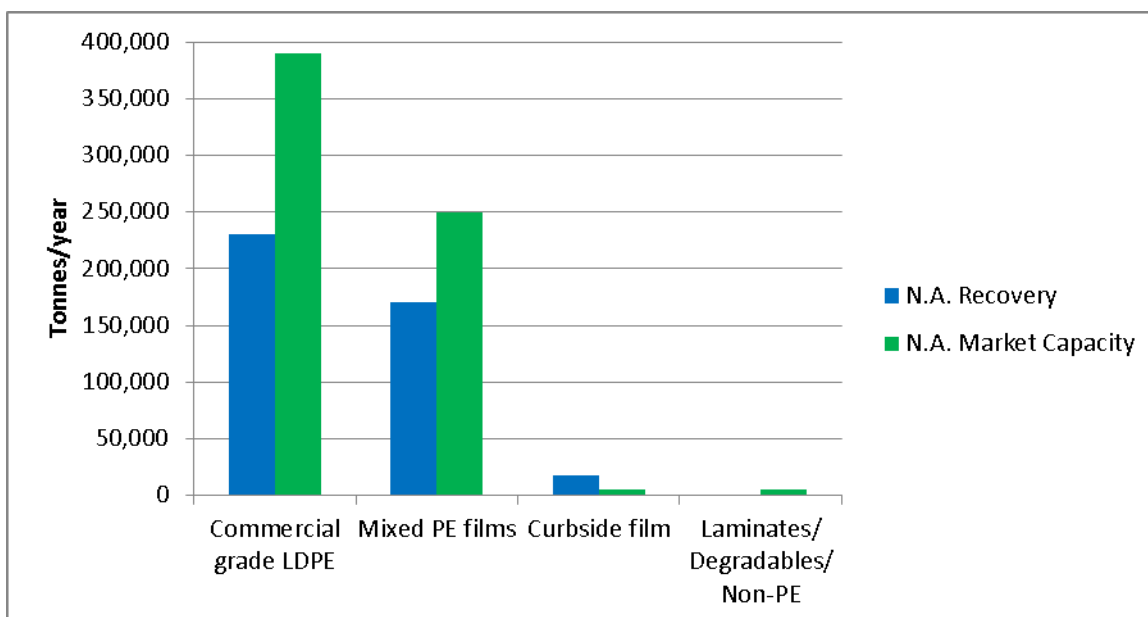
There is growing interest from a few U.S. reclaimers in the potential to recover polypropylene, polyvinyl chloride, polylactic acid, and specific laminates and there are existing markets for post-commercial materials of these types if separated by the source into individual commodity streams; however, at this time, existing film markets have identified all of these materials as being significant contaminants to the existing polyethylene film recycling infrastructure. Specifically, degradables and laminates were cited as the top contamination challenge by nearly all reclaimers in North America and nearly all reported zero tolerance for those materials.

Manufacturing success depends on a steady supply of known quality feedstock. The non-polyethylene film streams are varied and small compared to polyethylene; therefore, they have not yet been able to attract investment in sorting equipment or recycled end products. Currently, all such material, if diverted from disposal, goes to recovery markets that convert such materials to energy or chemicals.

Summary of Recycling Markets

Figure 3 below shows North American collection quantities and recycling market capacity for different grades of film that were discussed in this section. As the figure shows, Curbside Film has greater supply than North American demand. Yet, there is a significant room for growth in the collection of commercial and relatively clean postconsumer polyethylene material. The capacity to process non-PE film is a combined capacity for all of the distinct commodities such as PP film, specific laminates, and PVC film primarily generated in the commercial sector. If Ontario desires to expand curbside collection of PE film for recycling, there is a need for additional sorting and washing infrastructure in Ontario. The alternative is to collect film in ways that generate higher quality film (i.e., encourage source separation and avoid dirty environments such as the MRF environment).

Figure 3 North American Recovery and Recycling Market Capacity



Source: Moore Recycling Associates, Inc.. Excess curbside film above North American market capacity is exported to Asia for recycling.

Markets dictate quality standards and specifications based on their technological and economic ability to produce a recycled resin that performs as a cost-effective alternative to other sources of supply. Any decision regarding collection systems or investments in markets, therefore, needs to be based on whether the system can supply recycled resin that is a cost-effective alternative to other material sources. Table 5 provides a summary of the commodity grades that have been discussed in the sections above, including general specifications, end uses, and delivered market value of the recovered material.

Table 5 Summary of Recycling Market Specifications and Unprocessed Scrap Value

Commodity Grade	Specification	End Uses	Delivered Value (per tonne) ¹
Commercial grade LDPE	Clean, Clear LDPE (primarily stretch wrap)	Extrusion grade (possible PCR for film, lumber, and many other end markets), overseas, other	\$440-529
Mixed PE films	Clean Mixed Color HDPE/LDPE (minimal contamination from labels, tape, other resins)	Extrusion grade (possible PCR for film but mostly non film end markets), overseas, other	\$154-276
Curbside film	Mixed Color HDPE/LDPE (minimal contamination from labels, tape, other resins)	Overseas, extrusion grade (possible PCR provided extensive processing and blending), EfW, chemical, other	\$25-66
Other	Laminates, Degradables, Non-PE Film	Recovery technologies (not generally considered recycling) including chemical and energy recovery	No recycling market for this grade at this time unless sorted into separate resins

¹ Freight-on-board delivered value to a plastics reclaimer based on data compiled by Moore Recycling Associates, Inc.

Despite reported tight supplies, higher prices for the top grades, and challenges in consistent quality, more than fourteen North American reclaimers reported plans for upgrades to equipment as well as capacity expansion. These reclaimers generally want specific grades of material, such as a relatively clean mixture of HDPE and LDPE rather than curbside, or a pure stream of LDPE that may have some dirt or other non-plastic residue generally coming from commercial or agricultural sources. As noted, the profit margins for reclamation are very tight; therefore, reclaimers must be selective in adding reprocessing costs (e.g., washing, sortation) and must seek very specific grades of material. Some of the reported expansion is for curbside collected film, including film from Ontario, which will increase curbside capacity by approximately 7,500 tonnes in 2013.¹⁶ With North American Curbside Film collection exceeding 18,000 tonnes and the shrinking export market for lower grade material, there is a need for North American markets for such material to continue to develop and expand.

Given the delicate supply/demand balance in North America, growth in supply and capacity will have to move forward together. Reclaimers need a consistent supply yet often find that they cannot find or have to go far afield to find suppliers. Most material is sold on the spot market, which suppresses investment in reclamation infrastructure. A contracted supply would enhance reclaimers' ability to secure capital funding. Although supply can enable investment, it is difficult to start and then stop a collection program should supply outpace demand. Furthermore, demand is very dependent on the quality of the stream that is produced. Several companies have demonstrated that vertical integration of reprocessing and manufacturing of an end product allows for tight control over their recovered material supply: they are able to make adjustments to and compensate for variations in their feedstock. They may be able to save on some system cost elements, such as bypassing pelletizing and transportation elements that merchant reclaimers incur, which may give them a cost advantage over non-vertically integrated merchant reclaimers.

The cost to process low-grade bales of film (e.g., Curbside Film) into postconsumer recycled resin pellets is generally greater than the end market value (\$660-990 per tonne for postconsumer resin) in North America if the reclaimer has to bear the capitalization of the facility. According to research undertaken by Moore Recycling Associates, the Chinese export market is changing. Moore Recycling expects no future growth, and potentially a decline, in demand from China for lower quality film grades. This change is due to many factors including reshaping demographics, increasing operating and labour costs, and a changing political climate.

Recovery Options

Introduction

Recovery options include processes that convert material resources into energy, chemicals, or soil amendment/compost (if a biodegradable polymer) rather than return them to use as a polymer. Recovery options are less desired than recycling because they do not utilize the highest and best use of the material properties of the polymers. Furthermore, in many provinces (including Ontario), recovery does not count toward meeting packaging recycling goals. However, recovery options are preferred to loss of the resources through landfill disposal if those materials otherwise would not be recycled for technical or economic reasons.

¹⁶ Source: Stewardship Ontario.

The following recovery options are discussed in this section:

- Pyrolysis;
- Gasification;
- Engineered Fuel;
- Industrial Use; and
- Energy from Waste.

The discussion of each recovery option includes a description of the technology, a summary of the market status in North America, and a summary of specifications and approximate financial terms. The end of this section also includes a table that provides a comprehensive list of potential recovery markets for film plastics in Canada. Because non-recycled residential film is not currently diverted for recovery in Canada, these markets are considered potential markets for film – many accept other similar waste materials or recover film that is part of mixed municipal solid waste.

Pyrolysis

Technology Description: Pyrolysis is a high temperature (350 - 800°C) low-oxygen processes that breaks plastics down to simple hydrocarbons without burning them, unlike regular combustion that requires an oxygen-rich environment for combustion. Although pyrolysis can treat plastics, rubber (e.g., car tires), and organic materials, most pyrolysis systems have been developed primarily to treat otherwise non-recycled plastic waste streams. Products of pyrolysis include a gaseous fraction (that may be collected and combusted with oxygen to provide heat to fuel the pyrolysis process), liquid crude-like oils, metals (if material processed contains metals), and a sludge and/or carbon char. There are a number of technology vendors who are developing competing technologies that may yield varying amounts of the product streams listed, based on differences in process conditions, use of catalysts, and feedstock accepted. The primary product marketed by plastics pyrolysis companies in North America is crude-like oils, which average 80-90 percent of system output.¹⁷ This oil is normally sent to a refinery where it is refined and blended with other refinery products.

Market Status: Reclay StewardEdge is aware of three plants in all of the United States and Canada that operate on a continuous commercial-scale basis to process plastics (one in Ontario for electronics recycling byproduct plastics, one in Oregon, and one in Niagara Falls, New York). In addition there are a pair of facilities that only process tires through similar pyrolysis technologies. There are at least 8 additional commercial-scale plastics pyrolysis facilities that have been announced and are in various states of development or seeking financing, including one in Ontario. Existing commercial-scale facilities can be considered semi-commercial because they are primarily operated by technology developers; however, this technology can be considered to be on the cusp of being commercialized if merchant commercial plants that are under development prove economically viable on their own. The smallest commercial scale plant has a capacity of approximately 3,300 tonnes per year; however, most technology developers recommend plant sizes of approximately 9,000 tonnes per year or larger for economies of scale and economic viability.

Specifications and Financial: Pyrolysis technologies are able to accept mixed unsorted plastic resins, including multi-layer films, metalized/coated film, and plastics with contamination from food, dirt, and paper residues. Pyrolysis facilities, however, seek polyolefin resins and engineering grade resins as they

¹⁷ “Conversion Technology: A complement To Plastic Recycling,” 4R Sustainability Inc., April 2011.

provide the highest yield. PET and PVC are not desired because of the low yield of product oil. Furthermore, pyrolysis of PVC and PVDC results in organic chlorides in the product oil or production of hydrochloric acid, which requires further treatment of the product. Pyrolysis facilities generally request that a good faith effort be made to exclude chlorinated resins, but that such materials can be handled by pyrolysis systems at normal levels found in packaging waste streams. Business models for pyrolysis facilities are based on obtaining non-recycled plastic at little or no cost.¹⁸ This generally means that they will not source material from long distances because of the freight cost involved.

Gasification

Technology Description: Gasification is similar to pyrolysis in that it treats waste in an elevated temperature low oxygen environment so that plastics break down without burning. Gasification operates at a higher range than pyrolysis, typically 800 - 1200°C, and often includes the introduction of controlled amounts of oxygen and steam so that the material fully decomposes into synthesis gas (syngas) made up of hydrogen and carbon monoxide and ash or slag byproducts. Hydrogen syngas that is produced is utilized may be used as a renewable replacement for natural gas for heat production and electrical power generation. Syngases can also be collected and converted into methanol, ethanol, and other chemicals.

Market Status: Different technologies have been developed to handle various waste inputs for gasification, but they can be generally divided into thermal technologies and plasma arc technologies. Plasma arc uses an electric arc to heat the waste to extremely high temperatures, whereas thermal gasification technologies combust fuels to produce the heat needed in the gasification module. Like the development of pyrolysis, gasification technologies are just entering the commercialized stage of development. At the time of this report there were five plants operating in North America, all in the United States. Four of the five U.S. plants were demonstration scale facilities, or were designed at a smaller scale for industrial process waste streams – two of the plants use plasma arc gasification technology. One of the five U.S. plants, the largest, can be considered a commercial facility. It has a design capacity of 36,000 tonnes per year and is located in Dalton, Georgia, where it gasifies post-consumer carpet (composed of a mixture of plastic resins). Five large commercial-scale plants have been announced and are under construction or in planning phases in North America – two in the United States and three in Canada including one each in Edmonton Alberta, Ottawa Ontario, and Varennes Quebec. All of these plants have been designed to accept and gasify 100,000 tonnes per year of mixed municipal solid waste, including the plastics component of waste. Four of these five plants will convert the syngas to methanol, which in turn will be converted to ethanol, whereas the Ottawa plant will combust the syngas to generate electricity.

Specifications and Financial: Gasification facilities can process a wide variety of plastics (including PVC) and are often designed to process refuse derived fuel after mixed municipal solid waste has been processed to remove recyclables. One of the existing industrial gasification facilities was specifically designed to process chlorinated compounds, such as PVC. Cost data is difficult to obtain because plants are either operated by developers as demonstration facilities or for in-house industrial waste treatment. Estimates provided by technology vendors indicate the cost to process the waste is approximately \$50 per short ton,¹⁹ which depends on the cost of electricity or fuel required to run the process and amount

¹⁸ Ibid.

¹⁹ “Environmental and Economic Analysis of Emerging Plastics Conversion Technologies,” RTI International, January 2012.

of pre-processing of waste that is needed. The Edmonton and Ottawa plants are being developed under long-term municipal contracts to process municipal solid waste, and cost data is publicly available – the Edmonton plant will charge tip fees of \$75 per tonne and the Ottawa plant will charge \$83.25 per tonne. According to the City of Edmonton, any other suppliers of material to the facility must be charged a fee higher than what the city pays, even if it were baled non-recycled plastics.

Engineered Fuel

Technology Description: Mixed plastics and organic material, such as paper, are processed to remove unsuitable materials (or selectively sourced), size-reduced to a consistent particle size, and then most commonly agglomerated or pressed into uniform pellets or cubes. The pellets are then sold as fuel for industrial boilers, power generation plants, and cement kilns where they supplement and partially replace primary solid fuels including coal, wood/biomass, and petroleum coke. In some cases the fuel is not pelletized and is sold in loose form. The use of loose unpelletized fuel is discussed in the following section on Industrial Uses.

Market Status: Reclay StewardEdge has identified seven commercial-scale facilities in operation in North America that utilize scrap plastics and paper to manufacture solid fuel pellets (there are many more that make fuel pellets from clean wood waste). Six of these facilities are in the United States and the sole Canadian facility identified, the Dongara Pellet Plant, is located in York Region, Ontario. Three of these North American facilities, including the Dongara plant, process municipal solid waste (MSW) and use the nonrecycled paper and plastics in the waste to make their pellets. The others primarily use material that has been diverted from the commercial and industrial waste stream such as paper and plastics converting waste for their pellets. Increasingly, however, pellet producers are investigating using MRF residuals to produce a fuel pellet. In the United States Balcones Resources Fuel Technology tested using MRF residues in its pellet manufacturing facility and found it to be feasible; however, it is not using MRF residues on an ongoing basis because the company is able to produce pellets from industrial plastic and paper wastes with more favorable economics. Even large waste management companies are investigating this technology. Waste Management Inc. has a small pilot fuel pellet plant in San Antonio Texas (not counted in the seven commercial facilities discussed above) and the company plans a commercial scale facility to process MSW in Philadelphia, Pennsylvania. The sole Canadian facility markets its pellets to greenhouses, cement kilns, and for electrical power generation use.

Specifications and Financial: For product consistency, certificate of approval/permit limitations (for both themselves and their customers), and pollution control reasons manufacturers need to produce consistent product in terms of pellet size, moisture content, Btu value, non-combustible contaminants, and exclusion of materials that can release combustion pollutants. Fuel pellet producers do not typically accept PVC items above *de minimus* levels and some facilities prefer not to receive metallized film (e.g., potato chip bags). Pellet manufacturers that utilize only post-industrial or MRF scrap typically charge a small tip fee for collecting/receiving materials, whereas facilities that process MSW and produce pellets charge equivalent tip fees to disposal facilities.

Industrial Uses

Overview: There are several industries that have the potential to use film plastics in their processes. The industries discussed in this section combust solid fuels and most currently use some type of

recovered materials as supplemental fuel sources, such as tire-derived fuel.²⁰ Other industries such as the steel-making industry could use recovered film plastics as a chemical reducing agent in the steel-making process. Although the largest market segment for coal is electrical power generation, it is not discussed in this section as a potential recovery market for residential film plastics (as a supplement to coal) because of the additional expense associated with fuel preparation/handling, modifications of governmental approvals, and cost of pollution control system upgrades. Because the market potential differs across each of the industries that are discussed in this section, each is discussed separately below.

Cement/Lime Kilns

Technology Description: Portland cement and lime are industrial and construction materials that are produced from minerals using high temperature kilns. These kilns require a lot of energy and are substantial contributors to greenhouse gases. Cement kilns throughout the world make significant use of renewable and waste fuel sources; however, such is not the case in Canada and Canadian cement kilns rely heavily on traditional fossil fuel sources for 89 percent of their energy needs.²¹ The Canadian cement industry would like to increase their use of alternative fuel sources; however, there are public opinion and regulatory resistance challenges to be overcome if the alternative fuel sources are derived from waste. Cement kilns who desire to make use of such materials need governmental certificates of approval to do so, which normally includes expensive test trials and emissions testing.

Market Status: Canada has fifteen cement kilns with six in Ontario, three in British Columbia, three in Quebec, two in Alberta, and one in Nova Scotia. At least six of these kilns combust some waste materials including tire derived fuel and/or construction and demolition debris wood waste with incidental amounts of plastics; however, none currently formally accepts truck-loads of segregated plastics (there are a minimum of at least ten U.S. cement kilns that will specifically accept non-recycled plastics).

St. Marys Cement in St. Marys Ontario is the closest to having a formal ongoing ability to accept large quantities of plastics. The company has undergone extensive testing of film plastics screened out from organics processing/composting operations (polyethylene primarily) and plans to submit an application for a Certificate of Approval to accept up to 36,000 tonnes per year of film plastics in its kiln, although its St. Marys location would only be able to use approximately 22,000 tonnes per year. The company has a second kiln in Bowmanville that would also be a candidate for combusting film plastics as well, which has a greater capacity than the company's St. Marys location.

Specifications and Financial:

Cement kilns that combust alternative fuels, including plastics, typically charge a small tip fee, although in some cases they may pay a small positive value depending on the energy value of the material and whether the material has been processed into a form that can be readily fed into the kiln. St. Marys also plans to charge an as yet undetermined tip fee for the film plastic it intends to combust, although the fee will be less than charged by landfills. St. Marys planned specification for its alternative fuel will

²⁰ Materials used to make tires are closely related to those used to make plastics packaging and industries that use tire derived fuel can be considered potential markets for plastics derived fuel. Tire-derived fuel is used extensively throughout the United States and Europe in cement kilns, waste boilers at pulp and paper mills, coal-fired electricity generation plants, waste-to-energy (WtE) processes, and various industrial boiler plants. Relatively few tires in Canada go to such energy applications

²¹ "2012 Environmental Performance Report," Cement Association of Canada, December 2012.

include “film and other plastics, paper fibres and woody residuals from industrial and post-consumer sources” that is less than 25 percent moisture by weight and less than 1 percent halogen content (e.g., PVC). St. Mary’s needs its alternative fuel material to be shredded down to a 50 millimeter particle size so that it can be handled by its pneumatic alternative fuel handling system, and in the future St. Marys may purchase a shredder and perform its own fuel preparation. Other cement kilns have different specifications (both for materials accepted and for fuel particle size) and some can accommodate waste materials as large as 10 centimeters, whereas others have designed their fuel feeding system to accommodate whole passenger tires. Unlike most other recovery markets, cement kilns willingly accept metallized film.

Pulp and Paper Mills

Reclay StewardEdge is aware of with 32 pulp and paper mills in the United States that combust alternative fuels such as tire derived fuel; however, in Canada there currently appears only to be one pulp and paper mill that combusts such materials. In Canada, alternative fuel uses appear to be focused on combusting biomass and black liquor from the paper mills themselves. There does not appear to be good opportunities for sending non-recycled plastics to Canadian paper mills at this time.

Steel Mills and Coke Ovens

Steel is produced at thirteen plants in five provinces (Alberta, Saskatchewan, Manitoba, Ontario, and Quebec). The industry is concentrated in Ontario, with six plants operating there. Four of Canada’s steel mills produce steel from iron ore using an integrated process that first converts coal to coke in coking ovens, followed by blast furnace reaction of coke and iron ore to form iron, which in turn is followed a basic oxygen process treatment of the iron ore to yield steel. The other nine steel mills use an electric arc process and make steel almost exclusively from recycled scrap. All four of the integrated plants, which are intensive users of coal coke, are in Ontario. Coke ovens heat coal in an oxygen starved environment to drive off gases, oils, and other impurities leaving almost pure carbon. The gases and oils can be captured and used to heat the process, in part, but other fuels are needed to provide additional process heat. Like cement kilns, pulp and paper mills, and other consumers of solid fuels, waste-derived materials can be used as fuel, but none of the steel mills in Ontario are believed to be using waste-derived materials for this application.

The process of converting iron ore to iron is a high-temperature chemical reaction in which the ore, which is made of oxides of iron, reacts chemically with carbon monoxide to strip the oxygen from the ore, yielding elemental iron and carbon dioxide. Traditionally coke has been the primary carbon source to produce the carbon monoxide; however, producing it is energy intensive and expensive, and almost all integrated iron and steel mills in North America have sought to reduce their coke use by supplementing it with pulverized coal injection, natural gas injection, or heavy oil injection.²² In some European steel mills finely ground recovered plastics are mixed with these other reducing agents and injected into the furnace.²³ The use of plastics for this application is not believed to occur in North

²² “Available and Emerging Technologies for Reducing Greenhouse Gas Emissions from the Iron And Steel Industry,” U.S. Environmental Protection Agency, September 2012.

²³ Several German steel mills including the Arcelor Mittal mill in Bremen, Germany and the VoestAlpine steel mill in Linz, Austria are known to use recovered plastics for this application. According to PlasticsEurope, plastic waste first substituted for heavy fuel oils in the 1990s and several German companies have used approximately 300k tonnes per year of ground plastic waste in their blast furnaces (“The Compelling Facts About Plastics 2009 – An analysis of European plastics production, demand and recovery for 2008,” PlasticsEurope, 2009.

America, likely related to the fact that non-recycled plastic is not typically separated from disposed waste for recovery here compared to Europe. It would be feasible for North American integrated steel mills to also use non-recycled plastics if this market were to be deliberately developed and if a long-term supply of non-recycled plastics were to be guaranteed to North American integrated mills.

Energy from Waste

Overview: Energy from waste (EFW) is the process of combusting mixed municipal solid waste to produce electricity. Although EFW plants are designed to combust MSW generated from their partner jurisdictions, plants with excess capacity may accept some non-recycled film plastics from elsewhere.

Market Status: Canada has seven EFW plants and an eighth is under construction in Ontario that is scheduled for completion in 2013, at which time the total capacity to combust waste in Canada will be approximately 900,000 tonnes per year. Four of these plants are large and the other four are small (i.e., less than 40,000 tonnes per year of waste combustion each). These small plants include two in Quebec that are municipal solid waste incinerators (they do not recover the energy recovery), one in Alberta that combusts a combination of medical waste and municipal waste, and one in Prince Edward Island. The United States and Europe rely much more heavily on EFW than Canada. For example, the U.S. has 86 EFW facilities with a capacity to combust over 25 million tonnes of MSW per year (45 of these plants are in the Northeastern U.S. and other states that border Canadian provinces, and these plants have a capacity to combust 14 million tonnes of MSW).

Specifications and Financial: Most EFW plants are financed as disposal facilities under agreement with a host jurisdiction and so have limited ability to accept waste from outside the host jurisdiction. Any facility that would have excess capacity can be expected to charge at full disposal tip fee prices to accept such waste. Because segregated plastics has a higher energy value than MSW, any facility willing to accept plastics from outside their jurisdiction would need to blend and meter the plastics in with other waste in order to avoid temperature spikes and processing inconsistencies. EFW plants are able to accept all types of plastics for disposal and energy recovery.

Summary of Recovery Options

Table 6 summarizes the market specifications and value (or tip fee charged) for loads of film delivered to each type of recovery market

Table 6 Summary of Recovery Market Specifications and Material Value

Recovery Market	Typical Specification	Delivered Value (per tonne)
Pyrolysis	May be mixed with rigid plastics. PVC must be less than 10-15%. ¹ PET is not desired due to low oil yields. Most exclude metallized film.	\$0 to \$40
Gasification	None. Separation of film from solid waste is not required.	-\$75 to -\$85
Engineered Fuel (Pellets)	May be mixed with contaminated paper. No PVC or metallized film above incidental levels.	unknown to -\$85
Industrial Uses	No PVC. Specifications vary among industry types (e.g., cement kilns accept metallized film; others may accept plastics/paper mixes).	\$0 to -\$40
Energy-from-Waste	None. Separation of film from solid waste is not required.	-\$110 to -\$140

Source: Reclay StewardEdge

¹The threshold level for PVC is generally corresponds to the level that it is found in the residual packaging waste stream after bottles have been removed for recycling.

As Table 6 shows, there is a wide variation in specifications and delivered value. Those recovery markets that accept mixed municipal solid waste, such as energy-from-waste and gasification, have the least demanding specifications, but also have the lowest market value offered since they charge tip fees that are on par with disposal facilities. As materials move up the value chain the specifications typically get more stringent and the material value increases. It is possible for some recovery markets, specifically industrial uses and pyrolysis, to pay a small positive value for recovered plastics, under certain circumstances. This can occur when energy costs for traditional fuels are high. For engineered fuel and industrial uses, it also depends on the availability of other alternative combustible waste materials in a local area. As long as there is a surplus of these other combustible waste materials, it is not likely that positive value will be paid and that tip fees will be charged.

Table 7 presents a summary of capacity estimates for recovery markets in Ontario, Canada, and North America (combining both Canada and the U.S. capacities).

Table 7 Summary of Recovery Options Market Capacity

Recovery Market Type	Technology Stage ¹	Approximate Market Capacity (Plastics tonnes/yr) ²		
		Ontario	All Canada	North America
Pyrolysis	Semi-commercial	6,000	6,000	70,000
Gasification	Semi-commercial	0	50,000	130,000
Engineered Fuel (Pellets)	Semi-commercial	100,000	100,000	400,000
Industrial Uses	Commercial	40,000	40,000	1,000,000
Energy from Waste	Commercial	70,000	220,000	6,500,000

Source: Reclay StewardEdge

¹"Semi-commercial" as used in this table means that there are commercial scale plants that are continuously operated, but most of them are operated by technology developers who hope to license their technology.

²Plants known to be operating or under construction in 2013. Listed capacity is total capacity, with an appropriate allocation to plastics. Capacities listed may be utilized and not available for additional film plastics quantities. Only pyrolysis plant capacity for which the intended feedstock is plastics are included in the pyrolysis capacity estimates (i.e., tire pyrolysis facility capacity is not included). Plant capacity for technologies geared toward municipal solid waste processing (gasification, energy from waste) were counted as having 25 percent of their capacity available for plastics. Pellet fuel and industrial users were estimated to have half of their capacity available for plastics, except for St. Marys Cement which was fully counted.

The capacities listed in Table 7 are based on either facility capacity or limits imposed by governmental approvals/permits. Because many of the recovery technologies accept more than just film plastics (e.g., municipal solid waste or paper), the figures shown in the table are based on apportioning part of their capacity to plastics. What is not reflected in the table is the amount of capacity that is currently utilized versus unused capacity that is available for additional material. The Ontario pyrolysis capacity, for example, is used by an electronics recycler for their rigid scrap plastics, and this capacity is not generally considered to be merchant capacity that is available for film plastics. Alternatively, there is excess Ontario capacity that is available for engineered fuel pellets or for use by a cement kiln that can accommodate large volumes of additional non-recycled film plastics.

Table 8 lists potential recovery markets for non-recycled film plastics that are located in Canada.

Table 8 Summary of Potential Film Recovery Markets in Canada

Company and Location	Notes
Pyrolysis	
GEEP (Global Electric Electronic Processing), Barrie, Ontario	Converts internally generated electronic plastics waste to fuel oil
GreenMantra Recycling Technologies, Brantford, Ontario	Commercial scale facility under development at the time of this report – to produce waxes and lubricants
Gasification	
Energem, Edmonton, Alberta	Proprietary gasification/thermochemical technology to convert City of Edmonton municipal solid waste to ethanol/chemicals
Energem, Varennes, Quebec	Proprietary gasification/thermochemical technology to convert industrial waste to ethanol/chemicals
Plasco Energy Group, Ottawa, Ontario	Plasma arc gasification of City of Ottawa municipal solid waste to produce synthesis gas for electricity generation
Engineered Fuel (Pellets)	
Dongara Pellet Plant, Vaughan, Ontario	Produces fuel pellets from waste paper and plastic found in industrial and municipal solid waste
Industrial Uses (Cement)¹	
Holcim Cement, Joliette, Quebec ²	Combusts dried municipal sewer sludge, tires and tire fluff, asphalt shingles, and treated wood/plastics as supplemental energy sources
LaFarge Cement, Bath Ontario ³	Combusts construction and demolition wood waste (including incidental plastics) as a supplemental energy source
LaFarge Cement, Richmond, British Columbia ³	Combusts construction and demolition wood waste (including incidental plastics) and shredded carpet as supplemental energy sources
LaFarge Cement, St. Constant, Quebec ³	Combusts whole tires as a supplemental energy source
Lehigh Northwest Cement, Delta, British Columbia	Combusts whole tires as a supplemental energy source
St. Marys Cement, Bowmanville, Ontario	Considering future combustion of film plastics as a supplemental energy source
St. Marys Cement, St. Marys, Ontario	Plans to obtain governmental approvals in 2013 to combust film plastics as a supplemental energy source
Industrial Uses (Paper Mills, Steel Mills, Electric Power Plants)	
Catalyst Paper, Port Alberni, British Columbia	Combusts wood waste and tire shreds as a supplemental energy source
Arcelor Mittal Dofasco, Hamilton, Ontario Essar Steel Algoma Inc., Sault Ste. Marie, Ontario US Steel Nanticoke Works, Nanticoke, Ontario US Steel Hamilton Works, Hamilton, Ontario	These are the only integrated steel mills in Canada – they use significant volumes of coal in their coke plants and blast furnaces. None are believed to currently have an interest in supplementing coal/coke with recovered plastic.
<i>Numerous electric power plants</i>	There are numerous electric power plants in Canada that combust coal to generate electricity. None are known to be investigating the potential to supplement coal with recovered plastic.

Company and Location	Notes
Energy from Waste	
Algonquin Power from Waste Inc., Brampton, Ontario	Combusts municipal solid waste to produce energy for electricity generation
Burnaby Renewable Energy, Inc., Burnaby, British Columbia	Combusts municipal solid waste to produce energy for electricity generation
Durham York Energy Centre, Clarington, Ontario	Plant under construction – scheduled for 2013 completion – to combust municipal solid waste to produce energy for electricity generation
Incinérateur de la Ville de Lévis, Lévis, Quebec	Incinerates municipal solid waste – no energy recovery
Incinerateur de la Ville de Quebec, Quebec City, Quebec	Combusts municipal solid waste to produce energy for electricity generation
MRC des Îles-de-la-Madeleine, Madeleine, Quebec	Incinerates municipal solid waste – no energy recovery
Trigen-PEI, Charlottetown, Prince Edward Island	Three boilers, one of which combusts MSW and the other two biomass
Wainwright Energy From Waste Facility, Wainwright, Alberta	Combusts a combination of medical waste and municipal solid waste

¹These cement kilns are known to combust waste materials and so are believed to be potential markets for non-recycled film plastics. There are an additional eight cement kilns in Canada that the project team does not believe combusts solid recovered waste materials as fuel and those cement kilns have not been listed in the table.

²Supplementary fuels are sourced and prepared by Holcim's Geocycle division.

³Supplementary fuels are sourced and prepared by LaFarge's Systech Environmental division.

Reclay StewardEdge offers the following recovery market conclusions:

- There are few pyrolysis, gasification, and engineered fuel pellet facilities operating commercially in North America. There is market risk associated with such a small number of facilities, especially since the next best market may be a far distance and transportation to that market may be costly.
- For all the technologies discussed, commercial economic viability is highly dependent on local conditions (e.g. transportation costs, landfill tip fees, availability of other diverted materials with energy value, and electricity cost for those conversion technologies that use large amounts of electricity).
- A diversified approach to recovery for non-recycled plastics should be considered – there is sufficient available capacity at Plastic2Oil LLC (Niagara Falls, NY), Dongara Pellet Plant (Vaughan, ON), and St. Marys Cement (St. Marys, ON – prospective 2013 capacity) to process all multi-laminate film generated in Ontario until such time as feasible materials sortation and recycling technologies may become cost-effective and available. PE film recycling is currently feasible and PE film should be recycled rather than sent to recovery markets.

Section 4: Film Sorting Technologies

This report section discusses film sorting and processing technologies that can be employed by materials recovery facilities and reprocessors for the recycling of film plastics, including capital and operating costs of equipment and stage of technology development. System costs associated with integrated collection and processing recovery infrastructures, including materials revenues, is discussed in Section 5 Comparative Evaluation.

Materials Recovery Facility Technologies

At the time of this report technologies for sorting film in a MRF are very limited. Technologies and processes that may be employed also depend on which other materials the film is mixed with (e.g., two-stream versus single-stream collection) and the film market grade to be produced. Following is a description of the various sort technologies and discussion of how they are or might be applied.

Manual Sorting

Manual sorting is the most universal option in that it can be used to sort any film product from any mix in any size facility. Recently constructed/retrofitted large-scale MRFs commonly utilize overhead suction tubes at manual sort stations to collect and convey polyethylene film from multiple points in the MRF to one central point. Manual sorters snatch and lift plastic film to the suction tubes. The plastic film is pulled in by the suction and conveyed to a storage bin where bale quantities are accumulated. This approach to manual film sorting is shown in Figure 4. Older or smaller facilities may manually pick out film at only one point in the MRF and drop it down a chute into a bunker.

Figure 4 Manual Sorting of Film



Manual sorting provides the potential to collect all types of film and sort it into more than one film product grade. Collecting all types of mixed film and sorting it into more than one grade is not currently performed in any Ontario MRF. To do so would require a separate film sorting conveyor and the following processing steps:

- Separate film from non-film materials (the best practice is for manually sorting film is for all film to be “bags-in-bags,” i.e. all film stuffed inside a tied-off bag);
- Open bags-in-bags so each piece of film is individualized;
- Positively sort out bags and film that is obviously only polyethylene into a one grade;
- Leave all remaining film as a mixed resin/laminate grade.

When plastic film is delivered to a single-stream MRF it is important to capture as much of the film as possible at the pre-sort station to prevent the plastic film from wrapping around the rotating shafts of the disc screens that follow. Because of the depth of material on conveyors at the pre-sort, film may be buried under other materials and secondary sorting of plastic film is often needed on the fiber post sort lines to remove the film that has been carried through and been mechanically sorted with the paper.

When plastic film is delivered to a dual-stream facility, residents can be directed to include the plastic film either with fiber or containers. 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. Those problems include blinding shaker screens, wrapping around axles in disc screens and confusing optical sorters.

If the MRF is producing a polyethylene film product and another film product containing other films, one approach could be to train program participants to separate and package the different types of films into two separate types of bags that could be easily distinguished on the sort line. That might mean differently colored bags designated for each product. The project team is not aware of any collection program using this approach and none of the literature reviewed for this project had evaluated the effectiveness of such an approach.

Some plastic resins such as PVC fluoresce under black light and an enclosed black light manual sorting station can be used to separate out PVC and other materials that fluoresce from either a polyethylene stream or a stream of film to be sent for recovery. Because materials such as PP, PET, or PLA do not naturally fluoresce, manually sorting under black light is not effective for separating those materials from polyethylene or each other.

The entry-level capital cost of an installed manual film sorting system with multiple sort stations, suction system and storage bin is around \$125,000.²⁴ Additional sort stations can be added by adding suction stations, enlarging main suction ducts and increasing blower size. A large system with collection from many stations, including filtering for dust control, will cost over \$350,000.

The primary challenge of manually sorting plastic film is the amount of labour required and the resulting cost. Assuming a worker can make 50 picks per minute, one worker can sort a maximum of 3,000 individualized bags per hour. Using a conversion factor of 300,000 film pieces per tonne, it would take one worker 100 hours to pick one tonne. Manual sorting costs can be greatly reduced if residents can be trained to package all like plastic film (i.e., all polyethylene film) into a tied bag. To show the impact on sorting cost and efficiency, if 25 same-film items are in one bag, the productivity of the same worker can be increased from sorting 3,000 individualized film items per hour to sorting 75,000 film items per hour, and can pick a tonne in 4 hours. The degree to which film is bagged-in-bags is the single-most impactful factor on film sorting costs in a MRF. Table 9 shows the impact on costs.

Table 9 Sensitivity of MRF Manual Sorting Costs to Bags-in-Bags

Percent Bagged Film	Annual Capital ¹	Labour	O&M	Cost Per Tonne
0% Bags-in-bags	\$26/tonne	\$1,717/tonne	\$88/tonne	\$1,830/tonne
50% Bags-in-bags	\$24/tonne	\$893/tonne	\$88/tonne	\$1,004/tonne
90% Bags-in-bags	\$21/tonne	\$234/tonne	\$88/tonne	\$342/tonne

Source: Resource Recycling Systems

¹ Capital is estimated to include a pneumatic collection system with a cost of \$100,000, a \$35,000 bunker, and \$8,000 per sort station (new MRF construction assumed). Capital is assumed to be financed over a term of 10 years at a 4 percent rate. Equipment sizing is based on a MRF with a design capacity of 20 tonnes per hour, operating two shifts per day and 260 operating days per year.

The cost to manually sort film mixed with other recyclables in a MRF may therefore range from \$340 - \$1,800 per tonne. Manual sorting operating costs are highly dependent on whether best practices for film recycling are employed to keep film inside of bags up to the point that they are manually separated.

²⁴ This cost is based on a new construction MRF. Costs are normally higher to add a system to an existing MRF.

Film Grabber

A promising piece of commercially-available mechanical equipment for sorting plastic film from other recyclables is the Film Grabber offered by Bollegraaf, shown in Figure 5. The Film Grabber is mounted across a conveyor of mixed recyclables and uses a rotating drum with protruding fingers to comb through the mix of recyclables and hook the film. As the drum rotates the hooked film is lifted out of the other recyclables. When the film reaches the top of the drum the fingers retract and the film is blown off to the collection bin. 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 or thicker polyethylene films such as cereal box liners, chip bags, and laminated film plastic packaging. When this technology is used on a fiber or single-stream line this system also captures some paper that would need to be manually separated later.

Figure 5 Bollegraaf Film Grabber



Bollegraaf does not market its Film Grabber as being highly effective in separating film in a single-stream recycling operation. A consideration in placing a Film Grabber in a recycling facility is that the fingers on the grabber drum must be able to reach nearly to the conveyor belt surface to snag a majority of the film. This means that large materials such as OCC, buckets and large bottles need to be removed before the Film Grabber location, which means it would have to follow the pre-sort station and OCC screen in a single-stream facility (many facilities also add a glass screen at this point). Additionally, the Film Grabber must be placed ahead of the ONP screen (which normally immediately follows the OCC/glass screens) to avoid large volumes of plastic film wrapping around the screen shafts. As stated above, the Film Grabber is designed to capture very thin and highly flexible plastic films. Even if a Film Grabber were inserted just after the OCC screen, the Film Grabber will capture significant quantities of flexible papers (like newspapers) along with the plastic film, which would need to be removed through a manual quality control step at the MRF.

The Film Grabber is not yet in common use and has only been installed in a few facilities worldwide, including one MRF in Ontario. To evaluate this technology the Continuous Improvement Fund provided funds for the installation of a unit in the Hamilton, Ontario MRF, a dual-stream facility, which accepts plastic bags with the container stream. This facility has a Film Grabber installed on its container sort line that is effective in capturing between 30 and 60 percent of the plastic film in the 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 debugging equipment. These film grabbers were installed primarily to capture the large bags that recyclables had been set out in and thus opened by the bag breakers. In that MRF 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. Labour is still required after a Film Grabber to sort the film that the Film Grabber fails to capture.

The base price of a Film Grabber is \$450,000, but with the addition of an air system, storage bin/bunker, and installation costs, the total installed cost can be over \$500,000. Table 10 shows the estimated

sorting cost costs using a Film Grabber, followed by manual sorting for the film that is missed by the equipment, assuming that the equipment captures approximately half of film in mixed recyclables.

Table 10 Cost Estimate for Sorting Film Using Film Grabber

Annual Capital ¹	Labour ²	O&M	Cost Per Tonne
\$104/tonne	\$446/tonne	\$113/tonne	\$663/tonne

¹ Capital is estimated to include a Bollegraaf Film Grabber system estimated at \$450,000, a \$35,000 bunker, and an \$8,000 sort station (new MRF construction assumed). Capital is assumed to be financed over a term of 10 years at a 4 percent rate. Equipment sizing is based on a MRF with a design capacity of 20 tonnes per hour, operating two shifts per day and 260 operating days per year.

² The effectiveness of the Film Grabber is assumed to be 50 percent, which reduces the labour cost by half compared to manual sorting, and assuming 50 percent film in bags.

Air Separators

MRF equipment manufacturers make equipment to separate two dimensional flexible materials from three dimensional rigid containers. This equipment is normally employed in single-stream MRFs on the container sorting line immediately after the paper screens have separated paper from containers. The equipment has been designed to capture single sheets of residual paper that has carried over into the container stream, but it also separates individual plastic film products. Bollegraaf's technology, shown in Figure 6, is named the Paper Magnet, CP Manufacturing makes a piece of equipment called an Air Drum Separator, shown in Figure 7, and Machinex calls its equipment an Air Separator (illustration not available). All three vendors' equipment use suction to cause flexible materials like paper and film plastics to be sucked onto and adhere to a moving surface, which directs them down a separate chute, whereas curved rigid materials do not adhere to the surface and continue on their way for further sorting.

Air separation technology and equipment can be used to remove individualized plastic film from rigid containers in a two stream MRF if the film is collected in the containers stream. The current configurations of the various vendors' equipment have not designed to accommodate the weight or dimensions of bagged film and so their effectiveness for separating bagged film is not known, nor has the effectiveness of different vendors' equipment relative to each other for separating bagged film been evaluated. The primary limitation of air separation equipment is that it cannot distinguish plastic film from paper nor can it separate polyethylene film from other resins or laminates. Use of air separators to sort film from a mixed containers stream would require quality control checking to produce PE film that would meet recycling market specifications.

The Installed cost of air separation equipment on a new line starts around \$300,000 and varies with size and placement (retrofit costs are significantly higher). Total sorting costs for film using air separation equipment in a two-stream MRF where film is included with containers is estimated below in Table 11.

Figure 6 Bollegraaf Paper Magnet



Figure 7 CP Manufacturing Air Drum Separator



Table 11 Sorting Cost Estimate with Air Separation Equipment

Annual Capital¹	Labour²	O&M	Cost Per Tonne
\$56/tonne	\$89/tonne	\$35/tonne	\$180/tonne

¹ Capital is estimated to include air separation equipment with an installed cost of \$300,000, a \$35,000 bunker, and an \$8,000 sort station (new MRF construction assumed). Capital is assumed to be financed over a term of 10 years at a 4 percent rate. Equipment sizing is based on a MRF with a design capacity of 20 tonnes per hour, operating two shifts per day and 260 operating days per year.

² The effectiveness of air separation equipment is assumed to be 90 percent, which reduces the labour cost to only 10 percent compared to manual sorting, and assuming 50 percent film in bags.

Some MRFs in Europe where film is collected as part of a lightweight containers stream use a much simpler configuration of a blower system and air knife to separate lightweight individualized film from other heavier containers. The cost of this equipment is not large. However, the presence of ultra-lightweight PET bottles, loose labels, lids, and lightweight thermoforms in the stream can result in carryover of those materials into the separated film, so manual quality control sorting of the separated film is necessary. Manual sorting is also needed to separate polyethylene film from non-polyethylene/laminates. This combined equipment/manual sorting approach can only be used in a two-stream MRF where film is to be collected in the containers stream.

Optical Sorting

Optical sorters are common in large MRFs to sort rigid plastics. They work by measuring the spectrum of near infrared (NIR) light that is reflected off the surface of items they are sorting, and based on the spectrum from the surface resin, identify and separate plastics by resin type. Essentially they make a decision regarding composition based on what the surface layer is. This can be problematic with multi-layer film laminates and optical sorters may not see the differing layers. Likewise, because they are reading the reflected surface spectrum, NIR optical sorters are not effective in identifying whether non-PE film is inside a ball of bagged film, so if PE film is to be separated from non-PE film using optical sorters, each film item must be separate from other film items (and not in bags).

The spectrum for rigid polyethylene containers is the same as that of polyethylene film. This means that NIR optical sorters used in MRFs cannot distinguish between an HDPE detergent bottle and a PE film bag, and a NIR optical sorter would sort them both into the same category. If film is collected with rigid containers (either in a single-stream system or if included with containers in a two-stream system), manual labour or some other piece of equipment in tandem with an optical sorter would be required to sort polyethylene film as its own grade, limiting any potential cost savings of using NIR optical sorting over other film sorting approaches. Only if film were collected/sorted with paper in a two-stream system could an NIR optical sorter be considered for sorting out PE film from paper, potentially without the need for additional sorting labour or equipment.

NIR optical sorting is used on some paper lines in a handful of North American single-stream MRFs to remove multiple contaminants from paper all at once (including film of all resin types, aluminum cans, lightweight PET bottles, etc.), but not as a positive film sort to only separate PE film into its own market grade. A couple of MRFs in Europe use NIR optical sorters to either assist with sorting PE film and rigid containers from municipal solid waste, to sort film from paper, or to sort film by resin type (supplementing other sorting equipment described in this section). The project team is only aware of TITECH optical sorters being used by these European MRFs in this fashion. TITECH states that its optical sorters can sort a maximum throughput of 600 kg per hour of film per meter of optical sorter width. Pellenc in France has also worked to adapt its rigid packaging optical sorter technology to sort PE plastic film from other film resin types. This application is new and currently used on plastic film with a

thickness of 2.5 mils or more. Pellenc has had to adapt its machines to use airflow to keep the film from moving as it is scanned and sorted. Since a large percentage of North American residential plastic film is only 0.5 mils thick, Pellenc believes that its technology in its current stage of development would not be very effective for sorting residential North American film.

Reliable information on the effectiveness of sorting film from paper in a two stream MRF based on North American film characteristics does not exist. The project team performed some cost estimating based on NIR optical sorter capital costs (which are significantly more expensive than that of air separators) and made labour assumptions to evaluate the potential of sorting film from the paper stream in two stream MRFs. The labour estimates are acknowledged to be imprecise; however, the tentative analysis did not suggest that film could be sorted at less cost from the paper stream than from the container stream. Due to the lack of cost-competitiveness with other options and the unknowns regarding additional labour that may be required, optical sorters at the MRF level were dismissed from further consideration and no cost estimate for optical sorting of film in MRFs is included in this report.

Robotic Sorters

A future technology that may eventually assist in sorting plastic film is the robotic sorter, shown in Figure 8. Currently Bollegraaf is experimenting with this technology in Germany and Excel Manufacturing is installing prototype units in Minnesota. The design application of this technology is for quality control sorting and for production sorting in low to medium throughput applications. Units developed so far consist of an optical scanner over a conveyor belt followed by a robotic arm that picks low percentage contaminants from a conveyor and deposits them into a bin, chute or onto another conveyor. This system cannot support the same throughput as other technologies discussed above.

Figure 8 Robot Sorter



Source:

solidwastemag.com/news/robomrf/1000213709/

As compared to manual sorting at 50 picks per minute, a robot arm can make over 200 picks per minute. A single scanner can support multiple arms on a single conveyor, so theoretically, rates of over 1,000 picks per minute are possible. Also, robot arms have the capability of picking items that overlap other items, something that air separators and optical sorters that use air jets for sorting cannot do well.

A significant attraction of robot sorters is the potential to sort multiple products with a single robot system. As applied to plastic film, the limitations will be throughput (because of the low weight of each pick) and sufficient discrimination between products.

A robot sorter with a single sorting arm is predicted to cost less than an air jet optical sorter (approximately \$400,000 installed), but until commercial production units are available, pricing remains uncertain. Additionally operational costs are very uncertain, not knowing the true efficiency of a unit in sorting film in a MRF environment. Based on 100 picks per minute and the above capital costs, the range of allocated capital and operating costs may prove to range from \$250 - \$400 per tonne once this future technology is commercialized. However, it could also be significantly higher if the system cannot accurately handle bags of bags, if the burden depth is deep, or if manual quality control after the machines is still required (to separate PE film from PE rigid containers, for example).

Reprocessor Sorting Technologies

Depending on how plastic film materials are collected and the products produced at the MRF or return center, some secondary sorting by the reprocessor may be required and/or the film may need to be washed. The MRF sorting technologies discussed above can all be used. The German film reprocessor Relux uses NIR optical sorters at its reclamation facility in Germany to sort film that MRFs have separated from other recyclables using manual sorting or other technologies. The incoming bale specification calls for the bales to have at least 92% film plastics and the film is to exclude aluminized plastics. Relux begins by shredding the film into large pieces, optically sorts the pieces into PE and non-PE film, and then washes and pelletizes the PE film for sale into film and sheet markets. Multi-layer or non-PE film is sent for energy recovery. If optical sorting of film is to be employed in North America, the most logical place for it to be utilized may be at the reclamation stage rather than at the MRF stage. The project team is not aware of any film reclaimer in North America using optical sorters for film sorting.

Additional technologies that can be employed by a reprocessor include density separation in a wash system. Washing plastic film usually starts with shredding to reduce piece size, followed by washing in heated water containing detergents and wetting agents, where it is mechanically agitated through a series of chambers. The washing performs several functions including:

- Removal of residual foods, oils, and salts;
- Removal of dirt, dust, and glass grit the film picks up through collection and MRF processing;
- Dissolution/pulping and removal of paper and potentially plastic labels if water soluble label adhesives were used;
- Dissolution of water soluble printing inks; and
- Density separation of those plastic materials that are denser than water (e.g., PET, PS, PVC, PLA) from those that are less dense than water (polyethylene and polypropylene).

Washing is not effective in removing some adhesives and the materials attached by these adhesives. Foamed resins that otherwise would sink may float with the desired resins (e.g., polystyrene foam). Furthermore, depending on the relative proportions and densities of the resins used in multi-laminate films, they may either sink or float and not be separated from the targeted resin. Some polyethylene retail carryout sacks that are imported from Asia are made more than ten percent mineral filler and these sacks sink rather than float, leading to lower product yields from polyethylene film that is washed.

After washing, the plastic film must be dried. This is usually accomplished by first squeezing the water out and then by evaporation through direct application of heat, heating through friction, or application of a vacuum. The washing and drying process is very expensive, which can make residential curbside film virtually unmarketable if market demand can be satisfied by sufficient quantities of relatively clean film collected through retail and commercial return centers, or from film collected from industrial, commercial, and institutional generators.

Film that has been washed and dried can be made directly into new products or pelletized for sale as a commodity resin for various markets. The extruding process melts film and volatilized many of the inks used for printing. The gases that are formed must be vented to avoid gas bubbles in the final product, so specialized extruders are used for recycling film that has been printed compared to those used for rigid plastic bottle and unprinted film recycling. The final step to remove small remaining quantities of gels and chips of unmelted materials that are not polyethylene is to melt filter the resin before producing the final product or extruding it into pellets for merchant sale. Melt filters are not designed to remove large quantities of contamination and most dissimilar resins or aluminum foils – these

materials must be removed prior to the extrusion of pellets or directly producing demanding recycled-content products like film bags.

Film Sorting Technologies Conclusions

Table 12 shows the estimated costs to sort curbside collected film from other recyclables using different technologies that are commercially available and could be considered under single and dual stream collection systems.

Table 12 MRF Technology Sorting Cost Estimates

Technology	Annual Capital ¹	Labour	O&M	Cost Per Tonne
Manual	\$22/tonne ²	\$390/tonne ³	\$88/tonne	\$500/tonne
Air Separators (only for dual stream systems with film in the containers stream)	\$56/tonne ⁴	\$89/tonne ⁵	\$35/tonne	\$180/tonne
Film Grabber (only for dual stream systems with film in the containers stream)	\$104/tonne ⁶	\$446/tonne ⁷	\$113/tonne	\$663/tonne

¹ Capital is assumed to be financed over a term of 10 years at a 4 percent rate. Equipment sizing is based on a MRF with a design capacity of 20 tonnes per hour, operating two shifts per day and 260 operating days per year. All capital costs assume new MRF construction.

² Capital is estimated to include a pneumatic collection system with a cost of \$100,000, a \$35,000 bunker, and \$8,000 per sort station.

³ Assumes that film best practices are aggressively implemented resulting in over 75 percent of film remaining in bags when separated from other recyclables manually in MRFs, with the result that manual sorters can sort 0.039 tonnes per hour.

⁴ Capital is estimated to include air separation equipment with an installed cost of \$300,000, a \$35,000 bunker, and an \$8,000 sort station.

⁵ The effectiveness of air separation equipment is assumed to be 90 percent, which reduces the labour cost to only 10 percent compared to manual sorting, and assuming 50 percent film in bags under a less aggressive implementation of film best practices.

⁶ Capital is estimated to include a Bollegraaf Film Grabber system estimated at \$450,000, a \$35,000 bunker, and an \$8,000 sort station.

⁷ The effectiveness of the Film Grabber is assumed to be 50 percent, which reduces the labour cost by half compared to manual sorting, and assuming 50 percent film in bags under a less aggressive implementation of film best practices.

Based on the MRF cost models developed for this study, curbside film recycling best practices (i.e., bagged film), market specifications (separation of PE film from other film types), and the limitations in the ability to sort PE film from non-PE film in MRFs, if curbside collection of film is desired it should include requesting program participants to keep PE film separate from non-PE film for recycling and collect only one film type in the curbside program (with the potential for return center collection for the other type of film material). Air separator technologies hold promise for separating film from the rigid container stream in two-stream systems, but their effectiveness on separating bagged film has not been evaluated and is likely limited based on current designs. Currently no commercial or demonstration systems have been identified, and field data collection and research is required to provide sufficient data to adequately evaluate the effectiveness of air separation equipment for film separation, and the amount and cost of labour that would still be required to meet market specifications. However, this technology is believed to hold great promise for two stream MRFs. For single-stream MRFs, sorting of film manually appears to be the appropriate approach.

For North American demand for post-consumer polyethylene film to remain robust and grow, contamination must be minimized. There are two primary types of contamination—contamination from general residue, occurring from collection practices that fail to prioritize keeping the material clean and dry, and contamination from non-polyethylene film in the PE film stream that has market demand. Because of the current limits to technology discussed in this section, recycling program participants play a crucial role in ensuring the quality of collected polyethylene film. Unfortunately, the complexity of the film packaging stream is continually changing because of innovations in packaging and new materials. Unlike rigid plastic containers, there is no requirement for film plastic to be labeled as to its material

composition, and even when a material is labeled as to its composition the public may mistakenly think the product is recyclable when in fact the product may not be accepted in local recycling programs. This makes public education difficult for film packaging as well as other plastics labeled with a recycling logo.

GreenBlue's Sustainable Packaging Coalition (SPC) has developed a recycling label for use in the United States that packaging companies can voluntarily place on their products to objectively communicate to the public the recyclability of their packaging. It has been developed for all packaging material types—not just plastic film – and some parties have expressed interest in having a similar label used in Canada as well. The How2Recycle Label indicated general recyclability of each manufacturer's packaging based on whether the package has followed design for recyclability guidelines as expressed by recyclers²⁵ as well as the extent to which the U.S. public has access to collection for that type of packaging. The American Chemistry Council's Flexible Film Recycling Group (FFRG) is partnering with SPC to promote clear recycling information at collection locations and on packaging, in order to increase consumer participation in film recycling beyond bags, as well as encourage more design for recycling. Below is the new bag and wrap recycling poster. Figure 9 shows SPC's How2Recycle label and how it has been incorporated into film recycling educational materials in the United States.

Figure 9 How2Recycle Label and Flexible Film Recycling Group Educational Materials



²⁵ At the time of this report the Association of Postconsumer Plastic Recyclers, which represents more than 90 percent of the plastics reprocessing capacity in North America, was in the process of developing Design for Recyclability™ Guidelines for film plastics.

Section 5: Comparative Evaluation

Description of Recovery System Models

Based on current technology limitations and market conditions, the type of collection that is proposed for residential film plastics will significantly influence the potential end markets for the material. The main reason for this is the cleanliness of the material, both keeping dirt, moisture and other contamination out and also including only the resins that are compatible with each when recycled. Other significant factors influencing market demand include large volumes of alternative competing film collected through return-to-retail in the United States and relatively clean film that is collected from industrial, commercial, and institutional establishments.

Four recovery system models or scenarios for residential film are illustrated in the flow charts below, which display the potential pathways for material from collection to processing and eventually end market use. These diagrams show current material flows as well as ones that could become more prominent as technology develops or under the right economic and/or market demand conditions. Although collection of a mixed stream of film (i.e. all polyethylene and non-polyethylene film together) was investigated, it is not described here because it will follow the same channels as non-polyethylene film since it is not currently technologically or economically feasible to sort mixed resin films in North America now or in the near-term future.

In the flow diagrams below, each end-market is assigned a rating based on current barriers to film recovery, ranging from high to medium to low. No markets were deemed “low-barrier” for residential material due to the mix of incompatible resin types requiring separation and increased contamination that will be present. Curbside collected polyethylene film faces high barriers in North America and currently the vast majority of this material is marketed overseas to Asia where low-cost manual labour is used to sort and wash the film. Mixed non-polyethylene and multi-laminate residential film is not currently purchased for recycling by North American or export markets, but could be collected and sent to recovery either domestically in Canada or in the United States. Films that go to recovery markets have a processing step called “secondary processing” in the flow diagrams below, which includes shredding/grinding, mixing with other materials for some industrial and engineered fuel pellet markets, and/or processing by conversion technology to produce energy and/or liquid or gaseous products.

The four flow diagrams that follow are:

- Figure 10, Polyethylene Film Collected Curbside;
- Figure 11, Non-Polyethylene Film Collected Curbside;
- Figure 12, Return Center Collection of Polyethylene Film; and
- Figure 13, Return Center Collection of Non-Polyethylene Film.

Figure 10 Polyethylene Film Collected Curbside

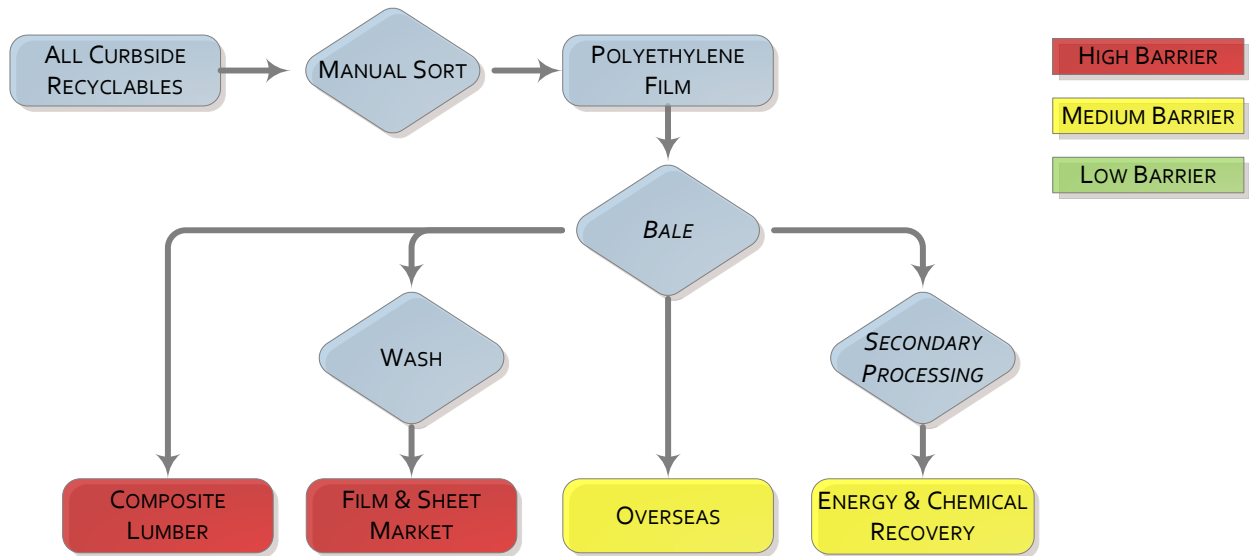


Figure 11 Non-Polyethylene Film Collected Curbside

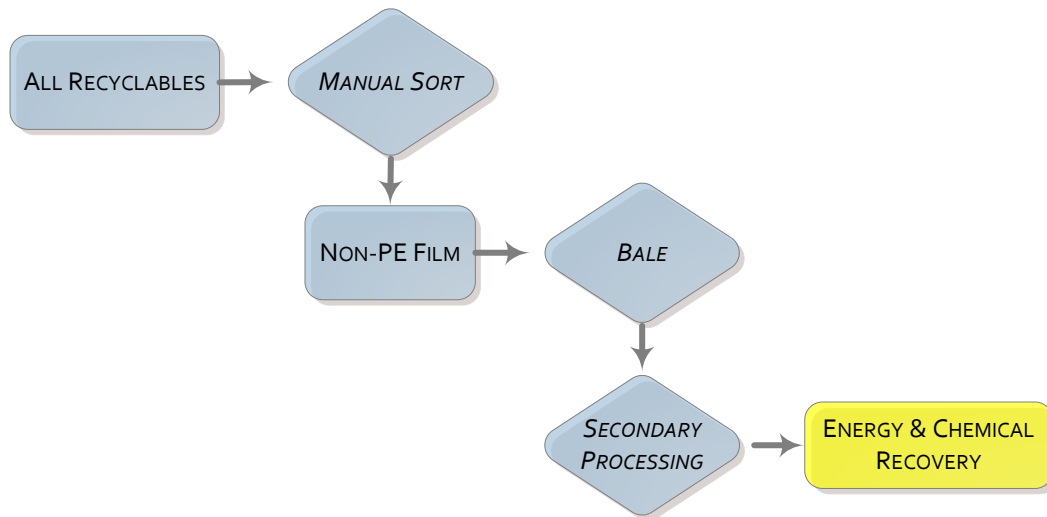


Figure 12 Return Center Collection of Polyethylene Film

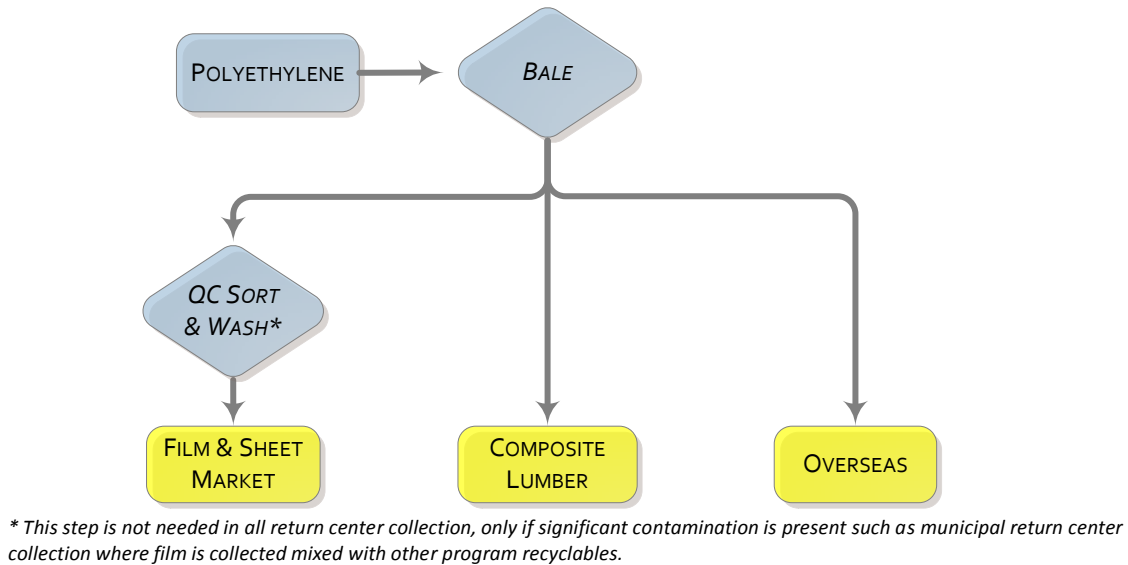
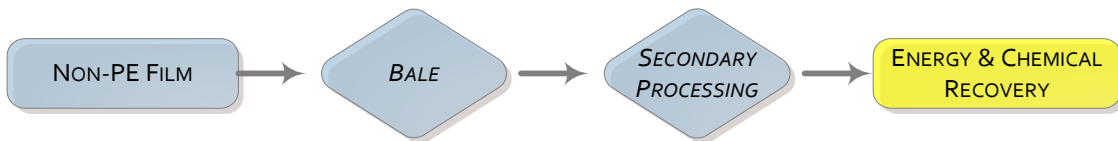


Figure 13 Return Center Collection of Non-Polyethylene Film



Collection Options

Collection of flexible film packaging can be done throughout Ontario either through the extensive existing curbside blue-box infrastructure or through a network of either commercial or municipal return centers. As discussed above, two material mixes have been evaluated for collection in streams that are source-separated from each other (i.e., not as mixed films that are later sorted from each other at MRFs or reprocessors). These streams are:

- **Polyethylene only:** This first mix is similar to what exists in many communities today (but not province-wide) and would include polyethylene films only. This material is accepted for recycling by existing reprocessors.
- **Non-polyethylene:** The second material mix would include all other films including multi-laminates. This material is not accepted by existing recycling markets; however, there is increasing recovery market demand for such materials.

As was explained in Section 4 Film Sorting Technologies, there are no current commercial technologies to cost-effectively separate polyethylene film from a mixed film stream other than hand sorting, which is very expensive in North America. To be financially feasible polyethylene and other film should be source-separated from each other, and collected in bags separate from other recyclables. Collecting film in bags serves two purposes. First it reduces sorting costs at the MRF, and second it improves film

quality because film kept inside the bag is less contaminated by moisture, dirt, grit, and the other materials it may be co-collected and processed with in a MRF environment.

Return Center Collection

Return center collection increases the options for end markets over curbside collection by potentially keeping the material segregated from other recyclables and out of the MRF environment, which otherwise will result in increased dirt and moisture contamination. Two separate return center collection scenarios were considered by this study – one based on a municipal return center approach and the other on a commercial return center approach.

Assumptions regarding the municipal return center approach are that the collection and handling approach is designed to preserve and maximize film quality for polyethylene film. This would be done by collecting film under shelter at municipal community service centers (these may also accept municipal hazardous and special waste or electronics). The collection containers for the film would be relatively small in size, approximately 500 liters. The film would be hand-unloaded from these collection containers and baled in a small vertical baler dedicated to film. This municipal return center approach generally does not assume that film will be collected at outdoor municipal return centers mixed with other Blue Box materials, other than perhaps at municipal return centers that happen to be located at MRFs where manual handling of the film separate from other recyclables would be possible.

Assumptions regarding the commercial return center approach are that it could be located at participating retail locations or could be a completely separate commercial return center that also collects other materials that are not collected directly from residences (such as deposit containers, municipal hazardous and special waste, or electronics). Similar collection containers and film handling procedures to the municipal return centers are assumed for cost and recovery modeling purposes for this study.

Both municipal and commercial return centers are assumed to be small-footprint collection points that are not located at MRFs where there are large amounts of covered storage space to accumulate truckload quantities of material. For this reason, film collected at return centers is assumed to be either:

- Transported loose to a central warehouse/distribution center where it is baled and aggregated for shipping to market, either with a small inexpensive dedicated vertical baler or potentially using a less labour-intensive approach using a small horizontal baler that would be shared with other materials such as OCC;²⁶ or
- Baled on site using a small inexpensive dedicated vertical baler, followed by hauling of individual bales to a central warehouse/distribution center for aggregation and shipping to market.

Estimated costs associated with both of these options are shown below. Table 13 shows the estimated costs of film recycling assuming that loose film is hauled to a central baling facility under both no-cost back-haul and hauling-cost scenarios.

²⁶ Sharing a baler would require significant storage space for loose film, estimated at 40 cubic meters, and a significantly greater capital expenditure.

Table 13 Return Center Cost with Loose Film Hauling to Central Baling Location

Cost Element	No-cost Back-haul \$ per tonne	With Hauling Cost \$ per tonne
Labour - loose film collection at return center	\$268	\$268
Cost to transport bags of loose film	\$0	\$250-300
Labour - baling	\$41	\$41
Baler capital cost per tonne ¹	\$30	\$30
Boxes and bags cost per tonne	\$5	\$5
Baling Wire	\$5	\$5
Baler Energy Cost	\$0.50	\$0.50
Total	\$350	\$600-650

Source: Resource Recycling Systems

¹Includes an estimate of the cost of small-footprint downstroke baler. Capital cost is estimated at \$10,000, financed over ten years at a 4 percent interest rate, which results in an annualized cost of \$1,233. The per-tonne cost depends on the amount of tonnes processed per year. For this table, a minimum of 40 tonnes per year was assumed.

The no-cost back-haul scenario shown in Table 13 would likely not be available to most municipal and many commercial return centers. Where there is a transportation cost to collect loose film from a network of return centers, an efficient “milk run” to pick up loose sacks of film from multiple return centers has been estimated to cost from \$250 - \$300 per tonne for the additional cost of collection.

Small footprint downstroke balers that would be used for on-site film baling have the potential to save on hauling cost of collected film. The per tonne capital cost of these balers depends on the quantity of film that each site would collect. The maximum baling capacity of these balers is approximately 650 tonnes per year if film is continuously fed into them one shift per day – this would present the least cost scenario since the baler capital cost would be allocated over the most tonnes. This scenario is likely difficult to achieve. Only eight programs in Ontario, all curbside collection programs, collected more than 100 tonnes of film in 2011 (e.g., more than approximately one bale per day). The project team performed sensitivity analysis to determine at what point that on-site baling may be preferred over hauling of loose film at a cost to a central baling location. The analysis revealed that on-site baling would be preferred for sites that collect 5 tonnes or more of film per year if there is a hauling cost (a cost curve from this analysis can be found in Appendix C). Table 14 shows the cost of recycling film through return centers that bale film on-site, assuming the average site collects 8.5 tonnes per year.

Table 14 Municipal or Commercial Return Center Collection with On-Site Balers

Municipal Collection With Distributed On-Site Balers	
Cost Element	\$ per Tonne
Labour - loose film collection at return center	\$268
Baler Labour Cost	\$41
Baler Capital Cost ¹	\$145
Boxes & Bags	\$5
Baling Wire	\$5
Baler Energy Cost	\$0.50
Milk Run to Collect Bales	\$36
Total Cost:	\$500

Source: Resource Recycling Systems

¹Includes an estimate of the cost of small-footprint downstroke baler. Capital cost is estimated at \$10,000, financed over ten years at a 4 percent interest rate, which results in an annualized cost of \$1,233. The per-tonne cost depends on the amount of tonnes processed per year. For this table, 8.5 tonnes per year was assumed.

The project team reviewed retail collection film recycling estimates and number of collection points data to estimate the quantity of film that could be collected from return centers. Because commercial film generated on site at the retail establishments is also often combined with the residential film, it is difficult to know with precision the amount of residential film recovered, but rough calculations suggests that the average site collects approximately seven tonnes of film per year, mostly of retail carryout sacks. This would suggest that a planning factor of 8.5 tonnes per year per site is reasonable assuming the collection of a broad variety of film through return centers is heavily promoted (beyond just retail sacks) and is done at convenient site locations.

For both municipal and commercial return centers, best practices for handling the material would be the same. Return centers should:

- Collect the material indoors;
- Visually inspect the material for contamination;
- Keep the material dry and out of dusty environments (such as found in MRFs);
- Dedicate a vertical baler to film to reduce storage needs and contamination;
- Provide clear signage for allowable materials; and
- Monitor bins for food contact films, such as chip bags, to ensure material is washed and not attracting pests.

Curbside Collection

The range of costs to collect film curbside, including sensitivity to route density and participation, is included in Table 15 Municipal Curbside Collection Cost per Tonne for Film Plastics. The costs shown in this table are based on allocation of the full costs of collection, including common costs such as driving between stops, in part to film. The figures in the table assume a relatively minor incremental cost of \$10 per additional tonne of film collected. Film is compressible and likely only 1-2 percent of the overall material stream, and adding film to existing curbside recycling programs is not expected to have a significant increase in collection costs. A recent film recycling pilot study in Langley, British Columbia came to the same conclusion. If film was added to all current dual or single-stream collection, and effectively promoted, there would likely be only a handful of communities that would require route adjustments or increases in the number of routes to accommodate this material.

Table 15 Municipal Curbside Collection Cost per Tonne for Film Plastics

Cost Sensitivity to # of Stops per Route	Low	Med	High
Daily Stops Per Route	700	1,000	1,400
Annual Capital	\$74	\$62	\$53
Annual Labour	\$104	\$76	\$57
Annual O&M	\$39	\$28	\$20
Annual Admin	\$52	\$39	\$30
TOTAL	\$270	\$204	\$160

Source: Resource Recycling Systems

The Langley, British Columbia pilot study investigated the cost and effectiveness of curbside film and polystyrene foam collection.²⁷ In the pilot, bags were given to residents to place polystyrene foam in one

²⁷ Reference 16 in Appendix D.

bag and polyethylene film in another bag for co-collection with other curbside Blue Box material. Major conclusions from the study were:

- Significant volumes of film were collected;
- Significantly more material (over 4 times as much) was collected when enough free bags were given to the residents for all generated film over the period of the pilot than when only a starter bag was given and thereafter residents had to purchase their own replacement bags;
- Collection time was not perceptibly affected (estimated at 8 min additional per route);
- Capacity on the trucks was sufficient to handle the increase in material; and
- Contamination rates in the polyethylene-only film stream were high (33 percent - 45 percent).²⁸

A review of the report offers the following analysis:

- It is quite expensive to supply all the bags, at \$2.20 per household per year, to get the high performance achieved in this study, which equates to between \$500 and \$1,000 per tonne for collection – the study instructed residents to purchase additional blue-coloured bags recycling bags if they ran out, and in neighbourhoods where only a starter bag was provided, after which residents needed to supply their own bags, the performance was no better than current Ontario film collection programs;²⁹
- There was a high rate of bag breakage, estimated between 10 percent and 27 percent, even though minimal compaction was done on the pilot collection; and
- Bag breakage could occur because of high compaction pressure, shearing with the compaction blade or improper tying of the bag by the resident.

In general, the following are recommended best practices for curbside collection of bagged film (curbside-collecting loose film is not recommended):

- Extensive and continuing education on what are acceptable packaging materials;³⁰
- Collect film in bags to reduce contamination of other materials and sorting costs at the MRF;
- Monitor/reduce truck compaction to reduce bag breakage; and
- Utilize carts to reduce moisture.

Processing Cost at MRFs for Curbside-collected Film

The Langley curbside film collection study found that even with residents bagging their film, ten percent or more bag breakage/spillage was observed when collected in the same truck compartment with other recyclables, so that at least ten percent of film becomes mixed with other recyclables. Processing costs at the MRF under even the best of circumstances, therefore, would range from \$400 - \$600 per tonne and can be much higher as discussed in Section 4. When modeling system cost for curbside collection of

²⁸ The objective of the study was to achieve a minimum of 80 percent polyethylene content. The short duration of this pilot program did not provide sufficient time for the project sponsors to provide additional education to program participants in order to reduce contamination.

²⁹ Ensuring that collected film is secured within bags is an important assumption in this study regarding the labour cost of sorting/separation in a MRF for curbside collected film, as will be shown later, significant sorting costs can be saved by ensuring collected film remains in bags rather than distributed throughout the other collected recyclables. The limited scope and duration of the pilot did not allow for testing of whether promoting the reuse of “free” retail carryout sacks as film collection bags in place of purchased bags could result in higher levels of film recovery (such retail sacks would need to also be tied tightly by participants to ensure film spillage does not occur).

³⁰ The cost of promotion and education associated with program changes has not been estimated in this study and is not reflected in the estimates of cost shown.

film, we used a \$500 per tonne estimate for processing cost, assuming a best practice approach is used that includes strong public education on the importance of bagging film. If programs collect recyclables in bags rather than bins or carts, bag openers will significantly increase the unintentional opening of film bags in MRFs and bags of film will need to be separately collected from other bagged recyclables or separated from the recyclables stream before bag breaking equipment in order to avoid high sorting costs. The other cost components that go into processing film in a MRF are discussed below.

When plastic film is added to the incoming mix at MRFs, additional costs include more than the cost of sorting plastic film from the sort line at the designated sorting stations. Some plastic film will always get past the pre-sorting stations at the front end of the sort line where film is normally picked. In a single-stream processing facility, this missed film will wrap on disc screens and conveyor shafts, causing lost sorting efficiency of disc screens from plugging, reduced efficiency of other sorting operations such as manual paper quality control, and reduced efficiency of optical sorters. Typically in MRFs that don't intentionally receive plastic film, the film must be manually cut off of disc shafts 1-4 times per shift. This is usually done at lunch, breaks, and between shifts to minimize lost production time. With the addition of much more plastic film to the mix, more frequent and more elaborate cleaning may be required. At a minimum, staff time required for cleanings is likely to increase significantly. Where shaft wrapping problems are severe, the line may need to be shut down between breaks to clear shafts, or the line will need to be run at a lower throughput as the screens plug up with wrapped plastic film. Estimates vary widely for the cost of these activities. Some cost projections may be possible from time/motion studies; however, it is not known if such specific activities have been documented and specifically allocated to film. The processing cost models constructed for this study have included additional cost estimates under the operations and maintenance (O&M) heading if film is included in programs to account for both indirect and direct costs of sorting film. Film that is removed from the screens is lost as residual and not recovered, further reducing the effectiveness of film sorting at single-stream MRFs.

In addition to these maintenance and efficiency costs, allowance for baling costs and bale storage space need to be considered. Baling and bale handling costs are estimated at \$15 per tonne for film in MRFs. Storage costs are usually calculated as the annual cost of the storage area required for the material divided by the number of tons of that material processed per year. Since ultimately the goal is to accumulate a truckload (20 tonnes) of material, the minimum required space is 20 square meters. If one truckload is accumulated at a \$100/square meter annual cost for the space, the storage cost could be estimated at \$100 per tonne. This cost is not included as an incremental system cost in this study but it is a secondary cost to the MRF.

Lastly, some cost may be incurred as a result of degradation of other MRF products, especially paper products. Most of the plastic film that is not captured for recycling or as residue will end up in the non-OCC paper products produced by the MRF (usually ONP and some grade of mixed paper). If the levels of plastic film exceed what is acceptable to the mills offering the best price for those products, the products may need to be sold to another mill at a lower price. The alternative is to add more quality control sorters to the stations that clean up those products. At this time, insufficient data is available to assign a cost to either the additional labour or lower paper product revenue that may result in MRFs that process film. Because these materials are the largest volume materials to the MRF and are 50-100 times the volume of the plastic film, a small loss in the value of these products or a small increase in the processing costs of the products would register as a large increase in the cost of sorting the plastic film.

Collection Volume Estimates

Flexible film is currently marketed in 108 curbside and drop-off collection programs throughout Ontario with over 75 percent of programs marketing less than 10 tonnes annually, and the total municipally-collected amount in Ontario equaling 4,214 tonnes. The overall range of per household collection is 0.06 kg/ HH/ year to 6.25 kg/ HH/ year. Table 16 Top Polyethylene Film Recovery Programs in Ontario shows the six top performing programs that serve over 10,000 households. No programs currently accept multi-layered laminates. If multi-layered laminates were added to collection programs, the amount of film diverted from disposal would be estimated to double.

Table 16 Top Polyethylene Film Per Capita Recovery Programs in Ontario

Municipality	Collection	Households Served	Marketed Film (tonnes)	kg PE per Household
District Municipality Of Muskoka	Curbside & Depot	47,627	241.9	5.1
County Of Northumberland	Curbside & Depot	37,966	169.8	4.5
Quinte Waste Solutions	Curbside & Depot	63,985	205.0	3.2
Niagara, Regional Municipality Of	Curbside	381,601*	983.0	2.6
Hamilton, City Of	Curbside	210,453	519.5	2.5
Peel, Regional Municipality Of	Curbside	411,800	842.0	2.0

* Households for Niagara include Waterloo since film is transferred for processing at the Niagara MRF

As Table 16 shows, there is a wide variation in per household recovery among even the top six best-performing municipalities, ranging from 2.0 to 5.1 kilograms per household per year. If a flexible film recovery program was implemented throughout the province, the total material collected would be highly dependent on the implementation details and promotion and education that accompanied it. Some programs promote the plastic film collection and others only tacitly. In the pilot study from Langley, BC, the recovery in their highest performing area (where collection bags were provided at significant cost to facilitate recovery) was extrapolated to be 5.95 kilograms per household per year; however, this included 33 percent contamination. Adjusting the recovery quantity for only polyethylene film would yield approximately 4 kilograms per household per year, which is consistent with the higher performing Ontario curbside communities. If collection bags were not provided, but if film recycling was aggressively promoted, it would be feasible to recover on average 3 kilograms per household per year.

A return center has the potential to recover as much film as a curbside program, but would need to be exceedingly convenient. A review of film recovery levels in municipal drop-offs in small population municipalities in Ontario that rely on drop-offs as their exclusive recyclables recovery method had several instances where film was collected at the same per capita levels of the better-performing curbside communities listed in Table 16 above. Unfortunately, no data was available for North American commercial return center or retail take-back programs on a per capita or per household basis. In this study, recovery of polyethylene film through return centers was estimated at 2 kilograms per household per year, assuming that return centers are well-distributed and convenient to participants, with the average return center serving an area of 4,250 households and collecting 8,500 kilograms per year.

Table 17 shows province-wide estimates for four recovery scenarios: where polyethylene only is collected under either curbside or return center scenarios, and where both polyethylene film and other film are collected, but where at most one is collected curbside and the other through return centers, or where both are collected through return centers. Recovery rate levels have also been estimated at two levels, with a low estimate based on an “average” curbside collection scenario or return center scenario,

whereas the high curbside estimate assumes a 50 percent increase over the low estimate. Since no programs currently accept non-polyethylene film, the estimate for that material was based the overall ratio of that stream in comparison to polyethylene generated and available for recovery – essentially the quantity of non-polyethylene/multi-laminate film recovered was estimated to equal polyethylene film recovery under any applicable scenario where it is collected.

Table 17 Ontario Film Recovery Scenarios

Total Film Collection Estimates				
Material Collected	Polyethylene Only		Polyethylene and Other Film	
Recovery Scenario	Curbside	Return Center	Curbside Plus Return Center	Return Center (Two Film Streams)
Recovery Rate	2-3 kg/HH	2 kg/HH	4-5 kg/HH	4 kg/HH
Total tonnes recovered	10,084-15,126 tonnes	10,084 tonnes	20,168-25,210 tonnes	20,168 tonnes
Percent Film Recovery*	11-17%	11%	23-29%	23%

*Based on 2011 generation data

Comparative Evaluation

Table 18 provides a summary comparative evaluation of curbside and return center system models for recovery. It also presents comparisons of moderate and high recovery rate scenarios for curbside-collected film, as well as comparisons if only polyethylene film is collected (recycling) or if non-polyethylene and multi-laminate films are collected (and directed to recovery markets). The comparative evaluation provides a side-by-side comparison of market factors, recovery level estimates, costs, and impacts on the existing system.

Table 18 Comparative Evaluation

Evaluation Factor	Curbside (moderate)	Curbside (high)	Return Center (on-site baling)	Return Center (no-cost hauling)
Market Considerations				
<ul style="list-style-type: none">Meets market quality specifications<ul style="list-style-type: none">RecyclingRecovery	<ul style="list-style-type: none">PoorAcceptable		<ul style="list-style-type: none">ExcellentExcellent	
<ul style="list-style-type: none">Current capacity in Ontario/Canada/ North America (tonnes/year)<ul style="list-style-type: none">RecyclingRecovery	<ul style="list-style-type: none">~5,000 (all N. America)←-----150,000/150,000/1,500,000-----→ (recovery capacity is for pyrolysis, engineered fuel, and industrial uses – capacity of mixed waste gasification/EFW is in addition to these figures)		<ul style="list-style-type: none">←----250,000 (all N. America) ----→	
<ul style="list-style-type: none">Market maturity/stability<ul style="list-style-type: none">RecyclingRecovery	<ul style="list-style-type: none">Immature—few North American marketsGrowing—only a couple Ontario markets, but more extensive in U.S.		<ul style="list-style-type: none">Excellent	
Recovery projections				
<ul style="list-style-type: none">Recycling (polyethylene) amount and rate	10,084 tonnes ¹ (11%)	15,126 tonnes ² (17%)	10,084 tonnes ¹ (11%)	10,084 tonnes ¹ (11%)
<ul style="list-style-type: none">Recovery (non-polyethylene) amount and rate	10,084 tonnes ¹ (11%)	15,126 tonnes ² (17%)	10,084 tonnes ¹ (11%)	10,084 tonnes ¹ (11%)
<ul style="list-style-type: none">Combined potential recycling and recovery amount and rate	Not applicable ³	Not applicable ³	20,168 tonnes (23%)	20,168 tonnes (23%)

Evaluation Factor	Curbside (moderate)	Curbside (high)	Return Center (on-site baling)	Return Center (no-cost hauling)
Cost Considerations				
<ul style="list-style-type: none"> Annual net cost <ul style="list-style-type: none"> Recycling of polyethylene film Recovery of non-polyethylene film 	<ul style="list-style-type: none"> \$3.6 million^{4,5} \$4.3 million^{5,9} 	<ul style="list-style-type: none"> \$6.7 million^{4,5,6} \$7.6 million^{5,6,9} 	<ul style="list-style-type: none"> \$2.3 million^{7,8} \$5.4 million^{7,9} 	<ul style="list-style-type: none"> \$0.8 million^{7,8} \$3.9 million^{7,9}
<ul style="list-style-type: none"> Other investments required <ul style="list-style-type: none"> First year promotion/education Recycling market development (PE) Recovery market development (non-PE) 	<ul style="list-style-type: none"> None \$4 million¹¹ None 	<ul style="list-style-type: none"> \$10.1 million¹⁰ \$8 million¹² None 	<ul style="list-style-type: none"> None None None 	<ul style="list-style-type: none"> None None None
Impact on Existing Approaches				
<ul style="list-style-type: none"> Consistency with existing approaches 	Consistent with many Ontario programs		Convenient municipal return centers may be lacking in areas with curbside collection	Commercial return centers at select retail grocers currently only accept PE carryout sacks
<ul style="list-style-type: none"> Single-stream versus dual-stream considerations 	Potentially more costly in single-stream systems; some potential to partially use separation equipment and reduce costs in dual-stream MRFs		Not applicable	Not applicable

¹Assumes collection of 2 kilograms of film per household per year.

²Assumes an increased recovery level of 3 kilograms per household per year based on an ongoing enhanced education and awareness program.

³Assumes opaque carryout sacks are reused as bags for curbside film collection. Because sorters in a MRF will not be able to distinguish between a carryout sack of PE film and a carryout sack of non-PE film, only one material stream or the other, but not both, can be collected curbside.

⁴Net revenue of \$25 per tonne.

⁵Includes a combination of sorting costs and equipment capital and operating costs. Manual sorting costs are estimated at \$500 per tonne, which assumes that the vast majority of film received at MRFs is in bags. In two stream MRFs, air separation equipment is assumed to be used for film separation from rigid containers, at a cost of \$180 per tonne. The weighted average for Ontario is assumed to be 60 percent manually separated and 40 percent air separated film, for a weighted average separation cost of \$372 per tonne. Cost of capital upgrades needed to separate film that is collected curbside includes the addition of vacuum conveying systems in MRFs that handle over 10,000 tonnes per year of recyclables, and air separators in two stream MRFs. Total province-wide capital cost is estimated at \$5.5 million, financed over ten years at a 4 percent interest rate, which results in an annualized cost of \$0.7 million. This cost has been estimated based on a general understand of technology employed in Ontario MRFs – a detailed MRF-by-MRF assessment based on individual facility needs and costs may result in a different estimate of cost.

⁶Includes ongoing communications expense of \$0.25 per household per year to encourage high levels of film recycling and reinforce film set-out best practices by consumers (\$130 per tonne), in addition to a minor incremental base collection cost of \$10 per tonne (based on information from a film recycling pilot program in Langley, British Columbia).

⁷Includes an estimate of the cost of small-footprint downstroke balers needed to handle film at return centers, where each return center recovers on average 8.5 tonnes of PE film per year, which would mean there are nearly 1,200 return centers in Ontario under this scenario. Capital cost is estimated at \$10,000 per baler, or \$11.9 million, financed over ten years at a 4 percent interest rate, which results in an annualized cost of \$1.5 million. This cost would be doubled if both PE and non-PE film are accepted at return sites, because the two types of film need to be kept and baled separately from each other.

⁸Net materials revenue of \$275 per tonne for clean return center polyethylene film.

⁹Net cost of -\$40 per tonne to send to a recovery facility.

¹⁰Assumes a province-wide promotion and education campaign with a cost of \$2.00 per household to institutionalize the use of film best practices and promote the use of retail carryout sacks as collection bags (including the messages to place film in bags and tie the bags tightly to avoid spillage).

¹¹Estimate of market development grant funding that may be needed to approximately double the reclamation capacity for curbside-collected film in Ontario (approximate cost estimate based on CIF/Stewardship Ontario funding expended for plastics market development in 2010/2011).

¹²Estimate of market development grant funding that may be needed to approximately triple the reclamation capacity for curbside-collected film in Ontario (approximate cost estimate based on CIF/Stewardship Ontario funding expended for plastics market development in 2010/2011).

The operating cost figures shown in Table 18 are additional incremental costs to recover greater quantities of film in Ontario and are based on the cost and recovery assumptions described above in this report section. These figures also assume that best practices with respect to collecting all film in bags

are adhered to (failure to collect film in bags can easily double the system costs). The cost figures include additional collection and processing costs, net of material revenues for polyethylene film, or costs associated with transportation and tip fees for non-polyethylene sent to recovery markets. Table 19 Ontario Province-wide System Costs for Film Recovery Scenarios presents additional detail for the annual operating cost and recovery figures shown in Table 18 above. It must be noted that the cost figures in this report do not represent allocated system costs that stewards of film would pay for their share of general capital, operating, administrative, and general promotion and education expenses, and including such costs would result in higher per tonne costs than the ones shown in this report.³¹

Table 19 Ontario Province-wide System Costs for Film Recovery Scenarios

Recovery System Model	Annual Tonnes	Collection Cost (millions)	Processing Cost (millions)	Market Value (millions)	Net Cost (millions)	Net Cost per Tonne
Curbside – polyethylene only – moderate recovery scenario	10,084 ¹	\$0.1 ²	\$3.8 ⁴	\$0.3 ⁵	\$3.6	\$357
Curbside – polyethylene only – high recovery scenario	15,126 ³	\$1.4 ⁶	\$5.6 ⁴	\$0.4 ⁵	\$6.7	\$440
Curbside – non-polyethylene film only – moderate recovery scenario	10,084 ¹	\$0.1 ²	\$3.8 ⁴	\$(0.4) ⁷	\$4.3	\$422
Curbside – non-polyethylene film only – high recovery scenario	15,126 ³	\$1.4 ⁶	\$5.6 ⁴	\$(0.6) ⁷	\$7.6	\$505
Return center – with on-site baling – polyethylene only	10,084 ¹	\$2.8 ⁸	\$2.3 ⁹	\$2.8 ¹⁰	\$2.3	\$225
Return center – with on-site baling – non-polyethylene film	10,084 ¹	\$2.8 ⁸	\$2.3 ⁹	\$(0.4) ⁷	\$5.4	\$540
Return center – with free loose film back-haul – polyethylene only	10,084 ¹	\$2.8 ⁸	\$0.8 ¹¹	\$2.8 ¹⁰	\$0.8	\$75
Return center – with free loose film back-haul – non-polyethylene film	10,084 ¹	\$2.8 ⁸	\$0.8 ¹¹	\$(0.4) ⁷	\$3.9	\$390

¹Assumes collection of 2 kilograms of film per household per year.

²Assumes a relatively minor incremental cost of \$10 per additional tonne of film collected to existing curbside collection programs based on information from a film recycling pilot program in Langley, British Columbia.

³Assumes an increased recovery level of 3 kilograms per household per year based on an ongoing enhanced education and awareness program.

⁴Includes a combination of sorting costs and equipment capital and operating costs. Manual sorting costs are estimated at \$500 per tonne, which assumes that the vast majority of film received at MRFs is in bags. In two stream MRFs, air separation equipment is assumed to be used for film separation from rigid containers, at a cost of \$180 per tonne. The weighted average for Ontario is assumed to be 60 percent manually separated and 40 percent air separated film, for a weighted average separation cost of \$372 per tonne. Cost of capital upgrades needed to separate film that is collected curbside includes the addition of vacuum conveying systems in MRFs that handle over 10,000 tonnes per year of recyclables, and air separators in two stream MRFs. Total province-wide capital cost is estimated at \$5.5 million, financed over ten years at a 4 percent interest rate, which results in an annualized cost of \$0.7 million. This cost has been estimated based on a general understand of technology employed in Ontario MRFs – a detailed MRF-by-MRF assessment based on individual facility needs and costs may result in a different estimate of cost.

⁵Net materials revenues of \$25 per tonne.

⁶Assumes a relatively minor incremental cost of \$10 per additional tonne of film collected to existing curbside collection programs based on information from a film recycling pilot program in Langley, British Columbia plus a more significant ongoing communications expense of \$0.25 per household per year (\$130 per tonne) to encourage high levels of film recycling and reinforce film set-out best practices by consumers.

⁷Net cost of -\$40 per tonne to send to a recovery facility.

⁸Based on an estimated cost of \$268 per tonne to empty collection containers and move film to a back room area, plus \$5 per tonne for collection container liners (a total collection cost of \$273 per tonne).

⁹Includes cost elements for baling labour, annualized baler capital cost, baling wire, energy cost, and cost to transport individual bales of film to a central warehouse that total an estimated \$227 per tonne (as presented in detail in Table 14). Baler capital cost is highly sensitive to recovery quantities at each site – this analysis assumes each return center recovers on average 8.5 tonnes of PE film per year, which would mean there

³¹ Allocated costs and steward fee rates must come from Stewardship Ontario cost allocation studies.

are nearly 1,200 return centers in Ontario under this scenario. Capital cost is estimated at \$10,000 per baler, or \$11.9 million, financed over ten years at a 4 percent interest rate, which results in an annualized cost of \$1.5 million. This cost would be doubled if both PE and non-PE film are accepted at return sites, because the two types of film need to be kept and baled separately from each other.

¹⁰Net materials revenues of \$275 per tonne for clean return center polyethylene film.

¹¹Includes cost elements for baling labour, annualized baler capital cost, baling wire, and energy cost that total \$77 per tonne (as presented in detail in Table 13).

Conclusions

Film Collection and Sorting

- The project team did not find any technologies that would be expected to be commercially available now or in the near future that would have the ability to cost-effectively sort polyethylene film from non-polyethylene/multi-laminate films, or to sort non-polyethylene/multi-laminate films into different resin streams in materials recovery facilities or at reprocessors;
- To promote greater recycling of flexible film, it is currently better to collect polyethylene film separately from non-polyethylene/multi-laminate films;
- It is not currently feasible to manually sort non-polyethylene/multi-laminate residential films into different streams for recycling, as evidenced by the lack of even low labour cost export markets for such mixed films; however, those materials may be suitable for recovery markets in Canada or the United States that will convert them into energy or chemicals subject to the market specifications;
- Currently, only polyethylene film may be collected curbside if film is to be recycled at a moderate cost (recycling costs would be much higher than shown in this report if all types of film were collected mixed curbside);
- Non-polyethylene/multi-laminate film cannot be recycled at this time, but has the potential to be utilized by recovery markets;
- Polyethylene and non-polyethylene/multi-laminate film may both be collected through return centers; however, they must be collected and baled separately from each other since polyethylene film goes to recycling markets and non-polyethylene/multi-laminate film could go to a recovery market;
- Collecting film through commercial return centers that have free back-haul of loose film to central baling locations is the lowest-cost way to produce high-end market ready material at \$75 per tonne for polyethylene, and \$390 per tonne for non-polyethylene film;
- If free back-haul of loose film is not available, collecting and processing film through return centers where there is a cost associated with hauling away the film is more costly than curbside collection on average that is operated under best practices; however, the high market value of polyethylene film collected through return centers results in a lower net cost of recovery of \$225 per tonne for polyethylene film – the same is not the case for non-polyethylene film whose net cost is \$540 per tonne, and there is no financial advantage to collecting non-polyethylene film through return centers;
- Curbside recycling of moderate levels of film in Ontario using best practices is estimated to have a net cost of \$357 per tonne for polyethylene film and \$442 per tonne for non-polyethylene film; if higher recycling rates are desired, additional ongoing program promotion may be required, which can increase net costs to \$440 and \$505 per tonne respectively;
- Return center collection can approach the recovery of a moderate curbside collection program; however, it will not achieve the recovery rate potential of a high performing curbside program.

Film End Markets

- There is sufficient market capacity to accept large increases in clean polyethylene film recycling and non-polyethylene/multi-laminate film recovery in Ontario;
- There is sufficient recovery market capacity to accept large increases in non-polyethylene/multi-laminate film collection in Ontario; and
- The reprocessing capacity in Ontario and North America for curbside-collected film is inadequate – if more polyethylene film is to be collected curbside and recycled in Ontario/North America and not sent to Asia, additional film wash line investments would be required, ranging from \$4 to \$8 million, depending on the additional quantity of polyethylene film to be collected.

Section 6: Packaging Design Barriers to Reprocessing and Opportunities and Lifecycle Implications of Alternative Designs

Design Barriers to Recycling

The choices that package designers make when designing a package result in characteristics of the flexible plastic film that impacts the technical and financial feasibility of recycling the film product. Table 20 presents several design-related barriers to reprocessing. The most problematic design choice elements reported by plastics recycling markets are listed first, followed by design choice elements that are less impactful. It should be noted that the recycled content product/market application affects the severity of the problem and impact. For example, a thick-section blow molded plant pot made from recycled film that is pigmented black is less sensitive to many of the design choice elements than would be a recycled content carryout sack application.

Table 20 Design Barriers to Reprocessing

Design choice element	Problem	Consideration/impact for this study
1. Use of a resin other than polyethylene (single resin)	<ul style="list-style-type: none"> Non-PE resins have different melting temperatures than PE and separate when melted/mixed – each needs to be sorted from all others for material recycling Existing North American <u>consumer</u> infrastructure only recycles PE and does not sort mixed resins 	<ul style="list-style-type: none"> Resins other than PE are contamination in the existing system There is no commercially-available automated equipment to sort mixed resin films Non-PE must be either separately collected, sorted by hand, or sent to recovery markets
2. Multilayer structures	<ul style="list-style-type: none"> Issue relates to #1 above; also layers are laminated and cannot be mechanically separated 	<ul style="list-style-type: none"> Only option is recovery markets
3. Degradability additives	<ul style="list-style-type: none"> Additives may cause product failure in recycled-content products depending on application 	<ul style="list-style-type: none"> Film with degradability additives generally cannot be identified and separated from film without additives If added to PE film, makes that film unacceptable by recycling markets
4. Metallized film	<ul style="list-style-type: none"> Metals (aluminum) cannot be separated from the film 	<ul style="list-style-type: none"> Minor visual aesthetic impact on recycled resin from vapour-deposited aluminum for thick (non-film) applications; non suitable for film-to-film applications Foil laminates are not considered recyclable due to large pieces of foil in the recycled resin
5. Use of fillers	<ul style="list-style-type: none"> Fillers change material density 	<ul style="list-style-type: none"> Washing of polyolefin films with fillers causes loss of polyolefins if the film density exceeds 1 g/cc (> 10% calcium carbonate filler)

Design choice element	Problem	Consideration/impact for this study
6. Fitments	<ul style="list-style-type: none"> Fitments added to flexible materials such as carrying handles or reclosure may be resin-compatible for recycling 	<ul style="list-style-type: none"> Significant weight of fitments in comparison to flexible materials means they need to be compatible/ recyclable if used on recyclable packaging
7. Colorants	<ul style="list-style-type: none"> Certain film colours may not be accepted by certain markets (e.g., blue, black) 	<ul style="list-style-type: none"> May require hand sorting adding to system cost
8. Printing	<ul style="list-style-type: none"> Heavily printed film can cause excessive off-gassing during reprocessing and off-colour recycled resin 	<ul style="list-style-type: none"> Reclaimers may need to upgrade extrusion equipment for venting if heavily printed films are reprocessed

Lifecycle Comparison of Alternative Designs

Package choices based on the recyclability of packaging materials fall into one of two categories:

- Choices between different package formats (e.g., steel can versus plastic laminate) where each format has different package recycling rates; and
- Choices between different flexible materials as part of a flexible film package (e.g., a multilayer laminate of recycling-incompatible films versus a single layer or multi-layer construction of compatible resins).

These two categories are discussed separately below.

Choice between Different Formats

Tables 21 and 22 provide two case study examples that illustrate the lifecycle impacts associated with different package formats for ground coffee and dried fruit snacks respectively.

Table 21 Summary of Lifecycle Impacts for Different Coffee Package Formats

Package Format	Package Weight ¹ (g)	Disposal after Recycling ² (g)	Energy Consumption ³ (MJ/package)	Global Warming Potential ³ (kg CO ₂ e/package)
Steel can with LDPE lid (11.5 ounces of coffee)	96.1	39.3	4.21	0.33
HDPE canister & LDPE lid (11.5 ounces of coffee)	58.6	28.2	5.18	0.17
Flexible brick laminate (11.5 ounces of coffee)	11.3	11.3	1.14	0.04

¹ Weights for the metal canister and plastic canister are from the Editors of *The ULS Report*, "A Study of Packaging Efficiency as it Relates for Waste Prevention" (2007); weights for the flexible brick laminate comes from the Flexible Packaging Association "Flexible Packaging, Less Resources, Less Footprint, More Value" (2009).

² Based on recycling rates for individual packaging components calculated from Stewardship Ontario's worksheet 2013_PIM_final.xlsm (lids were assumed to have the other plastic packaging recycling rate).

³ From the Flexible Packaging Association "Flexible Packaging, Less Resources, Less Footprint, More Value" (2009).

Table 22 Summary of Lifecycle Impacts for Different Dried Fruit Snack Package Formats

Package Format	Package Weight ¹ (g)	Disposal after Recycling ² (g/24 oz. snack)	Energy Consumption ³ (MJ/24 oz. snack)	Global Warming Potential ³ (kg CO ₂ e/24 oz. snack)
Round coated paperboard canister with LDPE lid (24 ounces of snack)	39.7	22.9	2.16	0.13
Folding paperboard carton with inner LDPE bag lid (12 ounces of snack)	22.7	29.5	1.95	0.16
Flexible laminate stand-up pouch (24 ounces of snack)	11.3	11.3	1.06	0.05

¹ Weights comes from the Flexible Packaging Association "Flexible Packaging, Less Resources, Less Footprint, More Value" (2009).

² Based on recycling rates for individual packaging components calculated from Stewardship Ontario's worksheet 2013_PIM_final.xlsm (lids were assumed to have the other plastic packaging recycling rate).

³ From the Flexible Packaging Association "Flexible Packaging, Less Resources, Less Footprint, More Value" (2009).

As Tables 21 and 22 show, different packages have different impacts. These impacts are primarily driven by how efficient the packaging is in terms of grams of package weight per equivalent amount of product delivered, with the less packaging required to deliver an equivalent amount of product the better. Other but less impactful effects are how energy intensive it is to produce the raw materials used, and to a lesser degree the recyclability, based on actual recycling rates of the package. The flexible laminate formats used in both of these examples have a zero percent recycling rate, whereas the other formats have recycling rates that range from 35 to 59 percent in Ontario. The conclusion to be drawn from these case studies is that lifecycle impacts such as minimizing landfilling, reducing energy use, and reducing global warming potential are minimized when flexible packaging is used, even if the flexible packaging is not able to be recycled as compared to other "recyclable" rigid package formats.

Choice of Different Film Resins

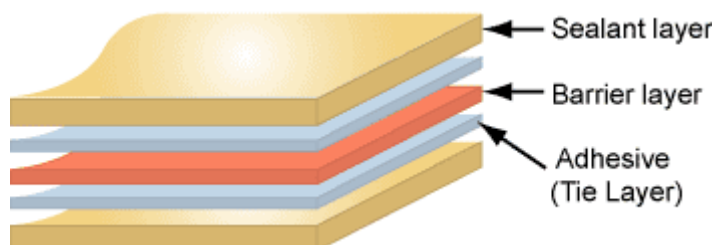
The package format choice that is preferred based on lifecycle considerations, therefore, comes down to whether there are redesign opportunities that can be considered for flexible film formats to improve their recyclability. There is no perfect, universal packaging material for all packaging applications. To illustrate this, it is useful to review some of the design considerations for packaging.

Packaging is typically asked to meet several requirements simultaneously, including:

- Mechanical properties, such as, tensile strength, stiffness, abrasion resistance, shrinkability, temperature stability, elongation, formability;
- Optical properties such as clarity, surface gloss;
- Sealability, such as package seals, safety seals, and closure/reclosure; and
- Barrier properties when packaging foods or pharmaceuticals, such as oxygen barrier, oil barrier, moisture barrier, or light barrier.

Laminates assemble different layers of materials into one multilayer structure, where each layer individually contributes a desirable or required property, so that the combination of layers optimally meets the total package requirement. Because individual film plastics layers are chemically different, they don't naturally adhere to each other, so tie layers are also required in addition to the performance layers to keep the whole structure together so the different layers do not delaminate. Figure 14 provides a generic example of a multi-layer film structure. Such structures may be composed of three, five, seven, and in some cases as many as nine layers.

Figure 14 General Multi-Layer Film Structure



As an example of how the different layers work together, consider the flexible laminate stand-up pouch shown above in Table 22 for snacks. A stand-up pouch for snacks is typically made of the following layers, from the outside of the package to the inside: 15 μ PET / 2 μ adhesive / 100 μ LLDPE. The PET layer provides an oxygen barrier (to keep the product fresh) and a transparent film and surface for high-quality printing, which is reverse printed on the inside surface of the PET layer. The LLDPE layer is then “glued” to the printed PET using an adhesive tie layer. For this example, the LLDPE needs to be thick enough to provide package stiffness so that the pouch can support the weight of the product without collapsing. The LLDPE also allows the package to be heat sealed after being filled so that additional sealing adhesives are not needed.

For this package to be redesigned of compatible polymers in order to be considered recyclable, it still would need approximately the same thickness so that it could stand and hold its product without collapsing (i.e., mechanical stiffness requirement). If a single layer of polyethylene were chosen, it would need to be over three times as thick in order to have the same oxygen barrier performance; however, this would not be desired from a lifecycle impacts assessment as illustrated in Tables 21 and 22 above, since less material usage provides better lifecycle impacts results. Alternatively, the following multilayer construction, which is related to that used for cereal box liners, could be used: 30 μ LLDPE / 4 μ tie layer / 5 μ EVOH / 4 μ tie layer / 70 μ LLDPE. This recyclable structure provides better oxygen barrier than the PET/LLDPE construction; however, its appearance won’t have the same surface gloss or as high quality of printing that can be performed with PET film. LLDPE also stretches much more than PET and such a construction would likely prove problematic from a mechanical perspective because it may stretch too much on the machines that are used to form and fill the package.

Oriented polypropylene (OPP) is often used in food packaging films because it can provide good mechanical properties for form and fill machinery in comparison to PET. It is often metallized to provide gas and/or light barrier properties that it lacks; however, OPP needs a separate heat seal layer, which can be provided by cast polypropylene or low density polyethylene. Polypropylene and polyethylene are generally not compatible with each other when recycled together (except at very low levels of one in the other). Although multilayer packages that are nearly all PP can be produced and recycled, the post-consumer recycling challenges would remain that were discussed previously in this report – namely, polypropylene packaging will need to be separated from polyethylene materials by the generator due to limitations in sorting technology and collected as a separate film stream. Consumer participation and education, and recycling system handling expense, become increasingly problematic if separating films into more than two film streams is contemplated.

An overarching consideration regarding any design for recycling change that is being contemplated is to consider whether the change may result in any increased product loss or spoilage. The primary purpose

of a package is to contain and protect the product. Lifecycle impacts of products normally far exceed those of the package itself. One packaging company, for example, has modeled that if a 2 percent increase in beef steak waste occurred due to a seemingly minor packaging performance compromise (such as a redesign for recyclability that diminishes package integrity or gas barrier properties), the negative impact on carbon global warming potential will be five times that of the total carbon footprint of the entire package itself.³² This is because hundreds of times more resources have gone into producing the product than the package itself.

Packaging Design Conclusions

Interviews were conducted with several packaging companies as part of this project to identify where potential redesign could improve recyclability. All persons interviewed concurred that any proposed redesign needs to be carefully considered for each specific package application individually, to see what the effects may be on the ability of package form and fill lines to handle the packaging material (whether at all or at efficient speeds), the cost of the final package, and environmental impacts. All packaging companies also concurred that any diminishing of package performance that could lead to increased product loss or spoilage would not be acceptable.

The above caveats do not mean that there is no opportunity to make some changes to packaging designs for certain applications that can result in improvements in the recyclability of those specific packages. A couple of packaging companies have developed or have researched flexible packaging materials that have improved recyclability. These materials are either more costly than alternatives, or are limited to very specific applications (e.g., frozen food vegetable packaging). Only one company representative offered a specific recommendation, which was to phase out chlorinated materials such as PVC and PVDC as it was his belief that alternative materials with equivalent performance properties are available. It should be noted that this suggestion also has applicability to recovery markets since chlorinated materials are problematic to those markets as well.

This section began by listing several design barriers in Table 20. Of the barriers listed, we believe that rarely is there a legitimate performance requirement for degradability additives to be incorporated into traditional non-biodegradable polymers like polyethylene and such additives are considered to be barriers to recycling by film plastics recyclers. We also believe that high use of fillers (over ten percent) is also not necessary, although this tends to be a severe barrier only if film retail carryout sacks are collected curbside and require washing as part of the recycling process.

In summary, the following film packaging redesign suggestions are broad in applicability and may be considered in Ontario:

- Phase out chlorinated materials such as PVC and PVDC;
- Restrict the use of degradability additives for otherwise non-biodegradable polymers;
- Limit the use of fillers to no more than ten percent content in film carryout sacks.

However, it was beyond the scope of this project to solicit industry-wide feedback on these redesign suggestions, so no firm recommendation is made in this report. The sponsors of this study should consider further consultations regarding these suggestions before acting on them.

³² “Thinking Beyond the Package: Focus on What Matters Most” Dr. Ronald Cotterman of Sealed Air presentation at the Sustainable Packaging Forum, September 21, 2011.

Appendix A – Residential Film Generation Growth Projections

Table 23 shows estimates for historical and projected future quantities of residential film packaging generated in Ontario, in metric tonnes.

Table 23 Generation of Forecast of Ontario Residential Packaging Films

	← historical							estimated →										
Generation Forecast	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
LDPE/HDPE film	61,500	32,000	31,100	39,100	38,300	35,600	37,400	37,800	38,200	38,600	38,900	39,300	39,700	40,100	40,500	40,900	41,300	41,800
LDPE/HDPE film carry-out bags	n/a	28,500	28,600	22,000	15,000	13,600	14,900	14,300	14,400	14,600	14,700	14,800	15,000	15,100	15,300	15,500	15,600	15,800
Plastic laminate non-beverage	25,800	26,900	29,300	30,200	32,600	33,700	34,700	35,700	36,800	37,900	39,000	40,200	41,000	41,800	42,700	43,500	44,400	45,300
Plastic laminate beverage	n/a	n/a	n/a	n/a	n/a	n/a	440	480	520	560	610	660	690	720	750	780	810	850
Biodegradable plastic film	n/a	n/a	n/a	170	240	190	250	280	300	330	370	400	420	440	450	470	490	510
Total	87,300	87,400	89,000	91,470	86,140	83,090	87,690	88,560	90,220	91,990	93,580	95,360	96,810	98,160	99,700	101,150	102,600	104,260

The historical estimates shown in Table 23 come from a combination of Stewardship Ontario data, internal Reclay StewardEdge data, laminated beverage per-capita consumption data from British Columbia, and data on bag-in-box wine sold by the Liquor Control Board of Ontario. Future projections are based on annual growth rates, with separate factors for the first five years (2012 through 2016) versus the period that follows. Table 24 provides a summary of the information that was considered in selecting growth rates for use in this study.

Table 24 Summary of Information for Future Estimates of Residential Film Packaging Generation

Category	2012-2016	2017-2022	Notes/basis of estimates
LDPE/HDPE film	1%	1%	<ul style="list-style-type: none"> Assumes steady per capita consumption and 1% population growth per year based on Reclay StewardEdge interviews of packaging industry firms
LDPE/HDPE film carry-out bags	1%	1%	<ul style="list-style-type: none"> Assumes steady per capita consumption and 1% population growth per year based on Reclay StewardEdge interviews of packaging industry firms

Category	2012-2016	2017-2022	Notes/basis of estimates
Laminates non-beverage	3%	2%	<ul style="list-style-type: none"> • PCI predicts growth "in unit volume terms demand for [flexible packaging in] the North American region as a whole is forecast at 2.0 – 2.5% per annum over the next five years." • Allied Development Corporation in "Stand-up Pouches 2012-2016" projects an 11.6% annual global growth rate for stand-up pouches (however, this is only for part of the laminate market, and other applications, such as chip/snacks are already in laminates will not grow at this rate; furthermore, a lower stand-up-pouch growth rate is expected in North America compared to other countries). • PCI predicts that the world growth rate for oriented polypropylene film will be 6.6% per year, with the bulk of this growth occurring in Asia • Reclay StewardEdge interviews of packaging firms suggested a North American growth rate for oriented polypropylene of 1-2% per year, due to conversions out of PE • For the overall category, assume a Canadian annual growth rate of 3% in the first 5 years, dropping to 2% later
Laminates beverage (juice)	1%	1%	<ul style="list-style-type: none"> • Assumes steady per capita consumption and 1% population growth per year based on Reclay StewardEdge interviews of packaging industry firms
Laminates beverage (bag in box wine)	10%	5%	<ul style="list-style-type: none"> • Box wine growth in the United States was 19.9% from 2009 to 2010 (http://www.time.com/time/business/article/0,8599,1995832,00.html) • Assume a more modest annual growth rate of 10% in the first 5 years, dropping to 5% later; note that this is highly dependent on the product selection offered by the Liquor Control Board of Ontario
Biodegradable plastic film	10%	4%	<ul style="list-style-type: none"> • A 2008 report by The Freedonia Group predicted 13% annual biopolymer film growth. In a 2012 bio-plastics report that included other non-film uses, Freedonia projected that biopolymers would grow from 220 million pounds in North America in 2011 to 550 million pounds in 2016 (a 20 percent annual growth rate – it is important to note that Freedonia is including PE made from bio-origin chemicals in its figures, even though those material are not biodegradable) • Reclay StewardEdge interviews of packaging firms suggested that consumer packaged goods company initial interest in biodegradable film is waning; furthermore, concerns over the potential to contaminate PE films collected in the existing recycling infrastructure is expected to limit growth as well – assume a 10% annual growth rate for the first 5 years, dropping to 4% later

Appendix B – List of Technology Vendors

MRF Equipment Vendors

CP Manufacturing
1300 Wilson Ave, National City CA 91950
6194773175
hanso@cpmfg.com
<http://www.cpmfg.com/>

Bulk Handling Systems (BHS)
3592 West 5th Avenue, Eugene, OR 97402 USA
8666882066
robbe@bhsequip.com
<http://www.bulkhandlingsystems.com/>

Van Dyk/Bollegraaf
78 Halloween Blvd, Stamford, CT 06902
2039671100
peenkemavandijk@vandykbaler.com
KBrogan@VanDykBaler.com
<http://www.vandykbaler.com/contact.htm>

Machinex
2121, rue Olivier, Plessisville, Qc, Canada
7738678801
nbelanger@mti.machinex.ca
chawn@mti.machinex.ca
<http://www.machinexrecycling.com/>

RRT (Resource Recycling Technologies)
125 Baylis Road, Melville, NY 11747-3895
6317561060
negosi@RRTenviro.com
mjones@rrtenviro.com
<http://www.rrtenviro.com/>

Green Machines
5 Gigante Dr., Hampstead, NH 03841 USA
6033297337
jgreen@greenmachinesales.com
<http://www.greenmachinesales.com/>

SC Enviromental
11520 N. Port Washington Rd. Suite 205
Mequon, WI 53092
Phone: 262-240-1992
<http://www.scenviro.net/contact.html>

JWR, Inc
322 N Watertown St Johnson Creek, WI 53038
(920) 699-2848
jwrinc.net

Recycling Equipment Manufacturing, Inc.
373 Shannon Ln Priest River, ID 83856
(208) 448-4736

Optical Sorter Vendors

MSS
3738 Keystone Av., Nashville, TN 37211
6154810828
hotrock@magsep.com
<http://www.magsep.com/>

NRT
1508 Elm Hill Pike, Suite 102
Nashville, TN 37210 United States
1.615.734.6400
Sales@nrtsorters.com
<http://www.nrtsorters.com/>

Titech
78 Halloween Blvd, Stamford, CT 06902
2035243555
wolf@titech.com
<http://www.titech.com/>

Eagle Vizion
262 PEPIN STREET, OFFICE 201, SHERBROOKE,
QUEBEC, CANADA J1L 2V8
8195637374
NLortie@EagleVizion.com
<http://www.eaglevizion.com/>

Pellanc
921 Arrowhead Terrace, Clayton CA 94517
9258908350
a.descoins@pellencst.com
<http://www.pellencst.com/>

Steinert
285 Shorland Drive
Walton, KY 41094
(800) 595-4014
sales@steinertus.com
www.steinertus.com/

Recovery Systems Company, Inc
1617 5th Street South
Hopkins, MN 55343
888-935-4330
952-935-4330
Colleen@recoverysy.com

Appendix C – Return Center Cost Assumptions and Sensitivity Analysis

Return Center Cost Assumptions

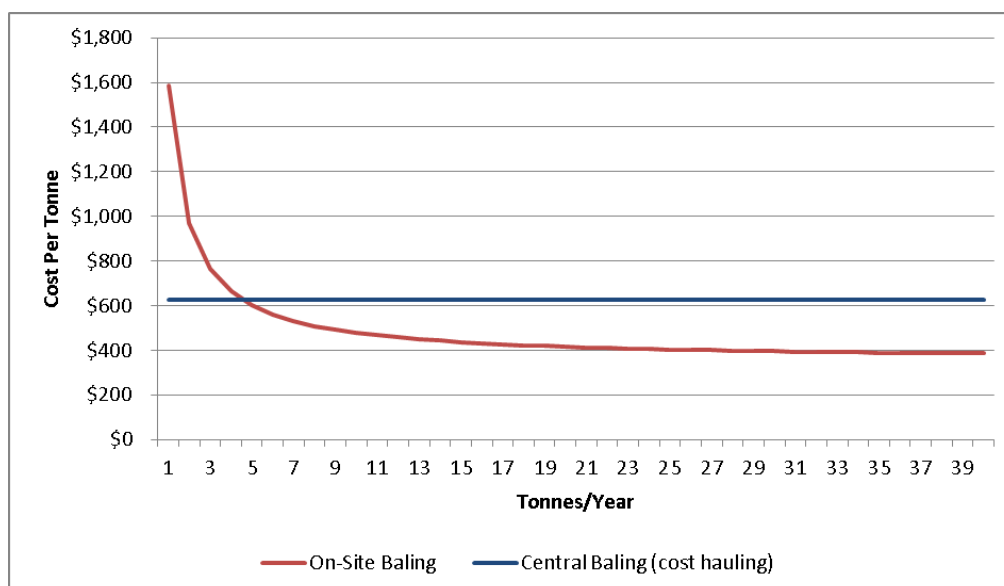
The following factors and assumptions were used to estimate return center film recovery costs:

1. Film collection/handling costs (composing slightly more than half of total cost):
 - Film is collected in boxes or gaylords assumed to have an average capacity of 0.5m³, although this size will likely vary across return centers;
 - The mass of film in 0.5m³ collection containers will be approximately 14kg when full, and require an estimated 15 minutes of handling time to empty and move to a back room; and
 - Labour costs were estimated at \$15 per hour, resulting in a cost of approximately \$268 per tonne to collect film.
2. Baling equipment and labour (composing slightly less than half of total cost):
 - Material is baled on-site with a low-footprint vertical baler costing \$10,000 that is financed over 10 years at a rate of 4 percent (\$1,233 annual cost).
 - Baler capital cost per tonne depends on the annual tonnes baled.
 - Boxes & Bags per tonne \$5 per tonne
 - Baling Wire \$5 per tonne
 - Baler Energy Cost \$0.50 per tonne
 - Baling Labour \$41 per tonne

Return Center Size and Cost per Tonne

Figure 15 shows the sensitivity of on-site return center baling equipment and labour cost as a function of annual tonnes per site compared to hauling of loose film (at cost) with centralized baling. As the figure shows, on-site baling cost increases exponentially and becomes significantly more expensive than hauling of loose film for centralized baling once return center tonnage falls below 5 tonnes per year.

Figure 15 Cost Relative to Return Center Size



Appendix D – References

This project included an international literature review of recent publications, articles, and reports of potential bearing on the work. An annotated bibliography of this review is included in this appendix.

Table 25 Literature Review Summary

	Document, Study or Report	Topic	Overview of Content
Online Articles			
1.	Dailyrecord.co.uk, 2012. Scottish supermarket buck UK trend with 'no significant rise' in number of plastic bags used by customers. <i>Dailyrecord.co.uk</i> , [online] 5 July. Available at: http://www.dailyrecord.co.uk/news/business-consumer/scottish-supermarkets-buck-uk-trend-1166101 [Accessed 3 August 2012] Provided by: CPIA	<ul style="list-style-type: none"> Plastic bags Generation United Kingdom 2 pages 	<ul style="list-style-type: none"> Overview of single-use plastic bag use at supermarkets in UK <ul style="list-style-type: none"> Scottish shoppers have not increased their use of single-use plastic bags used at supermarkets However, in the rest of the UK use of carrier bags has risen about 5.4 per cent to almost 8 billion-average of 11 bags a month per customer in 2011. This is the second year in a row that there has been an increase. However use of single-use plastic bags has fallen by more than a third (35 per cent) since 2006. Reason for increase in rest of UK: British Retail Consortium state it is due to financial constraints resulting in several small shops a week rather than one big shop, and more shoppers switching from using cars to public transport. Figures from Wrap showed the amount of new plastic being used to make carrier bags, including "bags for life", had fallen by more than half (51per cent) since 2006. In 2011 the amount of new plastic used rose by 11per cent but Wrap said the overall decline suggests more recycled materials are being used in plastic bags.
2.	Glaberson, H., 2011 rPET and rHDPE manufacturer to double capacity with £12m investment. <i>FoodProductionDaily.com</i> , [online] 1 February. Available at: http://www.foodproductiondaily.com/Packaging/rPET-and-rHDPE-manufacturer-to-double-capacity-with-12m-investment [Accessed 2 October 2011] Provided by: CPIA	<ul style="list-style-type: none"> Mixed plastics Reprocessing United Kingdom 2 pages 	<ul style="list-style-type: none"> Announcement of Closed Loop Recycling's expansion plan to double current capacity of its London site to 60,000 tonnes <ul style="list-style-type: none"> Closed Loop Recycling recycles PET and HDPE plastic bottles into food-grade material for new food and drink packaging. Its current capacity allows the production of 35,000 tonnes of mixed plastic bottles, producing 11,000 tonnes of rPET and 6,000 tonnes of rHDPE per annum.
3.	Harrington, R., 2011. Packaging body hails plastic film recycling plan. <i>FoodProductionDaily.com</i> , [online] 7 April. Available at: http://www.foodproductiondaily.com/Packaging/Packaging-body-hails-plastic-film-recycling-plan	<ul style="list-style-type: none"> Film Collection United Kingdom 2 pages 	<ul style="list-style-type: none"> Overview of initiative by UK retailers to collect clear plastic films for recycling <ul style="list-style-type: none"> Initiative could potentially divert up to 645,000 tons of plastics packing films from going to landfill A pact between the country's biggest supermarkets and the On Pack Recycling Label

	Document, Study or Report	Topic	Overview of Content
	recycling-plan [Accessed 10 April 2011] Provided by: CPIA		(OPRL) scheme means UK shoppers will be able to recycle thin plastic packaging such as bread bags and cereal liners for the first time <ul style="list-style-type: none"> o The British Retail Consortium (BRC) said thin plastic films account for 43 per cent of all plastic household waste. By comparison plastic bottles account for 32 per cent at 480,000 tonnes. o Thin plastic film is fully recyclable but until now most people have had no means of recycling it, it said.
4.	Sloley, C., 2011. Biffa Polymers officially opens mixed plastics plant. Let's Recycle.com, [online] 18 March. Available at: http://www.letsrecycle.com/news/latest-news/plastics/biffa-polymers-officially-opens-mixed-plastics-plant [Accessed 26 April 2011] Provided by: CPIA	<ul style="list-style-type: none"> ▪ Mixed plastics ▪ Reprocessing ▪ United Kingdom ▪ 2 pages 	<ul style="list-style-type: none"> ▪ Overview of Biffa Polymer's first large-scale dedicated mixed plastic sorting and reprocessing facility <ul style="list-style-type: none"> o 20,000 tonnes-a-year capacity plant o Will accept commercial and municipal material o Facility will process residues from the plastic bottle fraction, such as natural and mixed colour polypropylene, polyethylene and polyethylene terephthalate in addition to PVC and PS. o Some outputs will be processed through Biffa's food grade HDPE recycling facility on the same site, where material is cleaned extensively granulated in order to go back into the manufacture of plastic milk bottles.
5.	Staff~ The Guardian, 2008. PEI leads Canada with highest plastic bag recycling rate in North America. The Guardian, [online] 16 September. Available at: http://www.theguardian.pe.ca/Living/Environment/2008-09-16/article-1374293/PEI-leads-Canada-with-highest-plastic-bag-recycling-rate-in-North-America/1 [Accessed 3 August 2012]. Provided by: CPIA	<ul style="list-style-type: none"> ▪ Plastic bags ▪ Collection ▪ Reprocessing ▪ Canada (PEI) ▪ 2 pages 	<ul style="list-style-type: none"> ▪ Overview of Inteplast's closed loop bag-to-bag recycling program <ul style="list-style-type: none"> o PEI has a 57 per cent plastic bag recycling rate. The highest in North America o Program involves- Inteplast-made shopping bags are used and then collected from retailers, sent back to Inteplast and remade into new plastic shopping bags and returned to retailers for use. o Inteplast has some 200 stores across Atlantic Canada in the at-store bag recycling program- 17 stores in PEI.
Presentations			
6.	Davidson, P., WRAP, no date. Update on WRAP's Plastics Recycling Activities Provided by: CPIA	<ul style="list-style-type: none"> ▪ Mixed plastics ▪ Reprocessing ▪ United Kingdom ▪ 28 slides 	<ul style="list-style-type: none"> ▪ Presentation on WRAP's plastic recycling activities <ul style="list-style-type: none"> o Mixed plastics- use density separation- polyolefins float o Summary: mixed plastics recycling is rapidly developing (off a very low base); new technology and plant designs appearing; learning more about pack design influence on recycling. o Not much information within presentation in relation to flexible plastics.
7.	Kosior, E., Nextek Limited, 2010. Commercial scale mixed plastics recycling and recent innovations in plastics recycling. Plastics Recycling Conference. Austin, Texas, 2-3 March 2010 [presentation is of projects detailed in WRAP report- Final report: commercial	<ul style="list-style-type: none"> ▪ Mixed plastics ▪ Film ▪ Collection ▪ Reprocessing ▪ United Kingdom ▪ 66 slides 	<ul style="list-style-type: none"> ▪ Presentation from Nextek of projects <ul style="list-style-type: none"> o MRF processing project <ul style="list-style-type: none"> - Mixed plastics from household packaging waste - either recycled into film or EFW - Composition of 100 tonnes of mixed plastics: 0.5 % was film o Retail take back project <ul style="list-style-type: none"> - Front-of-store collection points

	Document, Study or Report	Topic	Overview of Content
	scale mixed plastics recycling, a report on the technical viability of recycling mixed plastic packaging waste from domestic sources on a commercial scale in the UK] Provided by: CPIA		<ul style="list-style-type: none"> - Composition of retail plastics collected: 3% plastic film o Film processing investigation <ul style="list-style-type: none"> - Hand sort trial- very slow and difficult - Automated sorting (NIR sort and agglomeration at Relux Germany) - Successful recovery of materials- commercial throughputs achieved with excellent odour removal, loss of dark colouration and devolatilisation o Conclusions of trial projects <ul style="list-style-type: none"> - Recycling of mixed plastics in UK is technically viable on a large (commercial) scale - Maximum material recovery achieved in the trials was 55% of total input - An integrated PRF + reprocessing site could achieve approximately 60% via optimal recovery of rejected materials - Residues from the trials are not recyclable due to complexity of separation but can be used for combined heat and power recovery
8.	Mascarello B., Hilex Poly Recycling, no date. Hilex Poly Recycling: materials used, technologies employed. The Plastics Recycling Conference. Provided by: CPIA	<ul style="list-style-type: none"> ▪ Plastic bags ▪ Collection ▪ Reprocessing ▪ USA (recycling facility in North Vernon, IN) ▪ 8 slides 	<ul style="list-style-type: none"> ▪ Overview of Hilex's Bag-2-Bag system <ul style="list-style-type: none"> o Collection- shoppers can return clean and empty bags to recycling bins o Recycling centre- PC film washline (Sorema Model V773) o Recycling centre- Hand Sort Line (Erema Model 1702 TVE) o Not much information provided by presentation. ▪ From the Helix website (http://www.hilexpoly.com/): <ul style="list-style-type: none"> o Hilex operates the largest closed loop plastic bag recycling facility in the world, where plastic bags are turned back into resin pellets and then back in to new bags. o Focusing primarily on high density polyethylene (HDPE) film products and related services, their products range from bagging systems to packaging films.
Leaflets			
9.	American Chemistry Council, no date. Recycle plastics bags at your store. Provided by: CPIA	<ul style="list-style-type: none"> ▪ Plastic bags ▪ Collection ▪ USA ▪ 4 pages 	<ul style="list-style-type: none"> ▪ Leaflet providing advice of where and how to locate recycling bins for plastic bags <ul style="list-style-type: none"> o Entrances and exits, use clear plastic bags in recycling bins, place garbage bins before recycling bins to reduce contamination, use signage, employee training, include recycling instructions/ logos on plastic bags themselves
Articles			
10.	Bellucci Butler, N., 2007. <i>What's in store for plastic bags?</i> Resource Recycling, June.	<ul style="list-style-type: none"> ▪ Plastic bags ▪ Bio-bags ▪ Generation 	<ul style="list-style-type: none"> ▪ Overview of possible solutions to deal with plastic bags <ul style="list-style-type: none"> o Comparison between plastic and paper bags in terms of resource/ energy intensity- plastic bags

	Document, Study or Report	Topic	Overview of Content
	<p>Provided by: CPIA</p>	<ul style="list-style-type: none"> ▪ Collection ▪ Reprocessing ▪ Markets ▪ USA ▪ 4 pages 	<p>are less resource and generate less GHG</p> <ul style="list-style-type: none"> o Generation: in California film makes up almost half the plastic waste stream (possibly due to California's higher recovery rate of plastic containers) o Nearly 700 million pounds of post-consumer film was recycled in 2005 o Lists two companies that estimate they will need between 1.2-1.5 billion pounds of film feedstock in 2007 o End-use markets for polyethylene film into: those that require clean film and those that tolerate wider specifications o Key to a healthy recycling industry is local supply and local demand. o Film collection infrastructure needs to expand- most domestic film buyers complain about limited supply o Curbside collection is not effective- as yields lower grade commodity and creates significant processing costs and problems o MRFs not designed to separate loose film o Retail collections are a good option if retailers can provide plastic bags o Details what a successful in-store campaign should include o Bio-plastic bags offer no solution in relation to litter.
Reports			
11.	<p>4R Sustainability, Inc., 2011. <i>Conversion Technology: A Complement to Plastic Recycling</i>. Portland.</p> <p>Provided by: American Chemistry Council</p>	<ul style="list-style-type: none"> ▪ Non-recycled plastics ▪ Pyrolysis ▪ North America ▪ 58 pages 	<ul style="list-style-type: none"> ▪ Commercial scale pyrolysis plants range from 7,500 to 10,000 short tons per year ▪ Capital costs vary from \$1 to 7 million US dollars ▪ System economics are based on obtaining non-recycled plastics at no cost and not paying for the material ▪ Systems limit PVC and require high levels of polyolefins for financial feasibility
12.	<p>AECOM, 2011. <i>City of Hamilton: Review of the City of Hamilton Film Grabber System</i>. Markham.</p> <p>Provided by: CIF (Project # 119)</p>	<ul style="list-style-type: none"> ▪ Film ▪ Sorting technologies ▪ Canada (Ontario) ▪ 20 pages 	<ul style="list-style-type: none"> ▪ Review report on Bollegraaf Film Grabber System (FGS)- FGS added as part of Canada Fibers Limited update to container processing system <ul style="list-style-type: none"> o Test months were selected (July and December) to reflect the seasonality of incoming material stream o Part of review to determine capture rate for film, purity rate for film, and system throughput (expressed in kg/hour) o Purity rate of the FGS excluded from report- as FGS cannot distinguish plastic films with different plastic characteristics o System performance consideration <ul style="list-style-type: none"> - The discrepancy between the recommended and the actual capture rate achieved by the FGS is most likely a result of the different operations conditions that the system was performing under when tested by the

	Document, Study or Report	Topic	Overview of Content
			<p>manufacturer and in real operation.</p> <ul style="list-style-type: none"> o Capture rates from two test sessions should be used with caution as there is 31% variance. Difference in capture rate is most likely due to a higher quantity of plastic film available in the sample load.
13.	<p>Ayalon, O., Goldrath, T., Rosenthal G., Grossman, M., 2009. Reduction of plastic carrier bag use: An analysis of alternatives in Israel. Waste Management, 29</p> <p>Provided by: CPIA</p>	<ul style="list-style-type: none"> ▪ Plastic bags ▪ Generation ▪ LCA ▪ Israel ▪ 8 pages 	<ul style="list-style-type: none"> ▪ Research analyzed actual environmental aspects of consumption and use of plastic carrier bags and assessed the effectiveness of the proposed regulation in Israel. <ul style="list-style-type: none"> o Plastic bag environmental load is more political than an actual environmental hazard- therefore does not recommend a high levy or total elimination of plastic bags o Israel 2 billion HDPE carrier bags are manufactured annually, plus 3 billion bags manufactured and used for packaging fresh food and used in market places. o Consumption in Israel per household is 1000 bags per year- 2.7 bags per day. Every person in Israel uses an average of 300 bags per year, similar to other countries such as Ireland (before introduction of levy, 330 bags per person) o Total percentage of plastic bags in municipal solid waste stream is 0.8%- only one fourth of this represents thin single-use plastic carrier bags o Discussion of past LCA studies o Conclusion: implementing either a levy or a total prohibition of plastic carrier bags will not contribute to sustainable waste management or to a rational environmental policy.
14.	<p>CIAL Group, 2010. <i>Recycling Depots at British Supermarkets</i>.</p> <p>Provided by: CPIA</p>	<ul style="list-style-type: none"> ▪ Plastic bags ▪ All recyclables ▪ Collection ▪ United Kingdom ▪ 7 pages 	<ul style="list-style-type: none"> ▪ Photo essay of supermarket recycling facilities ▪ Consumer recycling through municipal depots and return-to-retail is established to a much greater extent in the United Kingdom than in Canada.
15.	<p>Editors of The ULS Report, 2007. <i>A study of packaging efficiency as it relates to waste prevention</i>. Rochester.</p> <p>Provided by: Reclay StewardEdge</p>	<ul style="list-style-type: none"> ▪ Flexible packaging ▪ LCA ▪ USA ▪ 56 pages 	<ul style="list-style-type: none"> ▪ Study to examine best ways to improve the environmental as well as economic efficiencies of consumer packaged goods ▪ Major finding: the best way to reduce net discards is through the use of flexible packaging. Includes table comparing net discards of flexible packaging vs rigid containers ▪ Major finding: products to which water is added at the point of use, or removed at the point of manufacture, are significantly more efficient than similar products that are purchased in liquid or moist form. Includes comparison table with pouches. ▪ Major finding: the rise of single serve items, especially for snack food, has the potential to increase waste. Includes table with pouches listed for multi vs single serving snack pack comparison. ▪ Conclusions: <ul style="list-style-type: none"> o As concluded in 1995, consumer good marketers should be encouraged to develop and aggressively

	Document, Study or Report	Topic	Overview of Content
			<p>promote flexible packaging, concentrates and refills, dry mixes, and larger sizes for appropriate applications.</p> <ul style="list-style-type: none"> o Given their interest in sustainable packaging, retailers should also encourage consumer purchase of items sold in flexible packaging, concentrated and dry form, refills, and larger sizes. ▪ Includes individual products and their packaging efficiency- includes examples of pouches.
16.	<p>Entec Consulting Ltd., 2012. <i>The City of Langley "Blue + 2" Pilot</i>.</p> <p>Provided by: CPIA</p>	<ul style="list-style-type: none"> ▪ Film ▪ Collection ▪ Canada (British Columbia) ▪ 84 pages 	<ul style="list-style-type: none"> ▪ Blue bag collection of film (set out apart from single-stream recyclables in blue bin, but co-collected with those recyclables and blue bag polystyrene foam) ▪ Pilot program collection of film bags with other household polyethylene film and overwraps <ul style="list-style-type: none"> o Found that providing free blue bags is important (participation is 72% greater and the material captured is nearly doubled) o Achieved annualized 9.29 kg/hh/yr recovery from participating households (61 percent capture of desired film) o Average household participation rate of 64 percent (5.95 kg/hh/yr on collection route) o Additional collection volume increase of 11.7 m3 of vehicle collection volume per day o Blue bag breakage/film spillage occurs if not adequately tied, if truck compaction exceeds 130 kg/m3 (2 percent breakage) or 184 kg/m3 (5 percent breakage), or if the loading hopper is overfilled so that the blue bag is sheared by the compaction blade o Contamination rate was 33 percent by weight – there is a need for quality sorting in MRFs and/or improved participant education
17.	<p>Environment and Plastics Industry Council, 2004. <i>A Review of the Options for the Thermal Treatment of Plastics</i></p> <p>Provided by: CPIA</p>	<ul style="list-style-type: none"> ▪ Non-recycled plastics ▪ Conversion technologies ▪ Canada ▪ 20 pages 	<ul style="list-style-type: none"> ▪ Overview of energy from waste, industrial uses, pyrolysis, and gasification technologies ▪ Emissions test results for gasification of waste plastics
18.	<p>Kelleher Environmental, 2010. <i>City of Toronto Future Blue Bin Study: Technical Memorandum #3 Blue Bin Quantity and Composition Scenarios</i></p> <p>Provided by: CPIA</p>	<ul style="list-style-type: none"> ▪ Bio-plastics ▪ Plastic bags ▪ Film ▪ Generation ▪ Collection ▪ Future trends ▪ Canada (Toronto) ▪ 34 pages 	<ul style="list-style-type: none"> ▪ Overview of composition trends from City of Toronto Blue Box materials <ul style="list-style-type: none"> o Revenue from plastic film 2009: 34 tonnes \$1360 ▪ Future trends <ul style="list-style-type: none"> o "Fast changes" scenario- conventional plastics do not show an overall volume increase in this scenario because high oil prices have provided the impetus for light-weighting. There is a significant increase in plastics, specifically bio-plastics (annual growth of 5%). The per person and total volume of bio-plastics is twice as high as 2010. o "Status quo" scenario-more plastics in Toronto Blue Bin (as although oil prices are higher they are not sufficiently high to drive a serious search for alternatives), moderate growth in bio-plastics

	Document, Study or Report	Topic	Overview of Content
			<ul style="list-style-type: none"> o “A smaller world” scenario- plastic growth rates are more moderate, plastic bag use continues to decline as people shift towards more durable bags o Selected impacts on Blue Bin generation in 10 years time: 25% increase in overall plastics generation, with growth especially in pouches, mixed rigid containers and film applications; continued growth in the use of multi-layer and flexible packaging; emergence of bio-plastics as a more common packaging material; increased substitution of heavier for lighter packaging, increased light-weighting across packaging materials and continued substitution with plastics packaging categories. o Estimated impact percentages summarized in Kelleher report spreadsheet along with 5 and 10 year projections for plastic film and laminate generation
19.	<p>Moore Recycling Associates for the Canadian Plastics Industry Association, 2012. <i>2011 postconsumer plastics recycling in Canada</i></p> <p>Provided by: CPIA</p>	<ul style="list-style-type: none"> ▪ Film ▪ Generation ▪ Recovery ▪ Reprocessing ▪ Canada ▪ 21 pages 	<ul style="list-style-type: none"> ▪ Report detailing results of survey to determine amount of postconsumer plastic recovered in Canada for recycling <ul style="list-style-type: none"> o 2011- a minimum of 269 million kilograms of postconsumer, including post commercial, plastic material was collected for recycling in Canada o Includes figures for amount of plastic exported and the amount purchased for processing in Canada or USA o 2010- 37.1 million kg film recovered in 2011, primarily polyethylene, 14% of plastics recovered o Estimates film and bag reclamation capacity in Canada to be 49.3 million kilograms with a 38% utilization of the capacity. Major end use for recycled film in Canada is new film and sheet. Additional end uses are lumber and decking, automotive applications, lawn and garden products, pipe, and to a lesser extent pallets, crates and buckets o Film by source: commercial film 37%, curbside film 36%, mixed film (includes grocery bags- mixture of commercial film and bags collected at retail drops) 12%, dirty ag film 1%, clean ag film 14%, other film 1% o At least 50% of recovered postconsumer film staying domestic (Canada/USA), 32% exported overseas, 18% destination unknown o Fewer than 5 companies can process curbside film in the U.S. and Canada.
20.	<p>Moore Recycling, 2012. <i>Plastic film and bag recycling collection: national reach study</i></p> <p>Provided by: CPIA</p>	<ul style="list-style-type: none"> ▪ Plastic film ▪ Plastic bags ▪ Collection ▪ End uses ▪ USA ▪ 10 pages 	<ul style="list-style-type: none"> ▪ Study into percentage of US population that has access to plastic retail bags and plastic film recycling ▪ US reclaimed end uses 2010 for film- lumber 42%, film and sheet 21% and other 37% <ul style="list-style-type: none"> o Results- widespread access to recycling yet access not being used to full potential, due to lack of outreach and education
21.	Moore Recycling Associates for the	▪ Plastic bags	▪ Annual report on pounds of plastic bags and film

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	<p>American Chemistry Council, 2012. <i>2010 national postconsumer plastic bag and film recycling report</i></p> <p>Provided by: CPIA</p>	<ul style="list-style-type: none"> Plastic film Recovery United States 11 pages 	<p>recovered in USA for recycling</p> <ul style="list-style-type: none"> Plastic bag and film recovery has increased nearly 50% since 2005. Recovery of postconsumer film (which includes plastic bags and product wrap) grew to an estimated 971.8 million pounds in 2010 in USA. Since 2006, more than half of film recovered in the United States has gone to overseas markets; however, in 2010 that trend reversed. In 2010, U.S. and Canadian processors consumed approximately 53 percent of U.S.-recovered postconsumer film and bag material. The export market consumed the remaining 47 percent. Composite lumber manufacturers continue to lead the domestic market, but there was continued growth in the amount of material going into domestic non-lumber end-use markets such as film and sheet. Scrap value for postconsumer film was higher on average in 2010 compared to 2009—primarily for the higher grades of film, such as clean, clear film and retail collected bags and film The total amount of postconsumer film collected for recycling in 2010 increased 14 percent over 2009. Historically Commercial Film has led the increase in film recovery, but in 2010 the amount of Commercial Film recovered decreased 8 percent compared to 2009. Recovery levels increased in all other large categories of film, including retail collected bags and film (Mixed Film), Curbside Film, and Agricultural Film. The amount of bags recovered in 2010 increased 27 percent over the previous year. This 2010 Postconsumer Bag and Film Recycling Report shows a 14 percent increase in recovery over 2009. Reason: the increase for retail collected film and bags is likely due to years of education and support for recycling as more consumers take advantage of store collection programs and businesses discover the economic benefits of film recovery.
22.	<p>Moore Recycling Associates, 2011. <i>Film, PET and Mixed Plastic Recycling in China</i></p> <p>Provided by: Moore Recycling Associates</p>	<ul style="list-style-type: none"> Plastic film Export markets China 10 pages 	<ul style="list-style-type: none"> China does not burn scrap plastics for energy Most postconsumer US material enters China through the port of Hong Kong; while the cost to ship to Hong Kong is minimal, the cost of shipping from Hong Kong to the mainland ports, including tariffs, is expensive Colored film is hand sorted and washed and often made back into blown film
23.	<p>Nextek Ltd., 2011. <i>A Review of Best Practices for the Recycling of Household Packaging Film Collected from Curbside</i></p> <p>Provided by: CPIA</p>	<ul style="list-style-type: none"> Plastic film Europe and UK 48 pages 	<p>Report evaluates methods to sort post-consumer household film collected from residential curbside collection programs.</p> <ul style="list-style-type: none"> MRFs in the UK are receiving significant amounts of film at 35 percent of plastics received; however, 40 percent of film is bags used for recycling collection and carry-out sacks In Germany 40,000 tonnes of film is collected in a

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			<p>lightweight packaging stream that includes aluminum, plastic bottles, and aseptic paper containers</p> <ul style="list-style-type: none"> ▪ The percentage of film recovery is relatively low in most European countries, typically in the range the 5-10 percent – recovery in Germany, Belgium, and the Netherlands is higher ▪ There is currently no mechanical recycling process for multi-layer films in the UK or the EU - the majority of these films are landfilled or if collected are sent for energy recovery ▪ Most PE film collected in Europe and the UK for recycling is baled and sold to China due to limited European markets ▪ Film is most often removed early at MRFs, most often manually ▪ A couple MRFs use near infrared (NIR) optical sorters to separate polyethylene film from other film ▪ Before using Other technologies are needed to separate film from containers, or film must be collected/sorted with paper, in order to use NIR optical sorters to sort out PE film ▪ The maximum NIR optical sorter throughput for film is 600 kg per hour per meter of belt width.
24.	<p>Ontario Bag Reduction Task Group, 2010. <i>Progress Report 2008/09</i> Available at: https://www.rco.on.ca/uploads/File/Progress-Report-2008-09---December-7-2010_FINAL.pdf</p> <p>Provided by: Recycling Council of Ontario</p>	<ul style="list-style-type: none"> ▪ Plastic bags ▪ Generation ▪ Canada (Ontario) ▪ 6 pages 	<p>Report detailing progress made in reducing carry-out plastic bag distribution.</p> <p>Provides quantitative data in relation to distribution of plastic bags in Ontario.</p> <p>Generation/Recycling/Reuse</p> <ul style="list-style-type: none"> ▪ Overall, Ontario retailers have reduced the number of carry-out plastic bags they distributed to customers by approximately 2.5 billion bags – a 58% reduction over three years. In 2009, the estimated total number of plastic bags distributed was 1.8 billion bags, compared to 4.3 billion plastic bags in 2006 (baseline). ▪ Ontarians have recycled more than 938 million carry-out plastic bags since 2007, using retailer and municipal recycling programs. ▪ An estimated total of 1.02 billion plastic bags were reused for secondary purposes (e.g., a container for garbage, organics or recyclables) in 2009.
25.	<p>RCC/CFIG/CACDS, 2012. <i>Alberta Plastic Bag Distribution Annual Report</i></p> <p>Provided by: CPIA</p>	<ul style="list-style-type: none"> ▪ Plastic bags ▪ Generation ▪ Canada (Alberta) ▪ 8 pages 	<p>Annual report detailing progress made since start of Alberta Plastic Bag Distribution Reduction Strategy Implementation Plan. 2008 is the baseline year.</p> <p>Provides quantitative data in relation to distribution of plastic bags in Alberta.</p> <p>Generation</p> <ul style="list-style-type: none"> ▪ 2008 approximately 741,120,220 plastic bags were distributed in Alberta by grocers, retailers and pharmacies. This represents 215.9 single-use plastic bags per capita. ▪ 2009 approximately 679,901,981 plastic bags were

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			<p>distributed in Alberta by grocers, retailers and pharmacies. This represents 193.1 single-use plastic bags per capita.</p> <ul style="list-style-type: none"> 2010 approximately 589,269,695 plastic bags were distributed in Alberta by grocers, retailers and pharmacies. This represents 166.3 single-use plastic bags per capita. <p>Therefore, plastic bag usage has decreased by 20.5 per cent, and industry is on track to achieve goal of reducing plastic bags distributed by 50 per cent by 2013.</p>
26.	<p>RTI International, 2012. <i>Environmental and Economic Analysis of Emerging Plastics Conversion Technologies</i>. Research Triangle Park.</p> <p>Provided by : American Chemistry Council</p>	<ul style="list-style-type: none"> Conversion technologies Plastics Economics Lifecycle Inventory 70 pages 	<ul style="list-style-type: none"> Conversion technologies are expected to begin breaking through to commercial viability in 5 to 10 years Life-cycle environmental review shows that waste conversion technologies have significant environmental benefits in energy saved and greenhouse gases averted compared to landfill disposal The cost to process waste is approximately U.S. \$50 per ton (for pyrolysis and gasification technologies), and U.S. averages for landfill disposal and recycling range from U.S. \$30-75/ton depending on region
27.	<p>Verghese, K., Jollands, M., Allan, M., 2006. The Litterability of Plastic Bags : Key Design Criteria. In: <i>5th Australian Conference on Life Cycle Assessment: achieving business benefits from managing life cycle impacts</i>. Melbourne, Australia 22-24 November 2006.</p> <p>Provided by: CPIA</p>	<ul style="list-style-type: none"> Plastic bags Australia LCA 10 pages 	<ul style="list-style-type: none"> Study to investigate the effect of bag design on litterability <ul style="list-style-type: none"> Number of plastic bags estimated in 2002 to be around 6.9 billion per annum in Australia (6 billion made from HDPE and 0.9 billion made from LDPE) Study looked at different designs from the samples collected- supermarket bags had best resource efficiency and bags from boutique retail shop had the worst resource efficiency Examination of bags showed that some were “overdesigned”- bags that could fulfil their application requirements (of volume and kilos of goods to be carried) with lower bag mass by reducing wall thickness Examines litterability in terms of tendency to be dispersed by the wind Conclusion: there is no current bag design that would yield significantly less littering
28.	<p>WRAP, 2012. <i>Final report: recovery of laminated packaging from black bag waste, feasibility study into the separation and recycling of laminated packaging from residual local authority-collected waste</i>. United Kingdom.</p> <p>Provided by: CPIA</p>	<ul style="list-style-type: none"> Laminated packaging Generation Sorting technologies United Kingdom 40 pages 	<ul style="list-style-type: none"> Study using Enval pyrolysis process on feedstock from residual municipal “black bag” waste and examines practical feasibility of including Enval process in waste recycling infrastructure <ul style="list-style-type: none"> Proportion of laminated packaging in residual municipal stream estimated to be 0.17% by mass One of more of the following sorting technologies could be used: hand picking, eddy current separation, optical sorting and air separation. Air separation is the lowest cost option however output will likely be lower quality than other more costly methods. Decision will depend on on-site factors (such as space, etc.) Net revenue from recycling laminated packaging is subject to considerable uncertainty, but currently appears to be lower than the cost of separation. Therefore not financially viable as a stand-alone

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			<p>activity.</p> <ul style="list-style-type: none"> o A number of uncertainties were identified which may affect the overall feasibility of a separation and recycling scheme. The status of the pyrolysis facility with regard to the Waste Incineration Directive requires clarification; and there is uncertainty regarding the revenue which could be obtained from sale or use of the hydrocarbons produced by the process, both pyrolysis oil and gas. o Laminated packaging is not currently recycled in the UK. o Includes information regarding management of laminates in Mechanical Biological Treatment (MBT) facilities o Result- a consistent finding for all facilities was that eddy current separators (ECS) are effective at separating a significant proportion of laminated packaging from the waste stream, alongside other non-ferrous materials such as UBC and aluminium foil o Based on visual inspection, laminated packaging formed a very small proportion of the overall input waste to each facility o Only within the non-ferrous metal stream could laminated packaging be clearly identified as a significant component of the waste stream. In these cases, it appeared to represent somewhere between 1% and 10% of the non-ferrous stream- i.e. between 0.01% and 0.1% of the total input waste. o Lists various sorting technologies/ methods of MBTs and residuals MRFs in sorting laminates o Dry MRFs- laminates are probably the major contaminates by volume/ mass. Therefore estimate that a dry MRF would have 12.5 tpa of laminated packaging, which represents approximately 0.5% of the 2,7000 tpa of non-ferrous outputs from the MRF. o Total amount of laminated packaging entering waste stream in UK is estimated at approximately 41,000 tpa (higher than other WRAP study). This is 0.13% of the total municipal stream, which is 0.17% of residual municipal stream- NB estimated amounts, no waste composition analysis information to support these estimates. \ o Includes options for separation of laminated packaging o Conclusions: <ul style="list-style-type: none"> - The proportion of laminated packaging in the incoming waste is likely to be in the region of 0.13% to 0.26%. - The following technologies have the potential to separate laminated packaging from various feedstocks

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			<ul style="list-style-type: none"> • Hand picking- proven effective at removing laminated packaging from a variety of feedbacks • Eddy current separation- potential for removing laminated packaging from other non-ferrous metals when used in a cascade with appropriate settings • Optical sorting- potential for removing laminated packaging from both mixed and non-ferrous streams, particularly when combined with a metal detection system • Air separation- proven effective for removing light material (including laminated packaging) from a non-ferrous stream, but will not distinguish between laminated packaging and other plastic film • There are no insurmountable technical obstacles to separating laminated packaging from residual municipal waste using one or more of the separation technologies identified. <p>- The cost of separating laminated packaging is estimated to be from £53 per tonne upwards. Uncertain revenue from recycling laminated packaging and therefore separating laminated packaging from residual municipal waste is unlikely to be financially viable as a stand-alone activity.</p>
29.	<p>WRAP, 2009. <i>Final report: commercial scale mixed plastics recycling, a report on the technical viability of recycling mixed plastic packaging waste from domestic sources on a commercial scale in the UK</i>. United Kingdom</p> <p>Kosior, E., Nextek Limited, 2010 [presentation is of findings from this report]</p> <p>Provided by: CPIA</p>	<ul style="list-style-type: none"> ▪ Mixed plastics ▪ Film ▪ Sorting technologies ▪ Collection ▪ Reprocessing ▪ United Kingdom ▪ Germany ▪ Austria ▪ 164 pages 	<ul style="list-style-type: none"> ▪ Report examines technical challenges to successful recycling of mixed plastics in the UK through MRF trials and reprocessing trials <ul style="list-style-type: none"> o Main conclusion- mixed plastics in UK is technically viable on a commercial scale and that there are markets for the majority (over 95%) of these recycled mixed plastics. Within trials reprocessed plastics was successfully substituted for virgin materials in end-product applications. - Film- MRFs need to remove films early in the separation process to minimise potential problems with sorting downstream - Collection- for front of store collection to be effective need a well-designed systems that minimizes the number of trips, maximises recovery of plastics yet minimises cross contamination from paper and cans. If household plastics are kept separate from paper and other materials, materials can go directly to a Plastics Recovery Facility (PRF) - Reprocessing of film- carried out by a number of specialists. Included a range of materials (crisp packets and carrier bags). PE based materials accounted for almost 78% of the

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			<p>total and PP making up 13%. Trials in Germany and Austria showed that plastic packaging films can be recycled at commercially viable speeds to produce PE pellets. Manufacturing trials at CeDo's plastic film production facility demonstrated that recycled film has the potential to be used to make new film products such as refuse sacks. Whilst these are very encouraging- further trials are needed to verify findings.</p> <ul style="list-style-type: none"> - A PRF and reprocessor on one integrated site will be more efficient and will produce less residual waste through increased recovery yields. The expected achievable material recovery by an integrated PRF and reprocessing facility is 55% and could be as high as 60%. - *disclaimer in report- no direct comparison of individual equipment, technology or process performance should be drawn from the tables and information published through this report. <ul style="list-style-type: none"> o Data- report takes data relating to percentage of plastic film received at MRFs o Technologies- film sorting technologies used at MRFs listed o Section within report dedicated to recycling of household plastic film packaging <ul style="list-style-type: none"> - 36 tonnes of mixed polymer post-consumer packaging waste was sourced from 3 different MRFs - CeDo is keen to source UK film if high enough quality can be achieved. CeDo currently sources from Austria as the input quality of films is considered higher due to lower levels of cross-contamination from other non-film materials. o Report also lists MRF, PRF, retail and processing conclusions- general mixed plastic conclusions and in relation to film
30.	WRAP, 2011. <i>Project report: recycling of laminated packaging, trials to optimize pilot plan for recycling of laminated packaging wastes</i> . United Kingdom. Provided by: CPIA	<ul style="list-style-type: none"> ▪ Laminated packaging ▪ Sorting ▪ Generation ▪ LCA ▪ United Kingdom ▪ 39 pages 	<ul style="list-style-type: none"> ▪ Report detailing series of trials using a pilot plant built by Enval to process laminates <ul style="list-style-type: none"> o Technology: Enval Ltd- process based on technology known as Microwave Induced Pyrolysis <ul style="list-style-type: none"> - Pyrolytic process in which the energy required for heating the material is provided by microwaves. Outputs- are aluminium flakes and hydrocarbons in form of oil and gas suitable for the production of energy. o Results show that process is technologically and environmentally sound o Generation UK- conservative estimate for laminated packaging in UK is 139,000 tonnes annually (containing 13,500 tonnes of aluminium) o Some laminated packaging formats are estimated to be growing by between 10% and 15% per year

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			<ul style="list-style-type: none"> o Eddy current separation can be used to recover pouches from the fines, along with any other aluminium waste streams that have evaded the MRF process. Stated hand picker would not be an effective option due to low feed of laminated packaging. Report recommends automatic sorting as the only recovery route. o Overall, laminated packaging (excluding laminated beverage cartons) accounted for 0.8% of the non-ferrous metal outputs o Includes LCA of trial results
Life Cycle Assessments (LCA) and Life Cycle Inventories (LCI)			
31.	<p>Boustead Consulting & Associates Ltd prepared for the Progressive Bag Alliance, no date. <i>Life Cycle Assessment for Three Types of Grocery Bags - Recyclable Plastic; Compostable, Biodegradable Plastic; and Recycled, Recyclable Paper.</i></p> <p>Provided by: CPIA</p>	<ul style="list-style-type: none"> ▪ Plastic bags ▪ Bio-bags ▪ LCA ▪ USA ▪ 64 pages 	<ul style="list-style-type: none"> ▪ LCA study comparing three types of bag ▪ Results: single use plastics (polyethylene) bags have advantages over compostable plastic (made with EcoFlex) bags and paper bags in terms of impact- in terms of energy used, fossil fuel used, municipal solid waste, greenhouse gas emissions, and fresh water usage <ul style="list-style-type: none"> o Not one category showed environmental impacts lower for either the compostable plastic bag or the paper bag ▪ Conclusion- any decision to ban traditional polyethylene plastic grocery bags (in favour of bio-bags/ recycled paper) will be counterproductive and result in significant increase in environmental impacts across a number of categories (global warming to water resources) ▪ Recommends to reduce impact of plastic bags: increasing recycling, better bagging techniques, secondary uses of plastic grocery bags, and addressing consumer littering behaviour ▪ Note: study excludes reusable bags ▪ Note: study excludes addressing issue of litter
32.	<p>Franklin Associations for the Plastics Division of the American Chemistry Council, 2008. <i>Peer reviewed final report: LCI summary for eight coffee packaging systems.</i> Prairie Village, Kansas</p> <p>Provided by: Reclay StewardEdge</p>	<ul style="list-style-type: none"> ▪ Flexible packaging ▪ LCA ▪ United States ▪ 83 pages 	<ul style="list-style-type: none"> ▪ LCI study for eight coffee packaging systems ▪ Results include energy consumption, solid waste generation and environmental emissions to air and water ▪ Result: 13-ounce brick pack- which weighs the least and so uses the least amount of materials, uses less energy and produces less solid waste and greenhouse gases than the comparable coffee packaging systems. The laminate bag system which uses the same laminated material as the brick pack- requires approximately 25% more total energy than the brick pack system ▪ 8 coffee packaging systems list with total energy, total solid waste and greenhouse gases comparison table <ul style="list-style-type: none"> o LCI uses weights from A study of packaging efficiency as it relates to waste prevention 2007(included within this literature review) ▪ Information for laminate bag and brick pack is of most relevance. ▪ LCI for brick pack and laminate bag states that disposal

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			is: 80% landfill and 20% incineration
33.	Franklin Associations for the Plastics Division of the American Chemistry Council, 2008. <i>Peer reviewed final report: LCI summary for six tuna packaging systems.</i> Prairie Village, Kansas Provided by: Reclay StewardEdge	<ul style="list-style-type: none"> Flexible packaging LCI United States 69 pages 	<ul style="list-style-type: none"> LCI study for six tuna packaging systems Results include energy consumption, solid waste generation and environmental emissions to air and water Result: the total energy of the 12-ounce pouch is significantly lower than the other five packaging systems (due to light weight and lower package to product weight ratio for larger package size), total solid waste by weight and volume for the 12-ounce pouch are significantly lower than all other tuna packaging systems, 12-ounce pouch produces least amount of greenhouse gases (due to lighter weight and lower amounts of carbon dioxide from the fuel combustion and production during production of plastics used in pouch layers) LCI for pouches states that disposal is: 80% landfill and 20% incineration LCI uses weights from A study of packaging efficiency as it relates to waste prevention 2007 (included within this literature review)
34.	Flexible Packaging Association, no date. Flexible packaging: less resources; less footprint; more value, third edition. Provided by: Reclay StewardEdge	<ul style="list-style-type: none"> Flexible packaging LCA USA 11 pages 	<ul style="list-style-type: none"> Leaflet featuring comparisons of flexible packaging containers compared to traditional containers in terms of weight, energy consumption and emissions. Examples include: <ul style="list-style-type: none"> Beverage packaging- stand-up flexible pouch Raisin packaging- stand-up flexible pouch Parcel mailer- HDPE flexible pouch mailer Multi-unit packaging- flexible collation shrink wrap Coffee packaging- flexible brick pad Foodservice #10 packaging- # 10 flexible pouch Rotisserie chicken packaging- hot n handy flexible pouch
35.	Khoo, H.H., Tan, R.B.H., Chng, K.W.L., 2010. Environmental impacts of conventional plastic and bio-based carrier bags. <i>Int J Life Cycle Assess</i> , 15 p.284. Provided by: CPIA	<ul style="list-style-type: none"> Plastic bags Bio-bags LCA Singapore USA 10 pages 	<ul style="list-style-type: none"> Aim of article: to investigate whether or not bio-based materials are environmentally friendlier options compared to plastics; attempts to explain the rationale of the results Three impact categories used: global warming potential, acidification, and photochemical ozone formation Conclusion: the life cycle production of bio-bags can only be considered as environmentally friendly alternatives to conventional plastic bags if clean energy sources are supplied throughout its production processes. Includes: data relating to air emissions, energy requirements Study excludes: disposal- scope of LCA ends once bag is with customer, issue of litter
36.	Lewis, H., Verghese, K., Fitzpatrick, L., 2010. Evaluating the sustainability impacts of packaging: the plastic carry bag dilemma. <i>Packaging Technology and Science</i> 23 p. 145.	<ul style="list-style-type: none"> Plastic bags Bio-bags Generation LCA Recovery 	<ul style="list-style-type: none"> Evaluation of environmental impact of plastic carry out bags. Critical review of role of LCA in evaluating packaging sustainability using plastic bags. Generation: 2007 approximately 3.9 billion plastic carry

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	Provided by: CPIA	<ul style="list-style-type: none"> Australia 16 pages 	<p>bags were issued by Australian retailers in 2007- 34% reduction since 2002.</p> <ul style="list-style-type: none"> LCA: <ul style="list-style-type: none"> Compares seven types of bags (includes reusable bags) Does not take into account broader environmental issues such as litter/ hazards to wildlife. 7 impact categories- global warming, photochemical oxidation, eutrophication, land use, water use, solid waste, fossil fuels, minerals. Results: depend on the environmental issue being considered. HDPE bags have a lower impact on global warming and eutrophication than biodegradable plastic bags, but a higher impact on fossil fuels and solid waste. Compares sustainability impacts of plastic, paper and reusable carry bags. LCA results suggest that replacing one single-bag (plastic) with another (e.g. paper or a biodegradable plastic) may increase rather than decrease environmental impacts). Benefits of HDPE bags increased if there was a higher recycling rate. Includes principles and strategies for sustainable packaging Recovery: <ul style="list-style-type: none"> Australia estimated 16% of HDPE bags recycled in 2007. If recycling rate increased to 50% this would reduce greenhouse gas emissions. Oxo-degradable carry bags are not recoverable. Plastic recyclers generally unwilling to accept them because can reduce quality of recycled material, and no evidence that they are compostable. <p>LCA studies cited:</p> <ul style="list-style-type: none"> Franklin Associates Carrefour LCA study- compared impact of four options in countries where Carrefour are based (France, Belgium, Spain and Italy): single-use carry bags polyethylene, single-use paper carry bags, single-use biodegradable plastic carry bag, and a reusable polyethylene. Conclusion: after reusable carry bag, and the next preferred options was single-use plastic bag. Israel life cycle thinking study- main issue with plastic carry bags was visual impact- litter.
37.	<p>No author, no date. Resource and environmental profile analysis of polyethylene and unbleached paper grocery sacks</p> <p>Provided by: Reclay StewardEdge</p>	<ul style="list-style-type: none"> Plastic bags LCA USA 15 pages 	<ul style="list-style-type: none"> Study to determine the energy and environmental discharges of polyethylene and paper grocery sacks. Three broad environmental categories: solid wastes; atmospheric emissions; waterborne wastes. Also recyclability, combustion and landfill impacts included. Generally plastic bags have less impact than paper bags.
38.	<p>WRAP, 2008. <i>Final report: LCA of management options for mixed waste plastics</i>. United Kingdom</p> <p>Provided by: CPIA</p>	<ul style="list-style-type: none"> Mixed plastics LCA Sorting technologies United Kingdom 121 pages 	<ul style="list-style-type: none"> LCA study of range of recycling technologies <ul style="list-style-type: none"> Technologies included are either already in use or have been proven in principle in pilot projects Study reflects situation in UK It is environmentally beneficial to remove mixed plastic from the waste stream prior to either landfilling or

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			<p>incineration. The diverted mixed plastics stream should be managed through a combination of mechanical recycling and solid recovered fuel.</p> <ul style="list-style-type: none"> ▪ In scenarios modelled in study- Stadler equipment had better performance than KME equipment due to different design objectives of each process (Stadler ballistic separator is designed to separate out films from rigid objects, whereas KME process is primarily designed to separate 2-dimensional objects from 3-dimesional objects) ▪ Results of LCA- landfill had least favourable environmental performance. Best environmental performance was clear-cut- as also need to take into account quality of the recycled plastic produced. <p>Overall the results indicate that recycling scenarios are generally the environmentally preferable options for all impact categories considered.</p>