Introduction

This guide is designed to help businesses, recyclers and local governments evaluate opportunities for diverting plastic films from the waste stream into emerging recycling applications. Indeed, everything from palletized goods to furniture and automobiles arrive from the producer with some type of plastic film packaging today. The result of this increasing presence of plastic films is a changing commercial waste stream. Many commercial businesses have long had programs in place to recover corrugated cardboard from their waste stream. Even on-site baling for pick-up by local recyclers is common for larger businesses. Some businesses also have recycling programs for scrap metals, glass or other commodities, but few have programs in place for the recovery of plastic films. This guide will help you decide if you can and should recover plastic film in your organization.

The content of this guide includes an outline of the fundamental components of plastic film recovery, from understanding market requirements to best practices for diversion and recovery. Most of the recovery practices discussed are geared for businesses that generate a minimum of one ton of plastic film waste per month, but may be applicable to smaller quantity generators. In order to identify recycling opportunities, this guide will provide a detailed overview of plastic films, how they are used, and where they are frequently generated as waste materials.
ACKNOWLEDGEMENTS

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King County Solid Waste Division
LeMay Enterprises
Merlin Plastics
Monarch Enterprises
Plastic Bag Association
Plastic Lumber Trade Association
Plastics News – Crain Publications
Rabanco Recycling Company / Allied Disposal
   RC Resources
   Recycling Today
   Resource Recycling
RST Disposal / a Waste Management Company
   Smurfit Recycling Company
   Strandex Corporation
   Trex Corporation
Waste Control - Willamette Resources
   Waste Management
   Weyerhaeuser Recycling
   www.plasticstechnology.com
**Film Recovery Cycle & Guide Contents**

**Executive Summary**

**Section 1. - Recovering Waste Plastic Films**
Recovering Films in Your Workplace: A Step-by-Step Guide

**Section 2. - Commercial Film Recovery Programs**

**Section 3. - More About Plastic Films**
Industry Film Waste Generation Patterns

**Section 3. - More About Plastic Films**
Identifying Plastic Films and Contaminants

**Section 6. - Markets for Recovered Plastic Films**
The Development of Plastic Films as a Commodity

**Section 6. - Appendix**
Information Resources
# TABLE OF CONTENTS

## EXECUTIVE SUMMARY

| Why Recover Plastic Films? | 1 |
| Challenges of Recycling | 1 |
| Technology Developments | 2 |
| Market Developments | 2 |
| Today's film-grade plastic resins | 3 |

## SECTION 1 - RECOVERING WASTE PLASTIC FILMS

Recovering Plastic Films in Your Workplace: A Step-by-Step Guide | 4 |

- **Step 1.** Identify the types and quantity of plastic films in your waste stream and determine which are recyclable. | 5 |
- **Step 1-A:** Determine Recyclability through Local Market Channels | 6 |
- **Step 1-B:** Develop Market Relationships & Transportation Logistics | 7 |
- **Step 2.** Assess the economics of diverting and recovering the films identified. | 9 |
- **Step 2-A:** Assessing capital equipment purchase for film recycling | 12 |
- **Step 3.** Establish collection points and consolidation strategy | 14 |
- **Step 4.** Establish storage, preparation and handling protocols | 16 |
- **Step 5.** Maintain Quality Controls and Education of Participants | 21 |

## SECTION 2 - COMMERCIAL FILM RECOVERY PROGRAMS

Collection for Recycling | 24 |

## SECTION 3 - MORE ABOUT PLASTIC FILMS

- What are plastic films? | 28 |
- Tips for Identifying Film and Resin Types | 29 |
  - Identifying Limited and Non-Recyclable Films | 34 |
- Common contaminants in the plastic film waste stream | 35 |

## SECTION 4 - INDUSTRY FILM WASTE GENERATION PATTERNS

- Post-Industrial Scrap | 37 |
- Post-Consumer - COMMERCIAL | 37 |
- Post-Consumer - RESIDENTIAL | 38 |
- Locating Major Film Sources | 39 |
MARKETS FOR RECOVERED PLASTIC FILMS 40

Domestic End-Use Markets for Recovered Plastic Films ........................................................................ 40
  Plastic Manufacturing and Reclaimer Markets 40
  Plastic Lumber Products 41
  Composites Manufacturing 41

Export Markets ......................................................................................................................................... 43

The Development of Plastic Films as a Commodity ............................................................................... 43

APPENDICES A-1

Information Resources .......................................................................................................................... A-1
North American Plastic Lumber Manufacturers .................................................................................. B-1
North American Wood-Plastic Composite (WPC) Manufacturers ................................................. B-2
Economics Worksheet ......................................................................................................................... C-1
Specifications ........................................................................................................................................ D-1
Executive Summary

Why Recover Plastic Films?
Businesses can save money by reducing their disposal expenses, both in the form of tonnage-based tipping fees and container hauling fees. This is especially evident with plastic films, where a high volume-to-weight ratio can mean more container pulls per ton hauled. The increased number of pulls directly translates to a higher effective disposal rate per ton for films.

Today, improved technologies for processing and more diverse market applications are creating new opportunities for plastic film recycling, and improved access to recycling channels for commercial businesses. Large generators of plastic film wastes are finding it economically beneficial to recover plastic films, even in areas with relatively inexpensive disposal costs. This guide will examine these recycling opportunities and provide analysis of the economic benefits of recycling plastic films.

Challenges of Recycling
Recycling plastic films requires many of the same elements as recycling other commodities:
1. Efficient diversion and consolidation of recovered materials
2. The ability to sort like materials
3. The ability to remove contaminants.

Efficient diversion and consolidation of recovered materials
Perhaps the most significant element in determining the viability of plastic film recovery, is ‘what does it take to get it out of the waste stream?’ This entails identification of films in the waste stream, determination of their recyclability, and implementation of steps to divert them. Once films are diverted from the waste stream, the quantity collected will influence the ability to market them. The more film an individual business can recover, the better its chances of finding a recycler willing to take it. Similarly, the viability of recyclers handling films depends on their ability to effectively consolidate films from several businesses to package quantities suitable to end-use buyers.

The ability to sort like materials
Plastic films are more difficult than plastic containers to identify by resin without some training. The plastics industry is working hard to address the challenges of recycling through programs to code rigid containers for resin identification and by stimulating the development of improved washing and sorting technologies. While some producers are using resin identification codes on film plastics, most films do not carry such identifiers, necessitating training for generators and recyclers on how to distinguish between film types. Sorting generally must occur early in the recovery process, near the initial point of generation, to be successful. Though specifications for how well separated films must be vary by market channel, better sorted films will have more recycling options.
The ability to remove contaminants

The greater amount of surface area of film plastics relative to their weight, means that they are likely to pick-up and retain more surface contamination than container plastics. This common surface contamination, such as labels, dirt and food residue can pose a bigger challenge to plastic film reclaimers than other recycled material users, because of tight quality tolerances. In other manufacturing processes, such as glass or aluminum production, the temperatures used in manufacturing are sufficient to burn off any surface contamination that may remain after processing. In most plastics reclamation, remaining surface contamination such as a single label must be mechanically screened from the melted resin before it can become a quality raw material for use in new plastic products.

In order to minimize contamination challenges, generators must work to prevent initial contamination at the point of diversion through education and signage, including plain language about what films are recyclable, and what materials are not acceptable. Pictures and graphics are proven aids to conveying information about film recycling. Once the quality of diverted films is controlled, additional controls can help to maintain quality through handling steps, including measures to avoid exposure to dirt, moisture, and sunlight.

Technology Developments

Advancements in processing and manufacturing technologies are creating improved opportunities for recycling films into mainstream plastic products and spurring the development of new end-use applications. These technologies are opening the door to an unprecedented level of plastic film recovery by broadening the types of films that can be processed, and the product applications in which they can be used. Advancements in processing include technologies for contaminant removal, film washing and drying, and pelletization into market-grade resins. Advancements in manufacturing include improved ability to compound resins to form new blends and the ability to combine plastics with other materials, such as cellulose wood fiber, to create a new generation of composite products.

Market Developments

The markets for recovered plastic films are in an early stage of development in the United States. The development of any new recovered commodity market requires both investment by end-users in technologies for recycled-content manufacturing and wide-scale recovery channels to provide a consistent, large quantity supply of materials. This is sometimes characterized as a chicken and the egg scenario – which comes first? The answer, most often, is a little of both. Investment at the research and development level by end-users precedes initial recovery efforts, but recovery channels must develop prior to, or concurrently with, large-scale investment in end-use. Both of these ingredients to success have begun to take hold and expand in the domestic film market.
Technology developments, combined with increased awareness of recycling opportunities in the public and private sectors, have already begun to stimulate new plastic film recovery efforts. One major area of emerging end-use applications involves the production of plastic lumber, and wood-plastic composites for building applications. These products are experiencing tremendous market growth, and several have developed vertical integration strategies to actively participate in the development of new recovery channels for plastic films. They represent a large capacity consumption potential for polyethylene and other recovered plastics resins, including recovered film resins.

**Today's film-grade plastic resins**

The majority of plastic films are made from low density (LDPE) or linear low density (LLDPE) polyethylene; comprising approximately 68 percent of the total film production, as illustrated in Figure E-1. In addition to LDPE and LLDPE, high density polyethylene (HDPE) resins are commonly used in film plastics. Non polyethylene resins constitute the remainder of film plastic types found in the marketplace. Polypropylene (PP), polyvinyl-chloride (PVC), and nylon resins comprise the bulk of these other film types. Increasingly, certain multi-ply or co-extruded films are used in specialty applications that seek to combine performance attributes of two or more resins for a specific application.

![Figure E-1](image_url)

**1997 Sales of Domestic Resin Production - by End-Use**

(Data in Millions of pounds, unless otherwise noted)

<table>
<thead>
<tr>
<th></th>
<th>Production Use</th>
<th>Percent of Total</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Low Density Polyethylene (LDPE)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Packaging Films</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Food Packaging</td>
<td>1,117</td>
<td>10.2%</td>
</tr>
<tr>
<td>Non-food Packaging</td>
<td>815</td>
<td>7.4%</td>
</tr>
<tr>
<td>Stretch &amp; Shrink Films</td>
<td>329</td>
<td>3.0%</td>
</tr>
<tr>
<td>Non-Packing Films</td>
<td>1,086</td>
<td>9.9%</td>
</tr>
<tr>
<td><strong>Linear Low Density Polyethylene (LLDPE)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Packaging Films</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Food Packaging</td>
<td>400</td>
<td>3.6%</td>
</tr>
<tr>
<td>Non-food Packaging</td>
<td>890</td>
<td>8.1%</td>
</tr>
<tr>
<td>Stretch &amp; Shrink Films</td>
<td>966</td>
<td>8.8%</td>
</tr>
<tr>
<td>Non-Packing Films</td>
<td>1,868</td>
<td>17.0%</td>
</tr>
<tr>
<td><strong>High Density Polyethylene (HDPE)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Food Packaging</td>
<td>162</td>
<td>1.5%</td>
</tr>
<tr>
<td>All Other (Includes t-shirt bags)</td>
<td>1,666</td>
<td>15.2%</td>
</tr>
<tr>
<td><strong>Polypropylene (PP)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Film</td>
<td>1,157</td>
<td>10.6%</td>
</tr>
<tr>
<td><strong>Polyvinyl Chloride (PVC)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Film and sheet</td>
<td>381</td>
<td>3.5%</td>
</tr>
<tr>
<td><strong>Nylon</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Film and coating</td>
<td>125</td>
<td>1.1%</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>10,962</td>
<td>100%</td>
</tr>
</tbody>
</table>

Section 1 - Recovering Waste Plastic Films

The recovery of waste plastic films often requires activity at more than one practical level. Chiefly, this means activity at the initial point of generation or the workplace, and at some subsequent point, either by a recyclables hauler, processor, end-user or some combination thereof. This section of our guide will look at strategies for the recovery of waste plastic films on two principal levels: in the workplace, and in the commercial waste and recyclables handling industry.


Recovering plastic films in your workplace means collecting and preparing materials internally for an external recovery program or market channel. Internal recovery program needs will vary with the types of plastic films accepted and requirements of the external recovery channels, but have basic elements necessary for success:

- A strategic diversion system design for separation and storage of plastic films
- Education of participants about quality requirements

The objective of these basic elements must be to provide a consistent, quality stream of material to the market, or the program will ultimately fail. These elements are integral to one another, and should coincide with the specifications prescribed by the external plastic film recovery channels.

Recyclability Begins with Purchasing

An important function precedes the considerations for successful film recovery that are discussed in this section: the original purchasing activity. In the course of evaluating recovery opportunities as described in this guide, a business may find that its films are not currently recyclable through local market channels because of certain limiting characteristics. For example, a business may use a particular packaging film that is recyclable, except for the lamination of incompatible resin type.

It may be relatively easy for that business to purchase an alternative film product that is fully compatible with the dominant resin, with a simple request to its packaging vendor. If problem film products are not directly purchased by the business seeking to recover them, but rather by its vendor, as is often

<table>
<thead>
<tr>
<th>Figure 1-1</th>
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</table>

Steps to Establishing a Successful Film Recovery Program

Step 1. Identify the types and quantity of plastic films in your waste stream and determine which are recyclable.
Step 1-A. Determine recyclability through local markets
Step 1-B. Develop market relationships and transportation logistics
Step 2. Assess the economics of diverting and recovering the films identified.
Step 2-A. Evaluate equipment acquisition
Step 3. Establish collection points and consolidation strategy
Step 4. Establish storage and handling protocols
Step 5. Maintain quality controls and education of employees
the case, the business can use its purchasing influence to affect the packaging decisions of its vendors. This might include asking vendors to standardize packaging types, reduce labeling or other contaminating materials, or simply to use more recyclable films.

Plastic film recovery must be convenient for users in order to achieve success. Convenience relies on the design of the diversion system for separation and storage of recovered plastic films. In today’s business environment, physical space and employee time are carefully managed for cost. A strategically designed system for plastic film diversion seeks to minimize both of these factors. The step-by-step strategies shown in Figure 1-1 are recommended for establishing a new film recovery program.

**Step 1.**

**Identify the types and quantity of plastic films in your waste stream and determine which are recyclable.**

The plastic films in a business’ waste stream must first be identified before any decisions can be made about those that might be recovered. Assistance with waste stream assessments is often offered by local governments, waste haulers, or professional consultants. Figure 1-2 illustrates some of the most common film types (Please refer to Section 3, for a complete description of the various types of plastic films, their identifying characteristics, and recyclability). The most readily recyclable types of films are those made with polyethylene resins (LDPE, LLDPE & HDPE). An analysis of the typical generation patterns among various industry sectors is also provided in Section 4.

Once the films in your waste stream have been identified, they need to be quantified. Barring extensive sampling and weighing to accurately characterize a business’ waste stream, the simplest method is to estimate the fraction of film relative to the total disposal stream. After estimating the volume fraction, some average weight-to-volume ratios can be applied in order to arrive at a reasonable estimate of weight. Volume estimates should be developed from visual observations of three or more different disposal loads prior to pick-up by your waste hauler to determine a reasonable average. Invoice statements from your local waste or recyclables hauler should indicate the total weight hauled. Figure 1-3 illustrates the process for arriving at a monthly film generation estimate, using only those two input values.
Step 1-A: Determine Recyclability through Local Market Channels

Once a business understands the types and quantities of film it generates, it must identify the types that can be recovered in the context of available markets and recycling infrastructure (Commercial recycling programs are discussed later in this section and end-markets are discussed in Section 5). Businesses that generate large quantities and consistent quality film waste streams have the greatest ability to access recycling markets, because of the potential to broker material nationally or even internationally. However, such large players represent a small percentage of the businesses that generate plastic film wastes. Most businesses rely on intermediate external recovery programs to provide access to recycling markets.

External recovery programs are typically operated either by a municipality, a local waste and recyclables hauler, an independent processor, or directly through a material end-user. Many businesses or institutions have existing programs in place for the recovery of other recyclable materials, such as old corrugated cardboard (OCC), paper, metal, or even other plastic containers. Opportunities to link plastic film recovery with such existing recycling programs should always be investigated first.

If you find that some of the film in your operation is not readily marketable, or causes excess contamination, it may be worth exploring whether this film can be replaced by another type of film. This is often the case. By working with your purchasing or supplier contacts, it is often simple to arrange for the packaging film to be switched.

Some investigation may be necessary to fully identify what plastic films are recyclable through local recycling channels. Because plastic films are a new commodity, some waste and recyclables haulers may have access to plastic film markets, but choose not to advertise that service to their accounts. Customers who request this service may find that haulers have the additional ability to assist with setting up an internal plastic film recovery program. Markets for recovered films, as discussed in Section 5, include both domestic and overseas buyers. Market applications for recycled films include reclaiming of resins for use in the manufacturing of new plastic products and other applications which use films directly in the manufacturing process, such as plastic lumber or composite products.
Step 1-B: Develop Market Relationships & Transportation Logistics

Once a business has determined the recyclability of the films in its waste stream, it must next develop relationships and logistics that will ensure the recovery effort is feasible. Whether working with a waste and recyclables hauler, or directly with an end-user, it is important to fully understand their needs. Asking some basic questions, as outlined below, can help in establishing the logistical details that will make your program work.

What are the acceptance requirements?
In initially assessing recycling opportunities, as described in Step 1, you should develop a general sense of what films are readily accepted through local market channels. Once your business decides to proceed with the development of a film recovery program, acceptance details need to be clarified, including the following:

---

### Figure 1-4
Sample Recycling Specification

**RESIN:** Polyethylene (PE)
**PRODUCT:** Mixed Plastic Films
(Stretch films, grocery sacks, other film packaging)
**TYPE:**
- Thickness: Up to 12 mil
  (some woven films OK)
- Color: MIXED COLOR
**CONTRAMINATION:**
- Total Allowable: 2% by weight
  1% by visual inspection;
- Food & Liquid: No Food or Liquid residue accepted
- Haz. Materials: Absolutely NO Hazardous, dangerous or medical wastes
- Moisture: No free flowing / <2% by weight
**STORAGE:** <1 month outdoor storage unless covered with UV protective materials
**LABELING:** Bar-code labels to be placed on one side of each bale
(see available flyer: Bale Labeling Protocols)

**PREFERRED BALE PROPERTIES:**
- Dimension: 72” max.
- Bulk Density: 15 lbs/cu.ft. minimum
- Strapping: Non-rusting material
- Integrity: Must be maintained through shipping, unloading & storage
- Shipping Configuration: stacked, without pallets

---

Common Unacceptable Contaminants (subject to 2% limit)
- Oriented Polypropylene (OPP)
- Woven Polypropylene (PP) (e.g. lumberwrap, food & grain bags)
- Polyurethane Foam
- Nylon (e.g. food pkg., co-ply and cast)
- Polystyrene packaging (e.g. rigid foam, molded, cast sheet)
- Strapping (e.g. PET, PP, nylon & twine)
- PVC of PVDC packaging
- Cross-linked PE packaging
- Rigid plastic (e.g. bottles, jugs, containers)
- Glass containers
- Ferrous and non-ferrous metals
- Paper and cardboard
- Dirt, rock & other inorganic grit

---

- Is more than one “grade,” or type of film accepted?
- Is there differential pricing for each grade?
- Is a printed specification available? (Figure 1-4 illustrates what an actual specification may look like).
- What are the specifications: form, resin, color, dimension, allowable contamination levels, bale densities, etc.?
- How will determinations of contamination level be made? Are there visual inspection protocols?
- What are the rejection practices? What is the procedure for resolving disputes over quality?
- Are there labeling requirements?
What are transportation arrangements?
• Do they pick-up, or is delivery required?
• What are scheduling requirements - how much advance notice?
• Are there requirements for shipping?
• Are pallets allowed?
• Minimum container weights?

Some commercial recycling programs offer pickup of less than truckload quantities of prepared films (e.g., two or more bales at a time). These programs may represent an attractive alternative to trailers when inside space and dock space are limited. Meeting container weight requirements can be exceedingly challenging if individual bales do not have adequate density.

What are the available agreement terms?
• Is educational support available?
• Is the buyer willing to offer long-term contracts?
• Is equipment placement assistance available?
• What assurances can the program offer that it will be around tomorrow?

Developing a clear understanding with the recycler about material requirements and handling logistics, will minimize problems in the future. Assurance of future stability and willingness of the commercial program to offer support are important to most businesses because of the time and effort involved with initial setup. Contracts minimize risk, but may be an inconvenience to smaller generators. Larger quantity generators may benefit more from the stability of a recycling contract, but also have more market options available in truckload quantity.

Section 5 provides more information about end-use markets. It is important to develop a working relationship with your account representative, and to call attention to any challenges you are facing. Most external recovery programs recognize that they are a service provider, and want to maintain your business. Some programs will provide leasing assistance to place equipment such as balers or trailers at your facility.
Step 2.

Assess the economics of diverting and recovering the films identified.

Several direct as well as indirect economic benefits may be derived from plastic film recovery. This section is focused on quantifying the direct economic benefits. However, it is important to note that indirect benefits may be important and legitimate factors in establishing material recovery activity for many businesses. These indirect benefits, while less tangible, can result in real economic impacts for businesses.

Avoided Disposal Savings

One of the most significant factors in motivating businesses to recover plastic films is the high cost of solid waste disposal. Disposal costs, long considered a minor overhead cost, are increasingly being assigned to cost center managers as a line item expense. This provides new incentive for managers to seek alternatives to disposal that will lower costs.

Most businesses incur more than one type of cost for disposal services. Costs typically include a variable fee based on tonnage disposed (tip fee), a fixed fee for each dumpster haul (pull charge), and possibly a rental fee for the disposal container or dumpster. The combination of tip fees and pull charges is particularly significant to plastic film disposal, because of the low weight-to-volume ratio of films. This means that each pound of plastic film disposed occupies a greater volume of space than other waste materials.

Businesses who have a significant percentage of film in their waste stream, fill dumpsters more quickly and require a greater number of pulls. For instance, a large 40-yard dumpster, that ordinarily will hold several tons of mixed commercial waste, may reach capacity with as little as one ton of plastic film. If the tip fee is $60 per ton, and the pull charge is $95, the effective disposal rate for that ton of plastic film is $155, more than twice the nominal tip fee.

In order to accurately estimate the disposal costs specific to the plastic film portion of a business’ waste stream, we must assess some basic data about the disposal profile. This process is illustrated in Figure 1-5, using sample data. The first step is to determine how much waste a business is generating. This information is usually readily available to the business from monthly statements provided by the local waste hauler. From here, we must visually estimate the fraction of the waste stream volume that is comprised by plastic films. Additional data needed is the disposal cost per ton or “tip fee,” and the container “pull charge,” along with the size of the disposal container used.
Once we have determined these five values, we can make some basic calculations needed to arrive at an accurate estimate of the average monthly disposal cost for plastic film. Using available information about the average densities of loose plastic films and mixed commercial waste, we can calculate a weighted average waste density for the business waste stream, based on the estimated fraction of film.

From this point we can determine the monthly volume and apply the estimated film fraction and density data to arrive at an average weight estimate for disposed plastic films only. We can further determine the marginal number of container pulls associated with that quantity of film. Using film weight and marginal number of pulls combined with tip fees and pull charges, we can calculate disposal cost.

**Determining the Total Cost of Plastic Film Disposal**

<table>
<thead>
<tr>
<th>Current Disposal Profile:</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Monthly Disposal Weight Estimate (all materials)</td>
<td>13.5 tons / month</td>
</tr>
<tr>
<td>Estimated Average Plastic Film Composition</td>
<td>45% film by volume</td>
</tr>
<tr>
<td>Disposal Cost per Ton</td>
<td>$ 60.00 per ton</td>
</tr>
<tr>
<td>Container Pull Charge</td>
<td>$ 95.00 per pick-up</td>
</tr>
<tr>
<td>Disposal Container Size (cu. yds.)</td>
<td>40.0 cubic yards</td>
</tr>
<tr>
<td>Estimated Average Density of Disposed Materials (all materials)</td>
<td>102.75 lbs. / cu. yard</td>
</tr>
<tr>
<td>Average Volume of Disposed Materials (all materials)</td>
<td>262.8 cu. yards</td>
</tr>
<tr>
<td>Average Number of Monthly Container Pulls</td>
<td>6.6 pulls per month</td>
</tr>
<tr>
<td>Total Cost of Waste Disposal per Month (all materials)</td>
<td>$ 1,434.09 per month</td>
</tr>
</tbody>
</table>

**Plastic Film Generation Estimate and Disposal Cost:**

<table>
<thead>
<tr>
<th>Plastic Film Generation Estimate and Disposal Cost:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Film Plastic Weight Estimate</td>
</tr>
<tr>
<td>Marginal Number of Pulls for Plastic Films Only</td>
</tr>
<tr>
<td>Total Cost of Film Disposal per Month</td>
</tr>
</tbody>
</table>

This analysis illustrates how disposal costs for plastic films relate to the broader disposal costs of a business. In the sample shown in Figure 1-5, calculations indicate that plastic film represents less than 20 percent of the total weight of mixed waste generated by the business. However, that film fraction accounts for 31 percent of the total disposal cost due to the additional number of container pulls it requires.

**Material Sales Revenue**

As we can see from the analysis of the disposal costs for films, establishing a film recovery program that eliminates or reduces film disposal cost can create a significant economic benefit on that basis alone. However, with the emergence of new markets for plastic films, as described in Section 5, and increased access to recycling channels, many waste generators now have the additional opportunity to derive sales revenue from the recovered films.
Sale of recovered plastic films is most practical when films are well prepared or baled for shipment, and accumulated to truckload quantity. However, some programs will service smaller quantity generators and still pay for the film, as long as it is baled. Programs that accept non-baled films typically do not pay and often charge a fee.

Revenue generated by plastic film sales will vary depending on local market channels, types of film recovered, and quantity. The historical average range of prices paid for baled PE films in the U.S. has ranged from $0.00 to $0.07 per pound. If transportation to a recycler's facility is required, the costs of transportation should be deducted from the material revenue, to arrive at a revenue rate FOB the supplier location. Using the same sample data from Figure 1-5, let's assume the business is baling the recovered film and selling it at $0.02 per pound at its dock. Figure 1-6 shows the gross benefit derived from plastic film recovery by the business.

Determining Costs Associated with Recycling

In assessing the direct economic benefits of plastic film recycling, you must be careful to only consider the marginal or net economic benefits relative to the next closest alternative. To do this you must now consider any costs associated with plastic film recovery and deduct those from the gross benefit. The most significant cost typically associated with recovery is the labor time required to bale the diverted films. There may be other supplies required for the recovery program, the most common of which are baling wire and recycling bags.

Labor Costs

It is important to identify the marginal labor costs associated with diverting films from the waste stream. In most cases, this is the labor time required to load and operate baling equipment, but may also include dedicated personnel time for internal collection or handling. All labor rates used in these calculations should be adjusted to include overhead costs. Remember to only include the marginal labor cost, and not that labor already required for disposal.

Labor costs associated with baling depend on the type of baling equipment used, as discussed in Step 3 of this section. Larger, more expensive balers produce more bale weight per labor hour, while smaller balers will produce less bale weight per labor hour. Baler efficiency is largely a function of the capital costs of the baling equipment.

Continuing with the same sample profile data, and assuming, a standard size downstroke baler is being used that produces 900 pound bales on average. Figures 1-7 illustrates the
calculation of the net benefit of plastic film recovery. The average time required to load, cycle and tie bales of this type is about an hour and fifteen minutes.

**Recovery Program Supplies**

Any additional supplies required by an internal recovery program should also be accounted for. This should only include supply costs not otherwise required for disposal, such as baling wire. Clear collection bags may, or may not, already be used in waste collection activities. Supplies may also include collection totes or educational materials used in the program. Standardized cost factors for baling wire and collection bags have been provided, using information developed from the cost of these supplies, average amount of wire required per bale, and average weight recovered per bag. Figure 1-7 shows the calculation of the per pound net benefit of plastic films recovery after accounting for these costs.

**Step 2-A. Assessing capital equipment purchase for film recycling**

Once a determination of the estimated net benefit of plastic film recovery has been made, a business can easily evaluate the merit of equipment acquisition. Acquisition of equipment for film preparation is only necessary if the business does not have suitable equipment already available, or if advantages can be gained by utilizing dedicated equipment. In addition to determining a budget based on the net economic benefit of recovery activity, the following ranges apply for matching baler size and type to the quantity of film generated:

- **1,500 to 3,000 LBS / Month** Minimum 30" downstroke baler
- **3,000 to 7,500 LBS / Month** Minimum 48" downstroke baler
- **7,500 to 25,000 LBS / Month** Minimum 60" downstroke baler
- **25,000 LBS and up** Need to consider horizontal baler

Since most baling and compaction equipment offers a broad range of uses, the equipment is common in many industries. As a result, leasing is a readily available alternative to purchasing in most markets, and there is a strong secondary market for used equipment. This means greater access to equipment for small businesses, and helps to mitigate risk associated with equipment acquisition.
The durability and age of the equipment should be considered in determining the economic life expectancy. Sufficient maintenance is important to the long-term performance of any waste handling equipment; and is especially important for equipment used with plastic film, because of its tendency to create slightly higher wear than comparable quantities of other materials such as corrugated cardboard. A good rule-of-thumb to estimate maintenance and service costs is to anticipate an annual cost equivalent to 10 percent of the capital cost (e.g., a $5,000 baler should be expected to have $500 in service costs annually).

The interest rate used in calculating amortized equipment cost may be either the leasing interest rate or an appropriate opportunity cost rate if the equipment is purchased for cash. Figure 1-8 illustrates the process of determining the amortized equipment cost. Referring to the sample data from Figure 1-7, we see that our hypothetical company could realize a net economic benefit of about $329 per month. In Figure 1-8, we see that the company could purchase a $5,000 baler at a total monthly cost of about $166, and still realize a net monthly savings of $163.

One last associated cost to be considered with any equipment, is the cost of installation and setup. In general, the larger the equipment, the greater the setup costs. Some small balers only need to be rolled into place and plugged in to a standard 15 amp, 110 volt outlet. However, most larger balers need to be anchored to the floor, and require 440 volt, 3 phase power service of 60 amps or more. Consult your vendor about any installation costs, and remember to include the total costs in your economic analysis.

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**Equipment Investment Cost**

(If adequate baling equipment does not already exist, it is necessary to evaluate purchase.)

<table>
<thead>
<tr>
<th>Capital Cost of Baling Equipment</th>
<th>$5,000.00 (used 48” downstroke)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Economic Life of Equipment</td>
<td>48.0 months</td>
</tr>
<tr>
<td>Annual Estimate of Service Costs</td>
<td>10.0% of capital cost</td>
</tr>
<tr>
<td>Interest Rate</td>
<td>9.0% annual</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Amortized Monthly Cost</th>
<th>$124.43</th>
</tr>
</thead>
<tbody>
<tr>
<td>Service Costs per Month</td>
<td>$41.67</td>
</tr>
<tr>
<td>Total Costs per Month</td>
<td>$166.09 per month</td>
</tr>
</tbody>
</table>

**Net Benefit of Plastic Film Recovery**

(After equipment purchase)

| $ 0.031 per lb. | $162.64 per month |
Step 3.
Establish collection points and consolidation strategy

Collection of recovered films should be integrated into the day-to-day operating environment, and focused on the films that have been identified as recyclable. Businesses that generate more than one type of plastic film must determine whether the market channel requires that the films be source separated. Market channels that do accept commingled film types will typically pay less than those accepting individual grades, however, your business may be able to avoid costs associated with sorting and may be able to recycle a larger quantity of film.

a) Identify discreet source locations
The first step in determining where collection points should be located is assessing where plastic film wastes are routinely generated, and what types are generated at each point. Many businesses that generate more than one type of plastic film generate those types at discreet locations, and it is only during waste consolidation that they are combined. For instance, a grocery store may collect used grocery sacks from customers at the front of the store, and generate used stretch wrap in it's stock room. Segregation of films by type in such circumstances, is relatively easy; they simply must be consolidated separately. Other businesses may only generate one type of plastic film, such as a lumber distributor, who generates only woven HDPE/LDPE lumber overwraps.

Beyond those businesses with relatively straightforward film generation patterns, more investigation is necessary to identify what films are found at individual locations. Some operations, such as a distribution warehouses, may generate plastic films at only one or two locations within the operation, such as the shipping and receiving department. Other operations, such as packaging facilities, may generate plastic films at several activity centers throughout the facility. In most cases, investigation will reveal that film types found at each activity center are consistent, and can be readily separated.

In some cases, however, several film types may be commingled before they are discarded. For instance, a furniture distributor may find individual units wrapped with LDPE foams, encased in an LDPE bag, and wrapped with LLDPE stretch wrap. These various film types may be laminated or taped together and may be difficult to separate. In such circumstances, the business should seek a market channel that will accept this type of commingled film stream, or exclude them from it's recovery program.

b) Coordinate Bin Placement with Disposal Practices
Next, the current trash collection points and any existing recycling points must be considered. If a trash container is located near a worker's station and the collection point for plastic film is 150 yards away, the likelihood of that worker participating in plastic film recovery is reduced. Additionally, locating...
recycling points near trash bins, as depicted in Figure 1-9, increases the incentive for people to deposit recyclable film in the recycling bin, and decreases the chance for contamination. Some existing waste collection points may need to be repositioned in order to strategically co-locate film collection points.

**Transparent Recycling Bags a Key to Quality**

Understanding that quality starts at the source is the first step toward setting up an effective plastic film diversion program. The next step is to ensure that quality can be monitored and maintained through the recovery process. Large transparent recycling bags can play an important role in achieving both of these objectives. Once plastic films have been sealed in a transparent recycling bag, handlers can easily monitor and evaluate the quality of the plastic films recovered. Additionally, the bags serve to consolidate and protect the recovered plastic films into a readily manageable form, protected from further contamination. Bagged films can be easily handled for loading or unloading, during transfer or baling activities.

When selecting bags for recycling, transparency is often the most important attribute to look for. Strength, size and cost are also significant decision factors. Transparency is another factor that increases cost relative to pigmented bags. However, bags with a slight opacity that are still transparent will generally function well for recycling purposes, and typically cost less than bags with higher clarity.

Strength is important to ensure that bags do not burst open during handling, causing materials to be less manageable. Stronger or thicker bags are typically more expensive than thinner ones, but may pay for themselves with higher performance. Bags of at least 1.25 mil thickness, with LLDPE content are recommended for plastic film recovery programs. As plastic films have a high volume-to-weight ratio, large bags are preferred to maximize handling efficiency. An average 38 inch by 65 inch flat bag, is found to work well with most bag racks and cans up to 55 gallons in size, and will generally accommodate films of all sizes when loosely hand compacted.

**Use Racks Instead of Cans or Bins**

Once plastic films are placed in a recycling collection bin, it can become difficult to monitor the quality of the films as they are diverted for recovery. Transparent recycling bags cannot solve this problem, if they are hidden inside of some other container. One proven successful and cost-effective solution to this problem used by many plastic film recovery programs, is the use of open frame bag racks in place of conventional bins.

**Figure 1-10**

A basic open-frame rack, combined with clear recycling bags, allows the user to see the plastic films as they are diverted.
Several different styles of racks, such as the basic design shown in Figure 1-10, or lighter weight folding styles, are available from industrial supply firms.

When combined with transparent bags, these racks can become highly effective tools for plastic film recovery. Strategically placed next to disposal containers, it becomes easy for users to pull unwanted materials out of the recycling bag, and properly deposit them in the trash.

c) Transfer Materials to Central Point
How the existing waste and recyclable materials are physically transferred must be considered. For instance, many facilities may use operations or janitorial staff on regularly scheduled rounds to transfer those materials to a central location. Other facilities may rely on staff at individual activity centers to transfer their waste materials to a central point. A thoughtful plan to collect plastic films as part of a business’ regular waste management activity will minimize the marginal labor and cost requirements of diverting plastic films. The central receiving point should be located near the central disposal or recycling point for other materials, to maximize the efficiency of transferring materials together.

Strategic plastic film collection points take into account all three of the above considerations to maximize convenience for users and the staff responsible for handling the materials.

Step 4.
Establish storage, preparation and handling protocols
Once materials are diverted from the waste stream they must be prepared for transportation to market, often requiring storage on-site. Baling is the most common way to prepare plastic films for shipment, and is required by most buyers. A properly prepared bale maximizes the use of storage space, and can be easily stacked and transported.

Interim Storage of Loose or Bagged Films
There are two types of on-site storage needs associated with film recovery programs at most businesses: interim storage of loose or bagged films prior to preparation, and storage of prepared films until truckload quantity is reached.

A principal challenge of baling plastic films is finding adequate space to accumulate enough film for a single bale. This challenge, may be compounded by the need to segregate film types during accumulation, and should be addressed either through:
- Strategic design of an interim storage area, adequate for the minimum quantity of each material type necessary to make a bale of sufficient weight; or
- The use of a dedicated baling device, so that material can be stored in the chamber as it is accumulated.
Interim storage should be established in an area where incidental contamination such as dirt, moisture, or other non-recyclable film materials can be minimized. Interim storage may consist of a partitioned area where bagged films can be stacked freely, or use some type of bins or racks to maximize use of space. Corrugated gaylord boxes (usually 40” to 44” inches cube) are a common low-cost storage vessel. Since dedicating an area of 200 to 300 square feet for interim film storage is often cost prohibitive for businesses, a dedicated densifying device for plastic films is often an attractive alternative. The footprint required for this alternative is usually less than 100 square feet, including the space for the baler, and one or two bins of loose plastic film.

**Baling Films**

Specialized baling equipment is not required to successfully bale plastic films, although certain balers will better accommodate the unique characteristics of films. Most specifications for baled films call for minimum bale densities of 12 to 15 LBS per CU FT. These density levels are necessary to achieve transportation cost efficiency and indicate the structural integrity of the bale. An underweight bale that does not meet these minimum densities does not exert adequate force on the baling wires to maintain tension, and in turn may break apart during handling. Conversely, an over-weight bale may exert too much pressure, causing baling wires to burst. When a single bale breaks apart or otherwise bursts, it becomes an expensive handling cost to the recycler or processor handling it.

**Downstroke Balers**

Downstroke, or vertical balers are the most common type used by generating businesses. These balers employ a platen press driven downward by a hydraulic ram cylinder. In most balers used for baling old corrugated cardboard (OCC), the ram cycle does not force the press to the bottom of the baling chamber, but rather about halfway down, and pressure is transferred through the cardboard (refer to figure 1-11).

Plastic films, however, have a much higher tendency to return to their original shape, resulting in a “bounce-back” effect. Additionally, pressure does not transfer well through loose films, so it is difficult to achieve desired density in the initial portion of a film bale, when using a ram that does not penetrate to the bottom of the baling chamber. As the ram cycles open, films tend to expand, filling the loading chamber and making it difficult to load additional material. Even mechanical fingers or “dogs” that many balers use to help hold the material down while the ram is raised, will not contain films as they expand and flow around them. Most baler manufacturers offer models that use full penetration ram cycles, which helps to offset these challenges.
As downstroke balers are widely used, there is a strong secondary market for used equipment. New standard sized 60” balers tend to range in cost from $10,000 to $15,000 installed (providing adequate power is available – usually 440v 3-phase). Used machines tend to range from $4,000 to $10,000 in cost, and can be found with dealer warranty. Service contracts are highly recommended for all recycling equipment, especially balers which can incur heavy wear on the motor and other working parts. These contracts usually cost between 5 and 10 percent of the original cost of the machine annually.

**Horizontal Balers**

Larger, horizontal configuration balers are also found at business locations generating large quantities (usually 25,000 LBS/month or more) of recyclables, although they are more common among commercial recycling facilities. Most horizontal balers provide adjustable ram penetration depths, and will perform adequately with plastic films. However, as these balers hold larger quantities of material (some horizontal balers can produce plastic film bales weighing ONE TON or more), the plastic exerts more force against the ram. It is important to consult with the equipment representative about the operating pressure of the baler and its suitability for plastic films. These balers typically cost from $30,000 up to $200,000, depending on size, infeed system and auto tying capabilities (please refer to Figure 1-12).

**Alternative Balers**

There are a handful of alternative baler designs available that can be used with plastic films, and are especially relevant to the baling needs of small to mid-volume film generators, and businesses preparing more than one recyclable. Most of these balers are manufactured in Europe, where diversion of multiple commodities is common, even among small businesses. Some of these alternative balers are designed for improved user convenience and

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**Figure 1-12**

Horizontal balers are made in a variety of shapes and sizes. On the left is a continuous extrusion auto-tie design by Balemaster. On the right is a fixed-door manual-tie model made by Ferrodyne.

**Figure 1-13**

Several alternative baler designs are common in Europe, but are increasingly showing up in domestic use. A few examples are shown here (clockwise from upper left):

- Orwak / Sweden - employs a sliding lid and side mounted hydraulics (100 LB bales).
- Pottinger / Austria - multi-chamber baler with sliding lid and press unit (250 LB bales).
- Welger / Germany - roll baler, employing auto feed, belt compression technology (derived from hay baling machines), and auto wrapping (50-70 LB rolls).
space efficiency, with features such as sliding lids, multiple baling chambers, or self-feeding (please refer to figure 1-13).

These machines hold potential to be employed in non-industrial environments, such as the back room of a retail shop, and may offer a cost advantage wherever square footage is a premium cost. However, at current prices of $6,000 to $20,000 US, including import costs, these machines are not likely to be used on a broad scale.

**Operating Tips for Baling**

Given an understanding of the difference in the characteristics of plastic films relative to other recyclable materials and the performance variations between balers, it is important to understand what makes a good bale. A "standard" bale, as shown in figure 1-14, is 900 – 1200 LBS in weight and roughly 60” L x 30” W x 48” H in size. However, a small bale may weigh 250 LBS and meet the same quality standards. Different programs will accept different size bales, and bale size is strictly a function of baler size. The fundamental measures of bale quality are density (LBS / CU FT), consistency of material type, and level of contamination.

There are some basic operating tips that can help minimize problems during baling, and maximize quality:

**Bale Headers**

Bale headers are recommended for most plastic films, especially for small bags such as grocery sacks. These are sheets of cardboard or other material placed on either end of a bale to help contain the contents after bales have been tied. Headers serve to evenly distribute the pressure of individual bale wires against the surface of the bale, and are most useful when baling smaller sized recyclables, that may tend to break through between the wires. This is an important function in maintaining bale quality and structural integrity through subsequent recovery handling. Some larger, heavy weight films, such as mattress bags or lumber wrap do not require headers.

Headers are generally considered a contaminant, depending on the end-user's process and specifications. Corrugated cardboard headers are commonly over sized resulting in a problem contamination level. These headers should be limited to one layer of cardboard. Alternatively, other materials may serve as headers, such as a heavy weight sheet of film or the common black HDPE slip sheets used in many warehouses.

**Baling Wire & Tying Practices**

As plastic exerts more force than other materials packed to similar densities, proper tying of bales is critical to their durability. For instance, a standard size bale of old corrugated cardboard may only require 5 ties of 14 gauge wire. A similar bale of plastic film should use a
minimum of seven ties of 12 gauge wire. Where heavy gauge wire is not available, double wiring each tie is recommended.

**Adjusting Ram Cycles**

The bounce-back effect experienced when loading film can be minimized somewhat by adjustments in the way the ram is cycled. Two principle adjustments to the ram cycle are: 1) increasing the pressure at which auto cycles retract; and 2) leaving the press down for a longer period of time between loading cycles. Most balers have an adjustable switch, which automatically reverses the ram cycle when it meets a certain amount of resistance. Increasing the pressure, or operating the ram on manual cycles will allow the operator to ensure that films are properly densified.

Leaving the press down longer between loading cycles, is another way to help maintain density between loading. This is especially applicable if the baler is dedicated for plastic films, and loading occurs as the film is accumulated. In this case, the press can be left down until the next bin of film is accumulated for loading. If the baler is shared between films and other materials, then it is likely that loading cycles will occur continuously, and time will be constrained.

**Compaction Equipment**

Some businesses can use compactors to densely pack containers for subsequent baling at a local material recovery facility, but few programs offer such a service. Most compactor units (see Figure 1-15), such as those used for corrugated cardboard, do not perform well with plastic films because the pressure applied by the compacting ram does not transfer effectively through the load of loose plastic films in the compaction chamber. The inherent “memory” of plastic films (the tendency to return to original shape) may cause the films to expand to fill the container and trigger the cutoff switch of the compactor.

Generators considering the use of compaction equipment rather than baling equipment should consult with equipment vendors about the performance of the compaction equipment with the films handled. Compactors vary in design, and some allow for adjustments of the compaction stroke and ram pressure necessary to perform adequately with plastic films. Pre-compacting films by hand, into plastic recycling bags, can improve container densities.

**On-Site Storage of Prepared Films**

Square footage (the footprint) represents a cost premium in nearly all business environments. Many businesses simply can not afford the space required to store baled plastic films on-site after they are recovered, and do not have access to recycling channels that will accept loads as small as 2 or 3 bales. As a result, baled plastic films often end up being stored outdoors
until adequate quantity can be accumulated for pick-up. This usually results in a degradation of the recovered films from moisture or ultra-violet radiation. In such a circumstance, both the recycler and the generator lose, because the recycler faces quality problems and the generator may be paid less or even charged for disposal. A low-cost solution to these problems is the use of dry-van trailers or containers for on-site storage.

Dry van trailers can be used for bale storage, and are generally not required to be in top condition, such that they can be purchased in used condition at a reasonable cost. The trailer, as depicted in Figure 1-16, can serve both as on-site storage while the generator accumulates their supply, and as the transportation vessel once accumulated. Trailers are available in a wide variety of sizes, most commonly ranging from 27 to 44 feet in length, 8 feet in width and 12 to 13 feet in height, requiring a standard loading dock slip or comparable space. Trailers can hold up to 45,000 LBS of baled films.

In some cases, generators may choose to use older non-roadworthy trailers for even lower cost temporary storage, transferring the materials to another trailer once ready for shipment. In other cases, trailers are not convenient for storage due to limited dock space for loading. In this case, some generators have found used inter-modal shipping containers, or roll-off boxes placed at grade level to be a convenient alternative for temporary storage. In any case, keeping plastic films out of the weather is essential, and any number of solutions can be developed, based on individual facility characteristics and zoning restrictions.

**Step 5.**
Maintain Quality Controls and Education of Participants

Quality controls and ongoing education are two final ingredients to long-term success. Contamination of recovered plastic films often constitute the largest barrier to successful recycling. Quality controls must seek to minimize contamination and generate the most consistent supply of materials possible. This means implementing quality guidelines at the source, the point where plastic films are initially diverted from the waste stream, and maintaining those controls throughout the recovery process.

The consistency of your recovered film stream is the most significant element to the market channel, because technological solutions can overcome individual issues, but will fail if the stream is not consistent. Too often, plastic films that are sufficiently clean to be recycled, are separated
from the waste stream, only to be contaminated by foreign materials placed in the recycling bin, or during subsequent handling steps.

Many of the market channels developed to-date have focused on specific sub-streams, such as LLDPE stretch films or HDPE grocery bags. Each market specification has its own criteria, which quality controls must seek to meet. Businesses should seek clarification on any particular film or contamination types that they are not sure about.

There are several levels to which quality controls can be taken, including expensive testing and sampling procedures. Market buyers for recovered films do not expect businesses to undertake extensive measures to guarantee tight quality requirements, but rather expect a good faith effort to minimize contamination and maintain consistent standards.

Quality control measures can be as simple as:

- Demonstration boards such as that shown in Figure 1-18, illustrating what recyclable plastic films are.
- "Recyclable Plastic Films Only" signage at all collection points with brief description of what is acceptable.
- Specifications posted at baling station, with an easily readable list of non-acceptable materials.
- Careful handling and storage of baled films, protect from moisture and dirt.
- Ensure adequate weight is accumulated before baling to achieve proper density.
Employee Training and Participation

Education and training of employees is an important element of quality control. Training can be achieved without expensive consulting or lost labor hours. Rather many businesses have had success combining recycling training with other regular meetings, such as weekly safety meetings held by many industrial firms. Many external market channels will provide on-site training on film identification and baling at no charge. The key element of recycling training is providing adequate information, in easily understandable terms, to all program participants, such as the binder shown in Figure 1-19.

Enhanced participation may be achieved by allocating a share of net cost savings to an employee fund dedicated for employee gear or celebrations or other incentives.
Section 2 - Commercial Film Recovery Programs

The principal means of recovering waste plastic films are through segregating films from the waste stream at the source, as discussed earlier in this section, or through sorting films from other materials in a material recovery facility (MRF). In either scenario, commercial film recovery programs are likely to play a role in getting the recovered films from the business generating them to the end-market. Commercial film recovery programs are external to the recovery programs operated by generator businesses. They are typically operated by a municipality, a local waste and recyclables hauler, an independent processor, or directly through a material end-user.

Collection for Recycling

Source-Segregated Films
Commercial programs designed to handle source segregated films, typically focus on getting the generators to prepare the films through baling or otherwise compacting them to achieve transportation efficiency and minimize handling. What constitutes adequate weight for efficient transportation depends on the type of truck and the distance the baled film is being hauled. Large film quantities, or material which must travel 50 miles or more, should be transported by the "truckload" using a semi-trailer or intermodal container of a least 40 feet in length. Figure 2-1 shows the typical one-way hauling cost curve, given the assumptions shown. A full truckload requires at least 35,000 LBS. Truckload quantities of baled film can be shipped up to 200 miles for less than 1 cent per pound.

The collection of films below truckload quantity or which may not be baled to sufficient density typically necessitates the use of a smaller truck, such as a 20-22 foot flat bed with a capacity of about 15,000 LBS, with a shorter hauling radius. Figure 2-2 illustrates the typical cost curve for truckload
hauling using smaller trucks to haul baled films. Hauling of films which have not been baled to significant density, is limited to local area routes, because of high transportation costs (see cost curves in Figure 2-3). Even a 40 foot dry van trailer can only hold about 3,000 LBS of non-compacted films. Smaller flatbeds or box vans can hold about that same amount if loosely bundled. However, as Figure 2-3 shows, the cost of hauling loose films within even a short radius can range from 2 to 5 cents per pound depending on the type of truck used.

**Just Bag It!**

As described earlier in this section, transparent bags like the one shown in Figure 2-4, serve as an excellent means of capturing recovered films in a way that can be easily handled and monitored for quality. Such bagging practices need to be implemented at generator locations, and should be promoted by any commercial recycling program using MRFs to recover film. Properly bagged and secured plastic films can significantly improve pick-line efficiency in MRFs handling films. Workers picking bagged films can retrieve an average of 15 LBS with each bag of film picked, instead of 1 LB or less with most individual film pieces.

**MRF Recovery Programs**

Material Recovery Facilities, or 'MRFs', are facilities that sort recyclable materials. Commercial film recovery programs using MRFs to sort film from the waste stream are likely to rely on film collected in loose form, as baled films are likely to bypass the MRF. There are two different types of MRF situations where plastic film may be recovered:

- commingled recyclables MRFs that sort film from other recyclables, and
- "dirty" MRFs that recover films from certain mixed-waste streams.
In some MRF environments, an adequate quantity of plastic films may be present in the material stream to warrant sorting even though the films are not neatly bagged by generators. This is especially true of mixed-waste MRFs handling commercial waste streams where large quantities of film can be found, but may also be true of certain MRFs where film ends up in the recyclables whether invited or not. If degradation of film, through contamination within the MRF can be minimized, and there is sufficient quantity of film in the waste stream, sorting the film for recycling can be feasible. This largely relies on access to a market with a commingled film specification. A study related to this guide, as referenced in Figure 2-5, examined the feasibility of sorting film in a mixed-waste MRF environment.

### Selecting Recycling Facility Equipment

**Baler requirements**

Commercial recovery facilities handling more than 25,000 LBS per month of film need to use horizontal design balers. Most material recovery facilities are likely to already have horizontal balers on-site. Horizontal balers come in a variety of specific configurations, and some provide adjustable ram penetration depths. As mentioned earlier, some plastic balers can produce plastic film bales weighing ONE TON or more, and the plastic can exert substantial force against the ram, and create a high degree of torque on the entire baler. For this reason heavy-duty baler designs and high operating ram pressure are recommended on balers used with plastic films. It is important to consult with the equipment representative about the operating pressure of the baler and its suitability for plastic films. These balers typically cost from $30,000 up to $200,000 or more, depending on size, in-feed system and auto-tying capabilities.

**In-feed System**

Most horizontal balers are configured for vertical drop-feed loading of the baling chamber. Some models have pre-compaction devices as part of the system, but most models have a top-mounted hopper to hold materials before they enter the baling chamber. Depending on the size of the in-feed hopper, it may be desirable to enlarge the hopper to ensure that adequate weight necessary for gravity feed can accumulate. An in-feed conveyor equipped
with an electric-eye sensor to determine when the hopper is full will further facilitate efficient baler loading.

**Auto-tie Capabilities**
Many horizontal balers can be equipped with auto-tie devices, and most will accommodate plastic films, but will not always lead to the highest quality bales. Fixed-door manual-tie balers will typically provide a bale of consistent density and shape. Single-ram extrusion balers, tie the bales as they are being extruded on the same axis as the ram. With the bounce-back and expansion properties of plastic films, pressure exerted on each wire may be different, and can result in irregular shaped bales that are difficult to handle. Plastic films will perform better in auto-tie balers that use two rams - a primary ram to compact, and a secondary perpendicular ram to eject the bales. With two-ram balers the tying is being done perpendicular to the stratification of layers in the bale, reducing bounce-back and improving bale consistency.

**Rolling stock for film handling**

**Clamp lift trucks**
Most plastic film recovery programs do not want baled materials to be palletized, consequently making fork lifts a less convenient option for handling of materials. Fork lifts perform poorly with non-palletized plastic bales because of high friction with bale surfaces, making stacking difficult. Forks also have a high potential to weaken the structural integrity of bales by breaking baling wires. Most fork lifts can be converted to use a hydraulic clamp device, also known as paddles, in place of forks (see Figure 2-6). Typical clamp devices run about $5,000, and can be configured for quick release, allowing rapid conversion to forks, thus allowing operators to maintain flexibility with rolling stock. The clamps lift bales by the ends, making stacking easy and minimizing the risk of damage to the bales during handling. Depending on truck or container loading requirements, it may also be desirable to use clamps with rotational ability, although these units will have a cost premium.

**Front loaders**
Operations handling loose or bagged films may need to move materials in bulk. Front loaders can be used for this purpose, although bucket dimensions are usually designed for heavier materials and may not allow for efficient handling of film. For operators using front loaders extensively to handle films, bucket modifications are recommended to increase the volume capacity of the bucket. The bucket extensions can be made with relatively light gauge materials because of the lightweight nature of plastic films, but should be durable enough to handle routine impacts on floors and other surfaces.
**Section 3 - More About Plastic Films**

**What are plastic films?**

Plastic films are the thin flexible sheets of plastic used in a broad range of packaging applications. Plastic film production and sales has experienced dramatic growth in recent years as a leading commercial packaging form. Plastic films are used to produce a broad spectrum of packaging types, from stretch and shrink wraps to large custom bags, as well as the common grocery bag. The increased use of plastic films is attributed largely to their low cost, durability and light weight. These attributes have not only given plastic films the ability to displace other forms of packaging, such as corrugated cardboard boxes, for certain applications; but have also led producers to begin packaging products that have not previously been packaged.

Understanding how each resin is used helps us to understand the commercial sectors where those film products may ultimately be found and recovered from the waste stream. One familiar category type of grocery bags is the “t-shirt” style bag shown in Figure 3-2. Many other types of bags are made from plastic films, including trash bags, garment bags, and merchandise bags of all types. Custom style bags and plastic sheets are commonly used to encase and protect durable goods such as furniture, appliances, mattresses, and even boats during shipment. Stretch and shrink-wraps, used to secure palletized merchandise or boxed goods, are common applications of plastic films.

Other niche applications for plastic films make up a smaller share of the overall total, such as heavy weight or woven construction films. Even bubble wrap is considered a specialty application of converted plastic films.

**Introduction to today’s film-grade plastic resins**

The majority of plastic films are made from low density (LDPE) or linear low density (LLDPE) polyethylene, comprising approximately 68 percent of the total film production. In addition to LDPE and LLDPE, high density polyethylene (HDPE) resins are commonly used in film plastics. Non polyethylene resins constitute the remainder of film plastic types found in the marketplace. Polypropylene (PP), polyvinyl-
chloride (PVC), and nylon resins comprise the bulk of these other film types. Increasingly, certain multi-ply or co-extruded films are used in specialty applications that seek to combine performance attributes of two or more resins for a specific application.

Improving resin technology is allowing the production of additional grades of polyethylene, especially LLDPE, with enhanced performance characteristics. In particular new processes, such as the use of metallocene catalysts, are improving properties of linear polyethylene and polypropylene through precise control of molecular weight and composition. These continuing trends mean that plastic films are likely to play an increasing role in future packaging, and represent a larger supply available for recovery.

**Tips for Identifying Film and Resin Types**

While many recycling programs will offer assistance with material identification, knowledge about plastic films is often limited, even among experienced recyclers. Techniques for identifying film resin types include evaluating clarity, stretch and strength properties, feel and flexibility, and even burning characteristics. Testing burning characteristics should be done outdoors with extreme caution, using a small sample, burning only one corner with a lighter or match. Each resin and its identifying characteristics are described below:

**Low Density Polyethylene (LDPE)**

LDPE was the first commercial polyethylene, and has been the most widely used in film applications. It remains widely used in the production of custom bags for durable goods and other products, and often carries the #4 SPI resin code. LDPE is increasingly yielding market share to LLDPE, an enhanced variation of the same resin, and specialty blends.

- **Unpigmented LLDPE & LDPE**
  - (Bags & Liners)

- **Mixed Color LLDPE & LDPE**
  - (Misc. Bags & Packaging)

- **Mixed LLDPE, LDPE, HDPE**
  - (MRF Pick-line Sort)

**Common LDPE Film Identifiers**

- Unpigmented films have high clarity
- Burn test: smells like a candle
- Will strand when pulled in molten state
- Moderate stretch & strength characteristics
- Foams: Flexible and compressible (unlike polystyrene foam) but firm (unlike soft polyurethane foams)
- Bubble Wraps: Sometimes contain nylon as strength enhancer, check with manufacturer.
In addition to film applications, LDPE is found in film-related products, including packing foams and bubble wrap materials. These materials are sometimes accepted by programs offering LDPE film recycling.

- **LDPE Carrier Sheet / Camel Back** – One niche application where LDPE is found in commercial use is as a backing for “pre-preg” composites, sheets of thermoset resins used in the automotive and aerospace industries. Known as camel back for its textured surface that minimizes adhesion, these films are commonly brightly colored and coated with traces of a release agent that may be a contaminant for some recycling processes.

- **LDPE Agricultural Films** – “Ag” films are those films use in various farming and growing applications. These include silage bags, greenhouse films and wrap for hay bales. Because these films often come in contact with the ground or moist farm products, contamination control presents a major challenge. Greenhouse films alone represent a major use, but are often painted by growers to decrease UV rays or coated with herbicides from overhead spraying. Some specialty programs have conducted feasibility assessments of recovering agricultural use plastic films. For more information, refer the APC publication titled: “Use and Disposal of Plastics in Agriculture.”
**Medium Density Polyethylene (MDPE)**
This is a variation on the production of low-density polyethylene, using a similar process. MDPE resins represent a small percentage of overall film-grade resins, and are included with LDPE resin production numbers by SPI. This resin is commonly used as a low-cost alternative to other resins in film applications where strength is not required, such as consumer paper goods as shown to the right.

**Common MDPE Film Identifiers**
- Unpigmented films have moderate clarity
- Burn test: smells like a candle
- Will strand when pulled in molten state
- Poor stretch & strength characteristics

**Linear Low Density Polyethylene (LLDPE)**
Linear low-density polyethylene was developed in 1978. Its production process is less costly than high-pressure processes used to produce standard low-density resins, making it attractive to manufacturers. Additionally, its improved stretch and strength characteristics relative to LDPE have led to an increased market share in a variety of film applications, especially for stretch wrap and bags. See also “Stretch Wrap Recycling: A How-To Guide,” American Plastics Council, 1997.

**Common LLDPE Film Identifiers**
- Unpigmented films have moderate clarity
- Slightly tacky feel to the touch
- Burn test: smells like a candle
- Will strand when pulled in molten state
- Very good stretch & strength characteristics

**High Density Polyethylene (HDPE)**
HDPE, a common resin used in the production of a variety of rigid container plastics, plays an important role in certain film applications. Produced predominantly by low-pressure processes, it is relatively cost-competitive with LLDPE, and offers improved strength, making it the preferred choice for grocery and merchandise sack manufacturing.

**Common HDPE Film Identifiers**
- Unpigmented films have some opacity
- Crinkles to the touch
- Burn test: smells like a candle
- Will not strand when pulled in molten state
- Moderate stretch - high strength
Polypropylene (PP)

Polypropylene has the lowest density of any common thermoplastic, but has good strength properties. One of the more common applications for film grade PP resin is the production of woven sheets, where the film is cut into narrow tapes after extrusion, and woven into durable materials, with further enhanced strength properties.

A type of PP used increasingly in film production is oriented polypropylene (OPP). OPP is produced by stretching the film while it is hot, to improve strength by orienting the molecules. OPP can be used to produce low-cost films with good clarity. These films are difficult to discern from PE films, except by texture and burn testing.

Co-extruded Recyclable Films

There are a variety of niche film products where two or more of the resins described above are combined to yield a film product with enhanced properties for a specific application. Most often, this involves the combination of LDPE and HDPE. In such applications, HDPE contributes strength, while LDPE provides a smooth, flexible surface with high printability. Common applications include:

- **Woven Lumber Wraps** – woven HDPE tapes, laminated with LDPE film: woven texture is apparent, but surface is smooth; often different color on opposite sides.

---

**Common PP Film Identifiers**
- Common resin in heavy gauge woven bags or tarps
- Burn test: distinct sweet wood odor

**Common OPP Film Identifiers**
- Unpigmented films have high clarity
- Common resin in garment bags
- Burn test: distinct rosewood odor
- Fairly stiff, crinkles to touch, tends to return to original shape.

**Unpigmented OPP (Textile Packaging)**
• **Mailing pouches, and bank bags** – HDPE and LDPE layers laminated: typically different color on opposite sides, relatively stiff feel.
Identifying Limited and Non-Recyclable Films

Cross-linked Polyethylene
Cross-linked polyethylene films are films which have been altered on a molecular level in order to significantly improve their strength. The e-beam or chemical processes required to create cross-linked films are expensive, thereby limiting the number of applications where such films are found. Unfortunately, cross-linked films are also non-recyclable, because they cannot be re-melted. These can sometimes be replaced by other polyethylene films with strength-enhancing additives.

<table>
<thead>
<tr>
<th>Common Crosslink Film Identifiers</th>
</tr>
</thead>
<tbody>
<tr>
<td>• No stretch – very high strength – difficult to tear.</td>
</tr>
<tr>
<td>• Crinkles to touch</td>
</tr>
<tr>
<td>• Yellowish hue when crumpled.</td>
</tr>
</tbody>
</table>

Polyvinyl Chloride (PVC) / Polyvinylidene (PVDC)
Vinyl films are common in food contact applications, especially frozen foods, because of their low oxygen permeability and strong cold temperature properties. Vinyl is sometimes laminated to lower cost LDPE films to achieve combined attributes. Vinyl films are recyclable, but due to contamination problems associated with common uses and its specialized recycling lines required, recycling is not cost-effective at this time. A common PVDC wrap is the Saran® brand food wrap.

<table>
<thead>
<tr>
<th>Common PVC/PVDC Film Identifiers</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Check with mfr. on all food contact films</td>
</tr>
<tr>
<td>• Burn test: won’t stay lit – don’t sniff this one – chlorine gas is toxic !</td>
</tr>
<tr>
<td>• Glue test: will dissolve when touched with solvent-base PVC pipe glues.</td>
</tr>
</tbody>
</table>

Nylon Web and Cast Nylon Films
Nylon films are also somewhat common in food contact applications requiring stronger packaging, such as soup pouches or seafood packaging. Nylon films may also be found laminated to LDPE films, and also offer low oxygen and odor permeability and strong cold temperature properties.

<table>
<thead>
<tr>
<th>Common Nylon Film Identifiers</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Check with mfr. on all food contact films</td>
</tr>
<tr>
<td>• Typically thick, high-strength films</td>
</tr>
</tbody>
</table>
Cast Polystyrene (PS) Films
These films are found in a small number of niche applications, and represent a very small fraction of the overall film stream, and are only recyclable in specialty programs. They are used in applications such as carrier sheets for other manufacturing materials. Because they are much crisper (less flexible) than most other plastic films, they may be classified as rigid sheet rather than films, and fairly readily identifiable.

**Common contaminants in the plastic film waste stream**
Some basic contaminants are shown below. In general, any non-plastic material, such as old corrugated cardboard (OCC), metals, food and liquid residues, and other inorganics are prohibited from film recycling specifications. The most prevalent contaminants found in recovered film streams are non-film plastics, such as rigid containers, rigid foam products and strapping. Rigid plastics cause problems in film recycling through the introduction of resin contamination, in the form of polystyrene (PS), polyethylene terephthalate (PET) and other resin types. Even rigid HDPE or LDPE rigid containers have very different characteristics from films made with the same resins. That's because resins are formulated differently based on production requirements to have particular melt flow properties.

<table>
<thead>
<tr>
<th>Rigid Containers &amp; Non-Films</th>
<th>Mylar or Anti-Static Coatings</th>
<th>Waxed Paper / Cellophanes</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image1" alt="Image of Rigid Container" /></td>
<td><img src="image2" alt="Image of Mylar" /></td>
<td><img src="image3" alt="Image of Waxed Paper" /></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Aluminum</th>
<th>Ferrous Metals</th>
<th>Paper or Cardboard</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image4" alt="Image of Aluminum" /></td>
<td><img src="image5" alt="Image of Ferrous Metals" /></td>
<td><img src="image6" alt="Image of Paper" /></td>
</tr>
</tbody>
</table>

**Common PS Film Identifiers**
- Burn test: PS emits a very distinct black smoke when lit – don’t sniff this one!
- Crinkles to touch
Additionally, non-film plastics will generally contaminate recyclable films, and may include rigid containers, PET or PP strapping, polyurethane and polystyrene foams. Other contaminants will vary by market, and may include resin type restrictions, labels, tape, staples, color, printing, foams, and blister packs.
Section 4 - Industry Film Waste Generation Patterns

Plastic film waste may be generated at several points in its life-cycle, beginning with manufacturing. Post-industrial scrap may be generated during the process of converting roll stock to other products such as bags. Post-consumer commercial and post-consumer residential plastic film waste is generated after the film products have served their intended use, and been discarded either by a business or a consumer.

Post-Industrial Scrap

Post-Industrial scrap is found in both primary and secondary (converting to bags, specialty prods.) plastics manufacturing sectors. This is typically the cleanest of all plastic sources, because it has not been in contact with other materials, and can be recovered within a controlled environment. Post-industrial plastic waste is often generated in forms other than film, such as extruder purgings. Post-industrial plastic film types include:

- **Manufacturing scrap** – includes residuals generated during the primary production of film products, such as edge trimmings produced following the extrusion process, or finished films that fail to meet quality standards.
- **Re-manufacturing scrap** – includes residuals generated during secondary manufacturing processes, such as the production of custom bags or other packaging products. This scrap is most often in the form of trimmings, roll ends or mis-printed stock.

Other plastic films that meet the definition of “post-industrial,” can be found in more diverse locations. These include unused products such as bags or wrap that are often still in their original boxes or rolls, but are not usable for a variety of reasons. Such reasons include misprinted labeling, discontinued product lines, or food contact products which have exceeded the FDA approval date. Unlike typical post-industrial scrap, these materials usually represent one-time recovery opportunities rather than regularly recurring quantities.

- **Out-dated food contact films** – includes bags and other food wraps that are no longer approved for food contact use because they have been stored for too long or have been exposed to possible contamination.
- **Discontinued product lines** – includes plastic film packaging with printing or labeling that is no longer current and therefore not usable to a manufacturer.

Post-Consumer - COMMERCIAL

Post-commercial plastic film waste represents the greatest potential for recovery. Waste films in this group are products which have served their intended-use, usually as packaging for some type of product, and have been discarded by a commercial business. Most post-commercial films meet the definition of post-consumer content under federal guidelines, for manufacturers that ultimately use these materials as raw material substitutes.

Post-consumer commercial plastic films typically contain contaminants such as labels, tape or staples, but have potential for high recovery rates with properly designed collection programs.
The larger the quantity of film waste produced by a commercial business, the higher the probability of developing a viable recovery program, either through a local recycler or directly with an end-user. Examples of principal commercial generation points include:

- Commercial businesses: shipping & receiving departments
- Warehouse / distribution centers
- Wholesalers
- Distributor bring-back programs for retail stores

### Post-Consumer - RESIDENTIAL

Post-consumer film waste is made up of products which have served their intended use and been discarded, by an individual consumer rather than a commercial business. These materials are widely dispersed among millions of households, making them the most expensive to recover, and have the most potential for contamination. There are two principal ways in which film can be recovered from this category, through bring-back programs sponsored by businesses or through curbside collection program where plastic films are commingled with other recyclables.

**Vendor Operated Bring-Back Programs**

Bring-back programs are highly economical because they are usually targeted at specific film types (most often bags), and consumers bear the cost of initial consolidation. Those costs are often minimal because consumers can drop-off their plastic films in conjunction with a routine visit to the retailer. Such programs are most common among grocery chains, but have also been used by dry-cleaners, furniture retailers, and other businesses that use large quantities of plastic film packaging.

**Curbside Collection and Material Recovery Facility Sort-Lines**

Curbside collection programs have been implemented in some areas, including parts of Canada. These programs are struggling because of contamination challenges and their inability to compete with cleaner film streams recovered from commercial sources. Such programs are not likely to be seen domestically due to the cost-prohibitive nature of collection and sorting. These programs require a tremendous level of consumer education to achieve success, because of the high potential for contamination in the form of foil laminates or specialty film resins common in the residential waste stream. Food residues are also a significant contamination challenge in this stream.
Locating Major Film Sources

To discover the major sources of recoverable plastic films, we must first review the major uses of film in today's marketplace. Figure 3-4 summarizes the types of product applications where plastic films are found. The point at which these various products enter the waste stream is dictated largely by how they are used. For instance, many food products are sold directly to consumers, so a significant portion of the film used in food packaging is likely to end up in the residential waste stream. Conversely, palletized products wrapped in stretch and shrink films are likely to be found exclusively at commercial and industrial locations.

The principal points where large quantities of recoverable film are generated are those business areas that involve handling and reshipping of products. Whether breaking down palletized products and re-packing to fill custom orders, or unwrapping automobiles at the port; wholesale and distribution activities generate the vast majority of post-consumer - commercial film wastes.

<table>
<thead>
<tr>
<th>1997 Sales of Domestic Resin Production - by End-Uses</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Data in Millions of pounds, unless otherwise noted)</td>
</tr>
<tr>
<td>Production Use</td>
</tr>
<tr>
<td>----------------</td>
</tr>
<tr>
<td><strong>Low Density Polyethylene (LDPE)</strong></td>
</tr>
<tr>
<td>Packaging Films</td>
</tr>
<tr>
<td>Food Packaging</td>
</tr>
<tr>
<td>Non-food Packaging</td>
</tr>
<tr>
<td>Stretch &amp; Shrink Films</td>
</tr>
<tr>
<td>Non-Packaging Films</td>
</tr>
<tr>
<td><strong>Linear Low Density Polyethylene (LLDPE)</strong></td>
</tr>
<tr>
<td>Packaging Films</td>
</tr>
<tr>
<td>Food Packaging</td>
</tr>
<tr>
<td>Non-food Packaging</td>
</tr>
<tr>
<td>Stretch &amp; Shrink Films</td>
</tr>
<tr>
<td>Non-Packaging Films</td>
</tr>
<tr>
<td><strong>High Density Polyethylene (HDPE)</strong></td>
</tr>
<tr>
<td>Food Packaging</td>
</tr>
<tr>
<td>All Other (Includes t-shirt bags)</td>
</tr>
<tr>
<td><strong>Polypropylene (PP)</strong></td>
</tr>
<tr>
<td>Film</td>
</tr>
<tr>
<td><strong>Polyvinyl Chloride (PVC)</strong></td>
</tr>
<tr>
<td>Film and sheet</td>
</tr>
<tr>
<td><strong>Nylon</strong></td>
</tr>
<tr>
<td>Film and coating</td>
</tr>
<tr>
<td><strong>Total</strong></td>
</tr>
</tbody>
</table>

Section 5 - Markets for Recovered Plastic Films

Domestic End-Use Markets for Recovered Plastic Films
Domestic end-use of recycled film grade resins has grown in recent years due to improved processing technology, new product applications and pressure from regulators to increase recycled content. As opposed to overseas markets, domestic convertors prefer to purchase ready-to-run material that does not require extensive labor to achieve manufacturing specifications. This section will examine existing and emerging market consumption channels for recovered plastic films.

Plastic Manufacturing and Reclaimer Markets
The use of recovered plastic films in the manufacture of new plastic products is fundamentally limited by the inherent resin and color variations of recovered film streams, low tolerance for non-plastic materials, and the costs of addressing these issues. However, numerous programs exist across the country to source specific types of recovered plastic films for use in the production of new plastic products.

Reclaimers buy recovered plastic films for reprocessing into recycled plastic pellets that can be used in extrusion manufacturing of new films, injection molding, and profile extrusions. Reclaimers wash, clean, dry and pelletize films before they are placed into extrusion lines. Washing technologies have improved the ability to remove a broad spectrum of contamination, but still represent one of the most expensive steps in processing films. Washing also necessitates energy intensive drying. The extrusion lines further purify the resins through the use of fines screens that filter impurities. The processed pellets can be marketed as commodity-grade PCR (post consumer resins). PCR resins are typically blended with virgin resins in the subsequent manufacturing processes.

New advancements in polyethylene blending and compounding technologies are opening the door to new applications. Some reclaimers actually compound resins during the initial pelletization process to produce market-grade blended pellets with PCR content. These compounding technologies allow converters to produce new polymer blends, enhancing the polymers’ general characteristics, physical properties, stability and processability.

Some end-users groups have strong interests in PCR content, based on requirements of their products, consumer demand, or even legislated mandates. For instance, products that require less consistent resin purity to maintain product standards, such as dark colored trash containers, or tennis shoe soles may be better able to handle recycled content.
Plastic Lumber Products

Another major end-user group that represents a large consumption of PCR plastics, including both recovered film and rigid container plastics are plastic lumber producers. The Plastic Lumber Trade Association represents a group of the major players in the field, and has been working to develop production and performance standards for these products in commercial applications. Plastic lumber products are heavier than wood and have limited structural applications, but have a demonstrated performance advantage in wear and moisture resistance, especially in ground-contact and marine applications.

Resins used in plastic lumber are mixed and pigmented during the extrusion process to allow for a relatively robust raw material mix that includes both HDPE, LDPE and LLDPE. These producers have focused on low-cost recovered polyethylene rigid containers. With the emergence of composite applications using similar technologies in recent years, some plastic lumber manufacturers have ceased operation or focused on specific niche markets. Many of the remaining solid plastic lumber industry participants are experimenting with composite formulations.

A table of plastic lumber manufacturers is provided in Appendix B-1.

Composites Manufacturing

Beyond mainstream plastic product manufacturers, and plastic lumber makers, is a broad new group of emerging composite applications. With an understanding of the challenges inherent with sufficiently cleaning plastic films to meet requirements for new plastics manufacturing, comes a need to evaluate other applications that may be better able to use recovered plastic films in a value-added way. Many composite products offer slightly broader tolerances to trace contaminant levels without sacrificing product quality. This subtle difference in specifications for recovered plastic films can mean less expensive processing steps and more economically viable recycling opportunities.

Composites draw on material science to combine the attributes of different individual materials to yield products that are often superior in performance attributes to existing materials. A large group of composites today, and the ones most relevant to recovered plastic film markets, are those which combine wood and plastic. These wood/plastic composites are being developed for building materials and other manufacturing components, such as panels used in automotive production. Building material markets targeted by composite products include those where moisture resistance is critical, including decking, exterior siding, wet-area underlayment, landscape products and marine components.

The most visible impact of these products to-date is in the residential decking market. The total decking market totaled nearly $2 billion in 1997. Solid plastic and wood/plastic composite products held a total market share of only about 3 percent, in 1997, while 97 percent of this
market was held by wood decking, including several species and chemically treated products. However, the inherent advantages of wood/plastic composites in consistency and moisture resistance is driving strong growth in this market. A growing consumer awareness of these products and their lower maintenance costs, along with expanded distribution, is pushing factory sales of non-wood alternative decking products to grow at more than 25 percent annually in recent years. The market share of non-wood alternative decking products is expected to nearly double to 6 percent by the year 2000.

Trex Corporation
This Winchester, Virginia-based company was initially commercialized by the Mobil Oil Corporation as its Composite Products Division in 1992. Its principal product line of wood/plastic composite decking materials, known as TREX® Easy Care Decking™ is made from recycled polyethylene and recovered wood fiber.

Sourcing specifications for this product application, beyond the basic contamination restrictions, include low tolerances for moisture and non-polyethylene resin contamination. The company has focused entirely on polyethylene films, specifically HDPE grocery sacks and LLDPE stretch wrap, and claims to be the largest buyer of recovered plastic films in the US. The company has worked with some specialty streams of polyethylene films including separated residuals from the recycling of poly-coated paperboard products. Trex® is aggressively expanding sourcing for their East-Coast production facility in Winchester, and recently implemented a West-Coast production facility in Fernley, Nevada.

According to company representatives, the existing facility has a yearly consumption capacity of 108 million pounds of recovered polyethylene products. The West-Coast facility is anticipated to be an even larger operation with a projected capacity of as much as 150 million pounds of recovered polyethylene annually.

Advanced Environmental Recycling Technologies (AERT)
Another sizable player in the production of recycled content fiber – plastic composite building materials, is Advanced Environmental Recycling Technologies (AERT) of Springdale, Arkansas. AERT has a proprietary process for the extrusion of its roughly 50-50 mix of wood and plastics into a variety of composite products.

To facilitate raw material sourcing, AERT has developed an in-house plastic reclamation facility and patented new technologies for cleaning recycled polyethylene plastics. Reclamation strategies are highly focused on AERT's specific production needs. AERT uses both rigid container and film plastic sources. Plastic film sources targeted include HDPE grocery bags and post-industrial HDPE and LLDPE stretch films. AERT is also sourcing plastic film residue separated during the recycling of polycoated paperboard by large paper mills.
AERT’s total capacity for the consumption of recovered polyethylene plastics, with five extrusion lines in operation, is estimated at more that 70 million pounds annually. AERT has the potential to consume polyethylene plastic films to meet a large percentage of that capacity.

Trex and AERT represent the largest domestic film users among U.S. composite producers. A table of other U.S. plastic composite manufacturers is provided in Appendix B-2.

Export Markets
The Asian market includes a number of Pacific-Rim countries such as South Korea, Japan, Taiwan, Malaysia and Indonesia as well as the Chinese mainland. These markets can, at times, offer better pricing than domestic markets, although often at the cost of higher volatility. The 1998-99 Asian market crises had depressed pricing for recovered plastics of all types, although some purchasing channels remain active. In some cases, this market situation led foreign brokers to dump PCR plastics into the domestic market to meet short-term cash requirements, further affecting domestic markets.

Three macroeconomic variables influence the economics of film plastic recycling among Asian markets. First, labor costs are lower than North American markets. This cost advantage can be used to decontaminate the recycled materials through sorting and cleaning. Second, many of the applications for the recovered plastics produced in those markets have a greater tolerance for contamination and polyethylene resin variations. These products are often commodity level products such as shoe soles. Third, much of the capital equipment in the Asian plastics industry is older and slower, and has broader operating tolerances than today’s higher speed processing equipment which dominates domestic markets.

Asian markets have an inherent cost advantage with respect to labor costs that can make recycling more feasible. While labor intensive contaminant removal is often more viable for export buyers, there is a significant perception barrier related to importing trash from western countries, and in some cases subject to severe penalties. Key among elements of prohibited contamination is odor level, usually a result of food or liquid residue. Other items such as rigid containers and paper must be kept to a strict minimum to pass customs. Asian market buyers are generally able to purchase recovered plastic films from very large generators and brokers as minimum container quantities are required to maximize transportation efficiencies for overseas shipping. Export containers must be loaded to a minimum weight of 40,000 LBS and are subject to steep price discounts if weight requirements are not met.

The Development of Plastic Films as a Commodity
As many recyclable material markets begin to mature, recovered plastic films have become the new kid on the block. Some waste and recyclable haulers have access to plastic film markets, and the ability to assist with setting up an internal plastic film recovery program, but choose not to advertise that service to their accounts. Such plastic film recovery programs are
discussed in Section 2. Plastic film recycling markets are still in the early stages of development in many parts of the country, and some waste and recycling haulers may consider them as marginal revenue sources. However, when requested by generator accounts to provide plastic film recovery services, many are willing to provide such services to retain the account.

As more processors and end-users commit to programs for the recovery and recycling of plastic films, recovered plastic film will begin to become an established recyclable commodity. This process takes time and collaboration between various industry levels, and in the form of public private partnerships. The market for recovered plastic films is in an early stage of development in the United States. The development of any new recovered commodity market requires the following elements:

- Investment by end-users in technologies for recycling
- Development of recycling processors to convert the materials
- Wide-scale infrastructure for diversion, collection and brokerage of materials
- Availability of a consistent, large quantity supply within the economy

Each of these elements are present, with regard to plastic film recovery. However, it takes several years for programs to take hold and expand, as they have with other recyclable materials. Moreover, developing recovery channels must be supported by market driven economic factors, if they are to be successful in the domestic economy.

Economic incentives for the recycling of plastic films are present in today’s economy, but are subject to cyclical variations, and global economic factors. The microeconomics of plastic film recovery are discussed in more detail in Section 1. The principal macroeconomic drivers of plastic film recovery and recycling in today’s marketplace include:

- Strong consumer demand for recycled content products
- Cost advantages of recycled resins relative to virgin resins
- Demand by generators for waste diversion opportunities

While the public demand factors are significant both in “pushing” and “pulling” on the supply of recovered plastic films, the cost benefits of recycling are perhaps the most significant driver of development activity. These cost benefits depend on the costs of virgin raw materials, and on the costs of recycling the recovered plastic films. Technical challenges to recycling plastic films have required expensive processing steps. These costs have inhibited the growth of plastic film recovery.

Today, developments are occurring both in new market applications for recycled plastic films, and in technological solutions to processing requirements. With these developments, plastic film recovery is being achieved at unprecedented levels and experiencing strong growth. This is significant
because the cost of virgin resins were near a cyclical low in 1998, and global economics have created an availability of low cost resins from off-shore sources.

Technical Market Barriers
Recovered plastic films have a number of technical barriers to overcome to achieve a strong market position as a commodity-grade recyclable. This is due largely to the broad diversity of recovered plastic films relative to very consistent virgin resin pellets. Recyclers and manufacturers must address these issues, including resin variations and contamination levels within recovered plastic film streams. These challenges are not uncommon to other recovered plastics, such as HDPE milk jugs or PET soda bottles. However, plastic films have a somewhat larger challenge to overcome on this front, because the high ratio of surface area to weight means that plastic films have a greater propensity to collect surface contaminants.

Contamination Challenges
Surface contamination such as labels, dirt and food residue can pose a bigger challenge to plastic reclaimers than other recycled material users, because of tight quality tolerances. In other manufacturing processes, such as glass or aluminum production, the temperatures used in manufacturing are sufficient to burn off any surface contamination that may remain after processing. In plastics production, remaining surface contamination such as a single label must be mechanically screened from the melted resin before it goes into a new product.

Labor intensive sorting and automated removal of contaminants, through wash systems and in-line screen changers, must be used to clean films to manufacturing specifications. These are expensive steps for manufacturers, and can make recycling films into new plastic products cost-prohibitive. Perhaps even more significant than individual contamination issues is the overall consistency of the supply streams. Technological solutions can often be developed to overcome individual issues, like contamination levels and resin variation, but if the stream is not consistent, those solutions will fail. Please refer to Section 3 for a detailed description of the most common contaminants found in recovered film streams.

Resin Diversity Challenges
Significant advancements in resin sortation technologies, including optical identification, air density and mechanical separation, have been made in the area of rigid plastic container recovery. However, most of these technologies have very limited applicability to plastic film recovery because of the fundamentally inconsistent size, weight and geometry of plastic films. The implications of this challenge are that plastic films must be separated for the most part, by discreet product types at the initial point of diversion, or market recycling applications must enhance their ability to use a mix of resins.

This problem is mitigated to some degree by the fact that a small number of polyethylene resin types comprise a large share of the total quantity of plastic films in the waste stream. Many of the
market channels developed to-date have focused on specific sub-streams, such as LLDPE stretch films or HDPE grocery bags, to minimize challenges associated with resin diversity. However, even within a single sub-stream, such as grocery bags, resin variations are common, with some grocery bags made of LLDPE still in production. Some market channels, including plastic lumber, composite products, and some resin compounders are better able to handle a mix of polyethylene resins.

Colored and Printed Films
Recycled films with pigments of any type or heavy surface printing, are usually re-formulated into dark colored resins for various product applications. These dark colored resins are often used in low-value products such as trash cans or shoe soles because of their lower sensitivity to minor variations in the blend. In general, resins that are blended into these dark colored batches, have limited marketability because of the narrower range of products that they can be used in.

Addressing Challenges
How well these challenges can be addressed depends on the ability to sort for like materials and the ability to remove contaminants. This must be approached through both technological solutions at the processing level, and through recovery system design and education at the initial diversion level.
Section 6 - Appendix

Information Resources

Plastic Industry Associations and Recycling Information Sources

American Plastics Council  
1300 Wilson Boulevard, Suite 800  www.plastics.org  
Arlington, VA 22209  703-741-5000

Association of Post-Consumer Plastic Recyclers  
1300 Wilson Boulevard, Suite 800  www.plasticsrecycling.org  
Arlington, VA 22209  703-253-0605

Environment and Plastics Industry Council  
5925 Airport Road, Suite 500  905-678-7405  
Mississauga, Ontario L4W 1W1 CANADA  
e-mail: ccirko@cpia.ca

Flexible Packaging Association  
1090 Vermont Avenue, N.W., Suite 500  www.flexpack.org  
Washington D.C. 20005-4960  202-842-3880  
e-mail: fpa@flexpack.org

National Association for PET Container Resources  
2105 Water Ridge Parkway, STE 570  www.napcor.com  
Charlotte, NC 28217  704-423-9400

Film and Bag Federation  
1817 E. Carson Street  800-438-5856  
Pittsburgh, PA 15203  
e-mail: pbainfo@aol.com

Market Film Buyers and Recycled Product Manufacturers

Trex Company, LLC  www.trex.com  
20 S. Cameron Street  
Winchester, Virginia 22601  
  Mike Vatuna  Corp. Procurement Mgr.  540-678-4087  
  Daniel Fling  Midwest & Northeast Region  610-559-8476  
  Nick Candela  Pacific & Mountain Region  760-729-5855  
  Joe Williams  Southeast Region  770-645-6199
A.E.R.T. Inc.
HC 10, Box 116
Junction, Texas 76849
   Doug Brooks     Procurement Manager     915-446-3430

U.S. Plastic Lumber / Earth Care Products
2300 Glades Road – Suite 440 W
Boca Raton, Florida 33431     800-65-EARTH

Boise Cascade / Re-Sourcing Associates, Inc. Film Recycling Program
21327 88th Avenue South
Kent, Washington 98031     www.rsarecycle.com
   Skip Gerber     Procurement Manager     253-872-0779

Recycled Plastic Building Materials

NAHB Research Center
HomeBase Hotline
400 Prince George’s Blvd.
Upper Marlboro, MD 20774     800-898-2842
### Appendix B

**North American Plastic Lumber Manufacturers**

*Source: Plastics News, 1998 Market Data Book*

<table>
<thead>
<tr>
<th>Name</th>
<th>City</th>
<th>Products</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aeolian Enterprises Inc.</td>
<td>Latrobe, PA</td>
<td>lumber, fencing, railing, decks</td>
</tr>
<tr>
<td>Aloha Plastic Recycling Inc.</td>
<td>Puunene, HI</td>
<td>lumber, picnic tables, benches, trash receptacles, mailbox posts, fencing, speed bumps</td>
</tr>
<tr>
<td>American Earth Friendly Inc.</td>
<td>Delray Beach, FL</td>
<td>lumber, picnic tables, park benches, trash receptacles, mailbox's, plants, bike racks</td>
</tr>
<tr>
<td>American Eco-Board Inc.</td>
<td>Farmingdale, NY</td>
<td>lumber, picnic tables, benches, trash receptacles, mailbox's, plants, bike racks</td>
</tr>
<tr>
<td>Bedford Industries Inc.</td>
<td>Worthington, MN</td>
<td>lumber, landscape timbers, decking, vehicle stops</td>
</tr>
<tr>
<td>BTW Industries Inc.</td>
<td>Hollywood, FL</td>
<td>profiles, picnic tables, park benches, vehicle stops, decking, walkways, benches</td>
</tr>
<tr>
<td>Carefree Recycled Products Inc.</td>
<td>Parker, CO</td>
<td>lumber, tables, benches</td>
</tr>
<tr>
<td>Carosone International dba</td>
<td>Carolina, SC</td>
<td>highway marker posts, utility line marker posts</td>
</tr>
<tr>
<td>Cascades Re-Plast dba</td>
<td>Quebec, CANADA</td>
<td>picnic tables, benches, planters, trash receptacles, decking planks</td>
</tr>
<tr>
<td>Coon Manufacturing</td>
<td>Spickard, MO</td>
<td>vehicle stops, tanks, seats, trash containers, gaylord boxes, splash guards, profiles, picnic tables, landscape timbers, pallets, car stops</td>
</tr>
<tr>
<td>Eco-Tech L.P.</td>
<td>McHenry, IL</td>
<td>dimensional lumber, car stops, pallets and creting</td>
</tr>
<tr>
<td>Envirowood Products Inc.</td>
<td>Auburn, AL</td>
<td>profiles, picnic tables, landscape timbers, pallets, car stops</td>
</tr>
<tr>
<td>Epic Plastics</td>
<td>Richmond, CA</td>
<td>deckings, picnic tables, benches, marine products, landscaping ties</td>
</tr>
<tr>
<td>Everfast Plastic Lumber Inc.</td>
<td>Hamburg, PA</td>
<td>picnic tables, car stops, speed bumps, benches, trash receptacles</td>
</tr>
<tr>
<td>GreenEarth Products Inc.</td>
<td>Charlotte, NC</td>
<td>cornerboards, fabricated parts</td>
</tr>
<tr>
<td>Hammer's Plastic Recycling Inc.</td>
<td>Iowa Falls, IA</td>
<td>profiles, picnic tables, pallets, landscape timbers, deckings, sheathing, custom extrusions, fabricated parts</td>
</tr>
<tr>
<td>ITW Angleboard</td>
<td>Luxembourg, WI</td>
<td>profiles, picnic tables, pallets, landscape timbers, benching, custom extrusions, fabricated parts</td>
</tr>
<tr>
<td>N.E.W Plastics Corp.</td>
<td>Luxembourg, WI</td>
<td>compost bins, landscape ties, planters, benches, picnic tables, table, borders, trellises</td>
</tr>
<tr>
<td>Obex Inc.</td>
<td>Stamford, CT</td>
<td>planks, decks, decks</td>
</tr>
<tr>
<td>Plastique Design</td>
<td>Blainville, Quebec</td>
<td>lobster, decks, decks, sheds, small homes</td>
</tr>
<tr>
<td>PDI Fenestration</td>
<td>Blainville, Quebec</td>
<td>lobster, decks, decks, sheds, small homes</td>
</tr>
<tr>
<td>Phoenix Recycled Plastics</td>
<td>Conshohocken, PA</td>
<td>lobster, picnic tables, benches, decks, docks, pallets, landscape timbers</td>
</tr>
<tr>
<td>Plastic Lumber Co.</td>
<td>Akron, OH</td>
<td>lobster, picnic tables, benches, waste receptacles, parking stops, speed bumps</td>
</tr>
<tr>
<td>Plastic Lumber Specialties</td>
<td>Glen Allen, VA</td>
<td>lobster, park furniture, fencing</td>
</tr>
<tr>
<td>Plastic Plinings Inc.</td>
<td>Rialto, CA</td>
<td>marine pilings, timbers</td>
</tr>
<tr>
<td>Polywood Inc.</td>
<td>South Plainfield, NJ</td>
<td>lobster, picnic tables, benches, roll-up walkways, trash receptacles, pallets, thermoformed pallets and trays</td>
</tr>
<tr>
<td>Productivity Corp.</td>
<td>Richmond, IN</td>
<td>lumber, sheet, special orders</td>
</tr>
<tr>
<td>Raguse Manufacturing</td>
<td>Wheaton, MN</td>
<td>lumber, benches, dock pilings, bike racks, tables, trash receptacles, picnic tables, piling caps</td>
</tr>
<tr>
<td>Recycled Plastic Man Inc.</td>
<td>Venice, FL</td>
<td>fences, lumber, cars, traffic barricades, safety devices</td>
</tr>
<tr>
<td>Recycled Plastic Products Inc.</td>
<td>Englewood, Colo.</td>
<td>lobster, compost bins, deckings, picnic tables, planter boxes, fencing planned targets, landscape timbers</td>
</tr>
<tr>
<td>Recycled Plastics Marketing Inc.</td>
<td>Redmond, WA</td>
<td>roof trusses, landscape timbers</td>
</tr>
<tr>
<td>Recycled Polymer Associates</td>
<td>New York, NY</td>
<td>lumber and timber, park and recreational site amenities, specialty and custom profiles</td>
</tr>
<tr>
<td>Resco Plastics Inc.</td>
<td>Coos Bay, OR</td>
<td>marine pilings and timber</td>
</tr>
<tr>
<td>Seaward International Inc.</td>
<td>Clearbrook, VA</td>
<td>composite plastic lumber for flooring, doors, bulkheads, walls, ceiling plastic lumber</td>
</tr>
<tr>
<td>SpaceAge Synthetics Inc.</td>
<td>Wahpeton, ND</td>
<td>fisher, picnic tables, park benches, trash receptacles, landscape ties, railroad ties</td>
</tr>
<tr>
<td>Timburon Industries</td>
<td>Stockton, CA</td>
<td>plastic lumber, benches, trash receptacles, landscape timbers, plants, bike racks</td>
</tr>
<tr>
<td>US Plastic Lumber Corp.</td>
<td>Boca Raton, FL</td>
<td>plastic lumber, sheets, picnic tables, benches, car stops, landscape timbers, planters, bike racks</td>
</tr>
<tr>
<td>Eaglebrook Products Inc.</td>
<td>Chicago, IL</td>
<td>plastic lumber, sheets, picnic tables, benches, car stops, landscape timbers, planters, bike racks</td>
</tr>
<tr>
<td>Earth Care Midwest/US Plastic</td>
<td>Ionia, MI</td>
<td>plastic lumber, picnic tables, benches, trash receptacles, landscape ties, railroad ties</td>
</tr>
<tr>
<td>Recycled Plastic Industries Inc.</td>
<td>Green Bay, WI</td>
<td>plastic lumber, sheets, picnic tables, benches, car stops, landscape timbers, planters, bike racks</td>
</tr>
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</table>
# North American Wood-Plastic Composite (WPC) Manufacturers

<table>
<thead>
<tr>
<th>Name</th>
<th>Location</th>
<th>Recycled Plastics?</th>
<th>Resins</th>
<th>Product Names</th>
<th>Product Types</th>
</tr>
</thead>
<tbody>
<tr>
<td>Advanced Env. Recycling Tech. (AERT)</td>
<td>Springdale, AS</td>
<td>yes</td>
<td>HDPE, LDPE</td>
<td>ChoiceDek</td>
<td>decking</td>
</tr>
<tr>
<td>Andersen Corp</td>
<td>Brooklyn, MN</td>
<td></td>
<td>PVC</td>
<td>Fibrex</td>
<td>millwork</td>
</tr>
<tr>
<td>B &amp; F Plastics</td>
<td>Richmond, IN</td>
<td></td>
<td></td>
<td></td>
<td>panel producer</td>
</tr>
<tr>
<td>Certainteed Corp</td>
<td>Valley Forge, PA</td>
<td>PVC, PP</td>
<td>CertaWood</td>
<td>millwork, windows, siding</td>
<td></td>
</tr>
<tr>
<td>Compton Corp</td>
<td>Connersville, IN</td>
<td>yes</td>
<td>HDPE, HIPS</td>
<td>Marmon</td>
<td>panel producer</td>
</tr>
<tr>
<td>Crane Plastics</td>
<td>Columbus, OH</td>
<td>PE, PVC</td>
<td>TimberTech</td>
<td>decking</td>
<td></td>
</tr>
<tr>
<td>Certainteed Corp</td>
<td>Valley Forge, PA</td>
<td>PVC, PP</td>
<td>CertaWood</td>
<td>millwork, windows, siding</td>
<td></td>
</tr>
<tr>
<td>Dura Products International, Inc.</td>
<td>Toronto, ON CANADA</td>
<td>yes</td>
<td>HDPE</td>
<td>TekDek</td>
<td>decking</td>
</tr>
<tr>
<td>Eaglebrook Products</td>
<td>Chicago, IL</td>
<td>PE, PP, ABS</td>
<td>Durawood</td>
<td>decking, railings, etc</td>
<td></td>
</tr>
<tr>
<td>Fiber Composites</td>
<td>Charlotte, NC</td>
<td>HDPE</td>
<td></td>
<td>decking</td>
<td></td>
</tr>
<tr>
<td>Formtech Enterprises</td>
<td>Stow, OH</td>
<td>PVC</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Hoff Forest Products</td>
<td>Caldwell, ID</td>
<td>PE, PP, PS, PVC</td>
<td></td>
<td>millwork</td>
<td></td>
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<tr>
<td>Lehr Corp.</td>
<td>Sheboygan, WI</td>
<td></td>
<td></td>
<td>automotive products</td>
<td></td>
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<tr>
<td>Louisiana-Pacific (LP) Corporation</td>
<td>Troy, MI</td>
<td>PP</td>
<td>PEP wood</td>
<td>automotive panels, laminate shells</td>
<td></td>
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<tr>
<td>Malakoff Plastics</td>
<td>Klamath Falls, CA</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Star Guard Inc</td>
<td>Lancaster, SC</td>
<td>PE</td>
<td></td>
<td>boxes &amp; pallet edge-reinforcements</td>
<td></td>
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<tr>
<td>Strandex</td>
<td>Madison, WI</td>
<td>PVC, PE</td>
<td></td>
<td>Strandex</td>
<td></td>
</tr>
<tr>
<td>Trex Company LLC</td>
<td>Winchester, VA</td>
<td>yes</td>
<td>HDPE, LDPE</td>
<td>Trex</td>
<td>decking, facia, trim</td>
</tr>
</tbody>
</table>
Economics Worksheet

**Worksheet: Economics of Plastic Film Recovery**

**Determining the Total Costs of Film Plastic Disposal**

Average Loose Plastic Film Density 45 lbs. / cu.yd.
Average Mixed Waste Density 150 lbs. / cu.yd.

**Current Disposal Profile:**

Total Monthly Disposal Weight Estimate (all materials) 13.5 tons / month
Estimated Average Plastic Film Composition 45% film by volume
Disposal Cost per Ton $60.00 per ton
Container Pull Charge $95.00 per pick-up
Disposal Container Size (cu. yds.) 40.0 cubic yards
Estimated Average Density of Disposed Materials (all materials) 102.75 lbs. / cu. yard
Average Volume of Disposed Materials (all materials) 262.8 cu. yards
Average Number of Monthly Container Pulls 6.6 pulls per month
Total Cost of Waste Disposal per Month (all materials) $1,434.09 per month

**Plastic Film Generation Estimate and Disposal Cost:**

Film Plastic Weight Estimate 5,321 lbs. / month
Marginal Number of Pulls for Plastic Films Only 3.0 pulls per month
Total Cost of Film Disposal per Month $440.47 per month

**Calculating the Net Benefit of Plastic Film Recovery**

**Benefits**

Avoided costs of disposal $0.083 per lb.
Realizable revenue for baled film plastic $0.020 per lb.
Variable Gross Benefit of Recovery $0.103 per lb.

**Recovery Costs**

Hourly labor costs (incl. overhead) $18.00 per hour
Average labor hours required per bale 1.25 hours
Average bale weight 900 lbs.
Average labor cost per pound of film recovered $0.025 per lb.
Baling wire & related (.005 default) $0.007 per lb.
Clear Collection Bags $0.009 per lb.
Variable Costs of Plastic Film Recovery $0.041 per lb.

Variable Net Benefit of Plastic Film Recovery $0.062 per lb. or $328.73 per month

*(Required input values shown in highlighted boxes)*