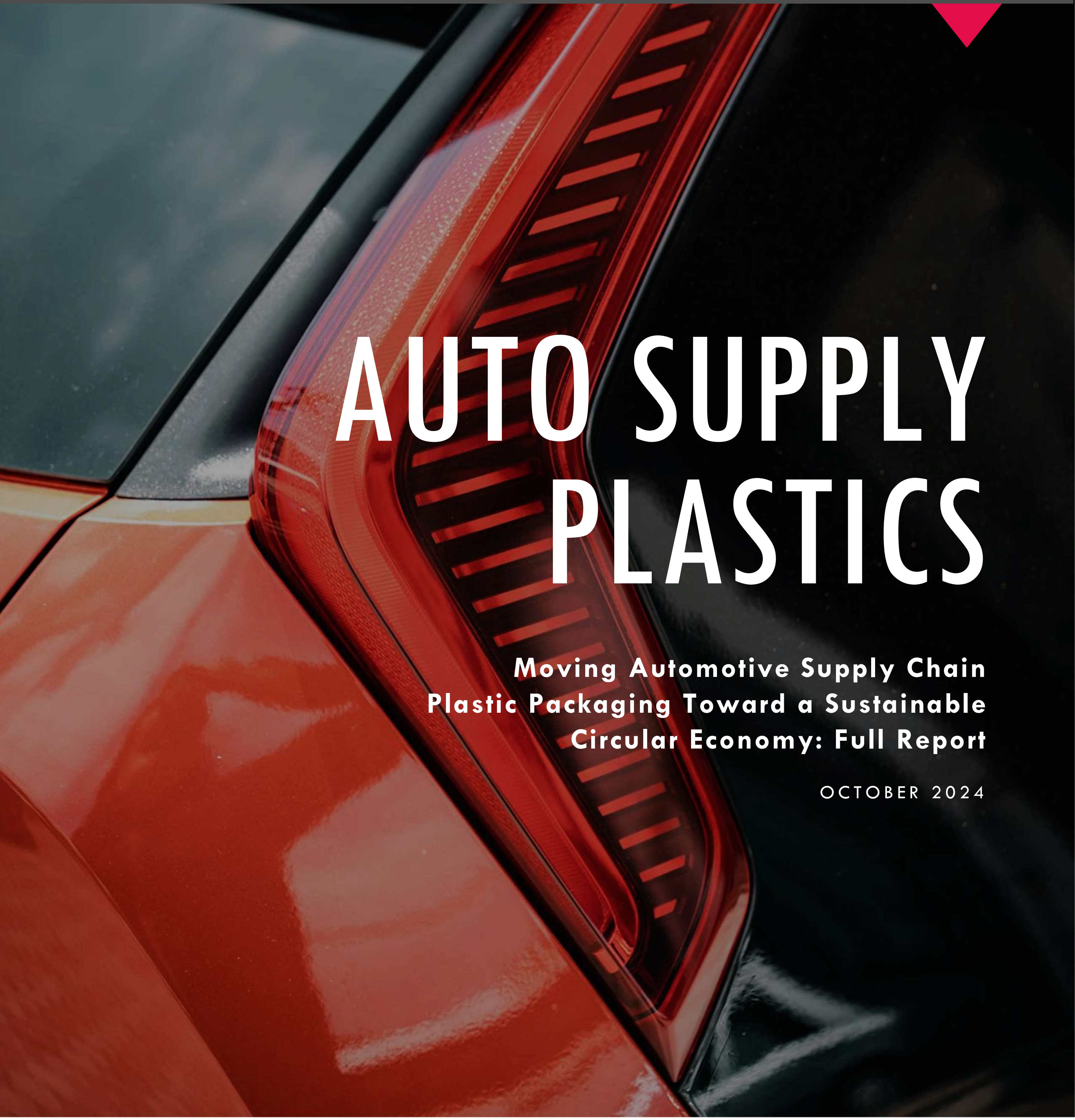

AUTO SUPPLY PLASTICS

Moving Automotive Supply Chain Plastic Packaging Toward a Sustainable Circular Economy: Full Report

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SUPPLIERS PARTNERSHIP FOR THE ENVIRONMENT

EXECUTIVE SUMMARY

The Suppliers Partnership for the Environment (SP) provides leadership to help advance environmental sustainability across the automotive supply chain. One of the opportunity areas for improvement is management of plastic packaging and dunnage used to ship parts and components from plant to plant across the supply chain.

To support this goal SP commissioned RRS to conduct a feasibility study and develop a recommended approach for recycling internal plastic dunnage and packaging within original equipment manufacturers (OEMs) and tiered supplier plants and through collaboration and consolidation of plastics generated across plants.

This report reflects the outcomes of this study and is designed as a guidance document to support programs for managing packaging in the automotive supply chain, while approaching partnerships to consolidate those plastics to meet economies of scale. This guide describes many actions that can be taken through a complex system within plants, across plants, and along the material recovery value chain to divert plastic waste and access recycling markets that reflect the highest, best use of those materials. Though there is no one-size fits-all approach to handling this plastic waste, this report provides an approach and framework for individual plants to evaluate opportunities that fit their circumstance considering economic, environmental, and behavioral aspects, and outlines how clusters of plants may work together to overcome common barriers.

The top five opportunities for diversion of plastic packaging waste based on a balance of these considerations across the automotive supply chain, based on this study, are:

1. **OPTIMIZE REUSABLES**. The impact of inventory loss from reusable programs directly influences the amount of single use expendable dunnage generated throughout the system. Keeping tight inventory can reduce the need for "exception" or "backup" packaging, which is a prominent source of single use dunnage. This can be considered a waste prevention strategy that hits the very top of the waste hierarchy of preferred management options. Opportunities for managing this include setting a target on "attrition rate" or "leakage rate," the amount of inventory loss over time, to use as a metric to track closely and from which to align performance. There are opportunities to further deploy systems using scanners, tags and color coding to track down lost inventory. Further study is needed in this area.

2. **MAXIMIZE IMPACT OF EXISTING RECYCLING** - by prioritizing closed loop mechanical options. A fair amount of plastic recycling is already taking place, particularly involving end-of-life reusable containers. However, there are instances where recyclers are bidding on reusable containers for use in downcycled products, such as pipes and other durable infrastructure. There are opportunities to direct these materials into more sustainable, circular pathways, by giving preference to a recycler that can demonstrate that the containers will be made into new reusable containers with the same intended use. Any instances where broken reusable containers are not being recycled should be immediately flagged as an opportunity. Such plants should create a system to stack and store containers until a truckload is produced or coordinate with recyclers and other regional suppliers to aggregate truckload quantities.

3. **ALIGN WITH PURCHASING TO USE MORE RECYCLED CONTENT IN PACKAGING**. Closely related to the previous recommendation, more circular opportunities can be unlocked by engaging purchasing departments of the packaging supplies to commit to procuring packaging with increasing amounts of recycled content. In situations where there is revenue generated from recycling, there may be opportunities to turn that payment into a credit applied when purchasing back new containers. This can show clear net value and allow recycled content containers to be seen as more cost competitive by the purchasing agent. This may require coordination across the value chain. Further exploration of this concept is recommended.

4. **DIVERT CLEAR BAGS AND WRAP.** Of the expendable dunnage and packaging observed in the waste stream across all researched plants clear bags and pallet wrap, made from LDPE or LLDPE (low density polyethylene) was the most prevalent. This material is also commonly referred to as clear film. Source separating this film is the best chance to divert plastics without adding costs. The recycled commodity has a consistent market value ($.14/lb five-year average[i]) and has circular potential with at least one established regional end market, Petoskey Plastics, that can incorporate recycled clear film into new packaging, such as seating bags. Seating plants would be a good initial target for this type of diversion program, though all plants generate meaningful quantities. Due to the light weight of these materials and the need to generate truckload quantities to reach recycling markets, a hub with baling and storage capabilities is a likely partner. Existing infrastructure found in recycling facilities should be sufficient to manage this. Plants should work with local recyclers and/or engage with other plants in the region to develop a hub and spoke network that can generate at least 30,000 lbs of film per month. Appendix D includes a map with recyclers and end markets.

5. **DIVERT MIXED PLASTICS.** Beyond reusable containers and clear film, a diverse range of resin and form factors of plastic packaging is used. This limits practical recycling opportunities based on low quantities of single commodity types and high level of sorting required at the plant to source separate. Plants typically do not have space or staff to perform this level of sorting. Markets for mixed plastics are the most likely pathway for these materials. These may be either open loop mechanical or chemical recycling. Most mechanical recycling markets accept rigid-only mixed plastics, while chemical recyclers typically include all film and rigid olefins, polypropylene (PP), polyethylene (PE) and polystyrene (PS), included in the mix. Some mixed plastic end markets, for example those using pyrolysis, may only want mixed plastic if it includes films. This presents a tradeoff between targeting the highest and best use of the film vs being able to recycle a broader range of mixed plastics in a less-preferred process.

This report is based upon work supported by the Michigan Department of Environment, Great Lakes, and Energy, with matching grant funding provided by Magna.

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BACKGROUND AND PURPOSE

Moving Toward a Sustainable Circular Economy

The Suppliers Partnership for the Environment (SP) provides leadership to help advance environmental sustainability along the automotive supply chain. The automotive industry is a leader in sustainability initiatives on many levels, from fleet decarbonization and EV transition to the use of renewable energy and reduction of net emissions in plants, to the reduction in materials used along the supply chain through deployment of reusable container programs. This is a continuous work-in-progress, and SP works tirelessly to close the remaining gaps in industry sustainability practices. One of the opportunity areas for improvement is the use and management of plastic packaging and dunnage used to ship parts and components from plant to plant across the supply chain.

The automotive industry uses many different packaging materials to safely ship parts damage-free through the supply chain. While reusable containers are a staple in the industry, the internal plastic dunnage and single use plastic packaging is often not recovered. This is in part due to difficulties in establishing an effective program to collect, aggregate, and market recyclable materials.

To date, SP has approached this problem by developing voluntary design guidance to address the type and variety of materials used in dunnage and packaging to improve recyclability of these materials. This step is very important, as recyclability and design for recycling are closely linked. As a following step, SP commissioned RRS to conduct a feasibility study to develop a recommended approach for recycling internal plastic dunnage generated by original equipment manufacturers (OEMs) and suppliers through collaboration and consolidation of plastics generated across plants in a given geography. The study was supported through grant funding from the Michigan Department of Environment, Great Lakes, and Energy, with matching grant funding provided by Magna.

This report reflects the outcomes of the study and is designed as a guidance document to support programs for managing plastic packaging in the automotive supply chain, while developing partnerships to consolidate those plastics to meet economies of scale. This guide describes many actions that can be taken within a complex system inside plants, across plants and along the material recovery value chain to divert plastic waste and access recycling markets that reflect the highest and best use of those materials based on a hierarchy of preferred options, presented below.

Methodology of Study

Michigan, the largest producer of cars and trucks in the country, was the focus of the feasibility study (MichAuto 2023). The state produces 21% of automobiles made in the U.S., translating to over 2.2 million vehicles per year (CEIC, 2023). Each vehicle contains hundreds of components comprised of thousands of parts, requiring packaging to ship safely from one facility to the next along the supply chain.

The industry supply chain in total represented 176,769 manufacturing jobs in Michigan in 2022, the most recently reported year.[ii] The system infrastructure includes over 350 supply plants with more than 250 employees (Dun and Bradstreet), 27 component assembly plants, and 12 final assembly plants (MichAuto, 2023).

This study focused on three areas of research to understand the types of plastic dunnage and packaging generated across the system, the current practices for managing them and assess strategies to improve the sustainable management of these materials at the end of life. There were three phases to the study.

1. Literature and Data Review: Data requests were made to OEMs and suppliers and desktop research was conducted to obtain information on waste generation and characterization. Literature review was also conducted on lifecycle impacts of various recycling pathways to define an environmental framework and prioritize options for plastics generated across the auto supply chain.
2. Interviews and Site Visits: 30 interviews and 12 site visits were conducted with stakeholders along the Auto Supply and Waste Management value chains, respectively. This included the following:
    a. Four Tier 1 Suppliers
    b. Three OEMS
    c. Seven Waste Management and Recycling Sorting Sites
    d. Nine Recycling Processing / End Markets
    e. Six Packaging Suppliers
    f. One Industry Researcher
3. Field Trial: A field trial was designed and executed including the following partners:
    a. Three Tier 1 suppliers
    b. One OEM
    c. One Total Waste Management Company
    d. Two Recycling Sorting Sites

Data gathered and lessons learned through this process are the basis for this report.

How to Use the Report

Through the research it became clear that many actions can be taken within plants and across plants to divert plastic waste in order to access recycling markets that reflect the highest best use of those materials. It also became clear that there is no one-size fits-all approach to handling plastic waste generated across the supply chain. The diversity of manufacturing activity and plant size varies greatly and, therefore, there is no universal recommended intervention that applies to all entities. At the same time the project team felt it important to provide guidance that could be useful to any plant, regardless of their size and positioning.

This report provides an approach and framework for each plant to evaluate the opportunities that are right for their circumstance and outlines how clusters of plants can work together to overcome common barriers for accessing recycling markets.

The following section articulates how a plant can identify and prioritize the right approach for diverting and recycling plastic dunnage and packaging within their context and the final section presents a checklist that plants can use to take a step-by-step approach to launching a plastic recycling program in their plant. While the research focused on Michigan the results could be used more broadly in any geography that contains clusters of auto assembly and supplier plants.

ENVIRONMENTAL IMPACT FRAMEWORK

THE ROLE OF RECYCLING IN A CIRCULAR ECONOMY

Zero waste, a goal held by several key players in the industry, is not just about reducing waste that goes to the landfill. It is about utilizing resources that may otherwise be disposed to enable environmental benefits. The main benefit of recycling plastics is not in freeing up space in landfills. In fact, plastics waste sent to landfills at end of life do not produce a large amount of greenhouse gas impact at the end of their life, as the embodied carbon is essentially effectively sequestered. The benefits of recycling are linked to the ability to use the recycled content as a substitute for virgin materials, thereby avoiding the lifecycle impacts associated with extraction and refinement of raw materials and initial production, which have a significant toll on the environment and contributes significant greenhouse gas emissions. The ideal plastic management and recovery framework enables the efficient circulation of resources, minimizes energy and material inputs, reduces climate change impacts and is feasible to implement given the current state of technology, end markets and behavior of those engaging with the system.

A circular economy is defined by the Ellen MacArthur Foundation as: “A system where materials never become waste and nature is regenerated. In a circular economy, products and materials are kept in circulation through processes like maintenance, reuse, refurbishment, remanufacture, recycling, and composting. The circular economy tackles climate change and other global challenges, like biodiversity loss, waste, and pollution, by decoupling economic activity from the consumption of finite resources.” The following are core principles of a circular economy:

- **Eliminate waste and pollution:** Materials re-enter the economy at the end of their use.
- **Circulate products and materials at their highest value:** This means keeping materials in use, either as a product or, when that can no longer be used, as components or raw materials.
- **Regenerate nature:** Shifts the focus from extraction of finite natural resources to regeneration. In this context this values plastic scrap to the extent that it is a substitute for virgin materials, reducing the impacts associated with resource extraction

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Sustainable Materials Management

Consistent with this framework, a Hierarchy for the environmentally preferred Management of Auto Plastic Packaging and Dunnage is presented in Figure 1. This is an adaptation of the Ellen MacArthur recommended order of preference and Zero Waste International Alliance Waste Hierarchy. The most preferred materials management strategy is prevention, eliminating unnecessary packaging. This is followed by reuse, which seeks to efficiently utilize packaging multiple times throughout its lifecycle.

Next comes recycling, which is broken into several different technologies. Each approach has a unique set of benefits and tradeoffs, as discussed below. The preferred recycling option is mechanical closed loop recycling, which seeks to cycle resources back to it's original use, minimizing new material extraction and reducing waste.

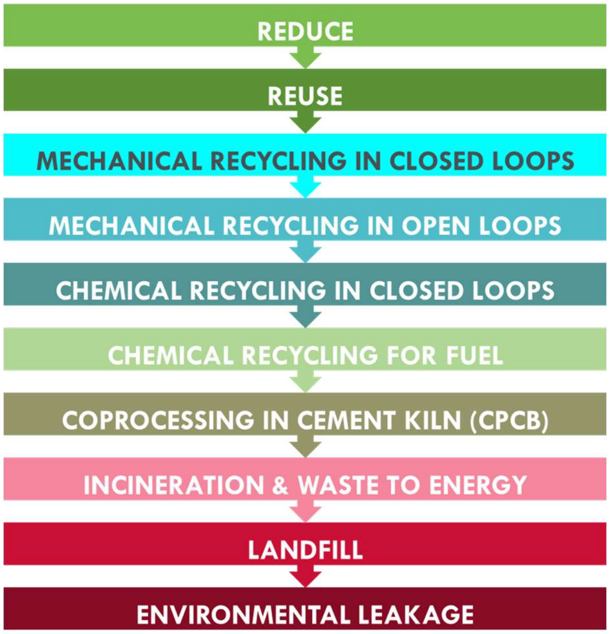

Figure 1. Hierarchy for the Management of Auto Plastic Packaging and Dunnage

Processing for fuel or energy is an option that provides some substitution value, but also requires more energy inputs than recycling, takes those resources out of circulation, releases greenhouse gases (GHGs) in the utilization of the output, and includes other pollution, reducing its overall benefit.

The least preferrable management method is landfilling or incineration which also removes the material from the production cycle and can have the potential for negative environmental impacts without associated positive economic contributions. There is a tradeoff between these two options, as waste to energy captures some resource value from the end-of-life material, while contributing more direct GHG than landfill. If only looking at carbon impacts landfill may be preferable. At the bottom of the hierarchy is the mismanagement of material where it is discarded in the environment as litter.

More detail on these options are presented in Table 1 and in the following section.

RECYCLING PATHWAYS

Table 1 provides a general overview of the options for managing plastic packaging waste and presents the benefits and tradeoffs from a substitution, resource intensity and GHG benefit perspective.

Table 1. Recycling Pathways

PROCESS	TARGET RESINS	END MARKETS	ABILITY TO DISPLACE VIRGIN	ENERGY AND MATERIAL INPUTS	GHG REDUCTION
Mechanical Recycling - Closed Loop	Single polymer: clear PET, natural or Colored HDPE, clear films and bags	Well established markets for PET and HDPE Regional markets for rigid and expanded (foam) PP and clear PE films	Medium - properties degrade with consecutive cycles, not appropriate for all applications, recycling of reusable containers and clear film and bags offer the greatest potential	Low	60-70% [iii]
Mechanical Recycling -Open Loop Recycling	Colored polymers or mixed polymer materials: HDPE, clear films, colored film, PP (rigid), mixed plastics	Well established markets for mixed plastics, color and rigid HDPE Regional markets for PP, clear films (VA, NV, AK)	Low - Often goes into durable products making recovery in its next life difficult, may not substitute for other material (e.g., wood, metal, etc.)	Low	25-75% [iv]
Chemical Recycling-Purification	Single polymer color or mixed polymer: PP Rigid, PE/PP	Emerging technology, early commercialization (One facility in OH for PP)	High - produces like virgin quality	Low	50-60% [v]
Chemical Recycling - Solvolysis	Single polymer, PET, polyurethane	Emerging Regional (U.S. South)	Potentially High — produces like virgin quality	Moderate	30%[vi]
Chemical recycling-Pyrolysis to Feedstock	Mixed & multilayer films, PS/EPS, HDPE, PP, flexible films, foams	Emerging Regional (Midwest/South)	Potentially High - produces like virgin quality, but typically a portion of output will go to fuels	High	Worse than virgin-30%[vii]
Chemical recycling – plastic to fuel or co-processing for fuel	PE, PP, PET, PS, mixed plastic	Established cement markets, emerging P2	Not circular	High	N/A

Mechanical Recycling
The dominant technology for recycling plastic presently is mechanical recycling. In this process, reclaimed plastic is reground and extruded to form pellets with no significant change to the plastic's chemical structure. This process generally has low material and energy inputs and provides an environmental benefit relative to virgin pellets. Mechanical recycling works best on pure materials, single polymers with low levels of contamination. In the U.S., established markets exist for polyethylene terephthalate (PET) and high-density polyethylene (HDPE) with newer regional markets for rigid and expanded polypropylene (PP, EPP) and plastic film (LLDPE, LDPE). Mechanical recycling is not suitable for thermoset polymers (such as XLPE, epoxies, and silicone).

The high temperatures and sheer force of the extrusion process causes a degradation in physical properties with each cycle which limits the suitability of mechanically recycled material for certain applications. For this reason, while mechanical recycling may extend the useful life of polymers, it is limited in its ability to infinitely cycle resources.

This has led to the distinction of two classes of mechanical recycling based on end-use applications. **Closed-loop recycling** utilizes the recyclate to make the same or similar products thereby replacing the use of virgin plastic. The best potential for closed-loop mechanical recycling of auto supply chain plastics is end of life reusable containers and clear bags and wrap. In contrast, **open-loop recycling** repurposes the recyclate into different products, allowing for a broader range of applications but often resulting in a one-time recycled product rather than an infinite cycle. Furthermore, the environmental benefit of open-loop recycling is dependent upon the impact of the substituted material (e.g., wood decking, metal in pipes, etc.). It is generally a lower environmental benefit than close-loop recycling.

Chemical Recycling
There are several technologies that fall under the category of chemical recycling. These technologies use heat, pressure, and/or chemicals to convert plastic packaging into end products that can potentially be further reprocessed into virgin-like quality plastic. They can generally be grouped into the categories of purification, solvolysis and pyrolysis.

> **Purification** (sometimes called dissolution) uses a solvent and a series of physical purification steps to separate a target plastic from additives, colorants, or other contaminants. Different purification technologies use single-polymer feedstock (e.g., polypropylene (PP) or multi-resins (e.g., polyethylene (PE)/polypropylene (PP), or polyamide (nylon)(PA)/polypropylene (PP) films.)). The result is a purified polymer enabling a plastic-to-plastic outcome. While this process can produce a food-grade and other high-quality polymers, there minor thermal degradation due to the final extrusion of purified resin, although less than mechanical recycling.
>
> The energy and material inputs are slightly higher than those in mechanical recycling, but the product is closer to virgin-like quality resulting in a similar environmental benefit to mechanical recycling. However, purification technologies are less mature with most in the pilot or early commercialization stage. There is one purification facility in Ohio that processes single resin polypropylene packaging. In the current context this is an unlikely pathway due to lower quantities of PP generation at plants and challenges associated with segregating and achieving truckload quantities of polypropylene.

Solvolysis involves breaking down the long polymer chains that make up plastic into monomers, through chemical treatments. Monomers are precursors to polymers and can be repolymerized to produce clear virgin-quality plastics. There are several types of solvolysis processes often denoted by the solvent used (e.g., methanolysis, glycolysis, and enzymatic hydrolysis).

Solvolysis requires single resins and is primarily applied to condensation polymers including polyesters (PET), polyamides (PA), polyurethanes (PUs), and polycarbonates (PCs). It is much more challenging for polymers that have a strong carbon-carbon bond, like polyolefins [e.g., polyethylene (HDPE, LDPE) and polypropylene (PP)] or polyvinyl chloride (PVC).

The monomers can be reprocessed into plastics, creating virgin-like quality suitable for food-grade applications. Because additional steps are required to transform the monomers to polymers, additional material and energy inputs are required and additional waste is generated, which can lead to higher environmental impacts. The state of the various technologies varies from experimental to prototype demonstration level. There are a few new planned or operational plants in the Southern U.S. In the current context this is an unlikely pathway due to lower quantities of non-polyolefin plastics, such as clear PET trays, and challenges associated with segregating and achieving truckload quantities of those materials.

Pyrolysis involves heating the plastic packaging without oxygen, breaking the polymer chains into simpler molecules (or sometimes monomers). The output consists of a variety of hydrocarbons typically including a liquid output (pyrolysis oil, or "pyoil") and a gas that is usually combusted along with solids, waxes, and char, which are wastes or low-value products. The pyoil can be processed in much the same way as oil, using conventional refining technologies. The materials best suited for pyrolysis include polyethylene (HDPE/LDPE), PP, and PS. Certain plastics, including PET, and PVC, can lead to contaminated output, greater char, and inorganic additives, such as carbon black, carbonate, and clay and are therefore limited as inputs to pyrolysis. Currently, most of the chemical recycling plants in the U.S. using pyrolysis are in the Midwest and Southern U.S.

Pyrolysis is a more feasible outcome in the current context, as it can accept mixed feedstocks, which are a more practical and likely outcome of a program for diverting plastics at plants along the auto supply chain. However, the presence of incompatible resins in the stream, such as PET trays, requires a step to sort that out of the stream, either at the plant or as a pre-sort at the recycling plant.

When the output is used to manufacture plastics, it is referred to as **pyrolysis to feedstock** *(or plastic to P2P)* recycling. The process requires additional materials and energy to repolymerize the outputs back into plastic and the additional process steps generate waste and yield losses. However, the resulting plastic is equivalent to virgin, leading to higher potential for circularity.

Although pyrolysis technology has been around for quite some time, there is limited data on commercial plastic to feedstock pyrolysis processes, and the data suggest that the yield and quality of the output are highly dependent upon the feedstock input. This influences life cycle analysis (LCA) results along with assumptions regarding the avoidance of alternative waste treatment for plastic, regional grid mix, and treatment of co-products. As a result, there is a wide range of reported climate impacts for pyrolysis to feedstock. A meta-study conducted by Sphera reviewed 15 LCAs from 2003 to 2023. It found that pyrolysis of plastic waste was generally ranked worse than mechanical recycling and better than incineration or landfill[viii]. The benefit is typically seen in regions where incineration of plastic is an end-of-life treatment (landfill is more common in the U.S. with incineration estimated at only about 20%). So, while pyrolysis processes can accommodate a variety of mixed and hard to recycle plastics and create potentially virgin-quality plastic, there are concerns over the net environmental impact. In addition, as this technology scales it faces some challenges to financial viability as well as political pressure.

When the output of pyrolysis is used to produce fuel, it is termed **plastic to fue**l (P2F). In this case the hydrocarbon outputs are used to produce energy or refined into fuels. This can often be achieved through changes in the process parameters and feedstock and is therefore subject to market forces. **Co-processing in cement kilns** involves using plastic-content waste as an alternative fuel and raw material in the cement manufacturing process. High temperatures in the kiln convert the plastic into energy that powers the kiln and contributes to the calcination process. While these strategies capture some of the value of waste plastic as a form of energy, it does not keep the resources in use or eliminate the use of virgin plastic and is therefore not circular. They do provide a treatment alternative to landfill or incineration, however.

THE ROLE OF PACKAGING DESIGN

Good packaging design is critical not only to the protection of the parts, but also to ease the navigation of the distribution environment. The distribution environment is complex and based on supplier location and may take extra protection due to distance or environment encountered. In the automotive industry, Packaging Design & Engineering is a role that primarily is the responsibility of the Packaging Engineer, but due to the product supply chain, thorough testing and involvement at each step of the supply chain and collaboration with various teams is required.

Packaging required for inbound, from the supplier's location to the assembly plant and tiered suppliers, as well as packaging required for in-plant handling needs to be thoroughly tested. Once the product is un-packed at the customer plant, an end-of-use solution needs to be in place that is sustainable for each type of protective packaging. Protection and end-of-use sustainability are the focal points of packaging design.

IDENTIFYING AND UNLOCKING OPPORTUNITIES

System Components

The recovery of plastic packaging across the auto supply chain reflects an interaction of two separate complicated systems: 1) Auto Supply Chain, and 2) Material Recovery Value Chain. Figure 2 demonstrates this complexity and highlights pathways with coloring aligned with the waste hierarchy. The complexity of this system is itself a challenge, as many different supply chain partners are required to manage the material flows across the supply chain and downstream through the material recovery system. Each additional step in the process adds transportation and handling costs. Identified circular recycling pathways have the greatest number of steps and thus highest associated costs, impacting the economic viability of those pathways. The most efficient and sustainable process is found in the reusable container pathway. Otherwise, there is an inverse relationship between sustainability and supply chain efficiency. This explains why the status quo favors landfill and waste-to-energy (where available) for any non-reusable plastics; even though there may be revenues associated with other pathways, those are often offset by associated costs moving them along that material recovery pathway.

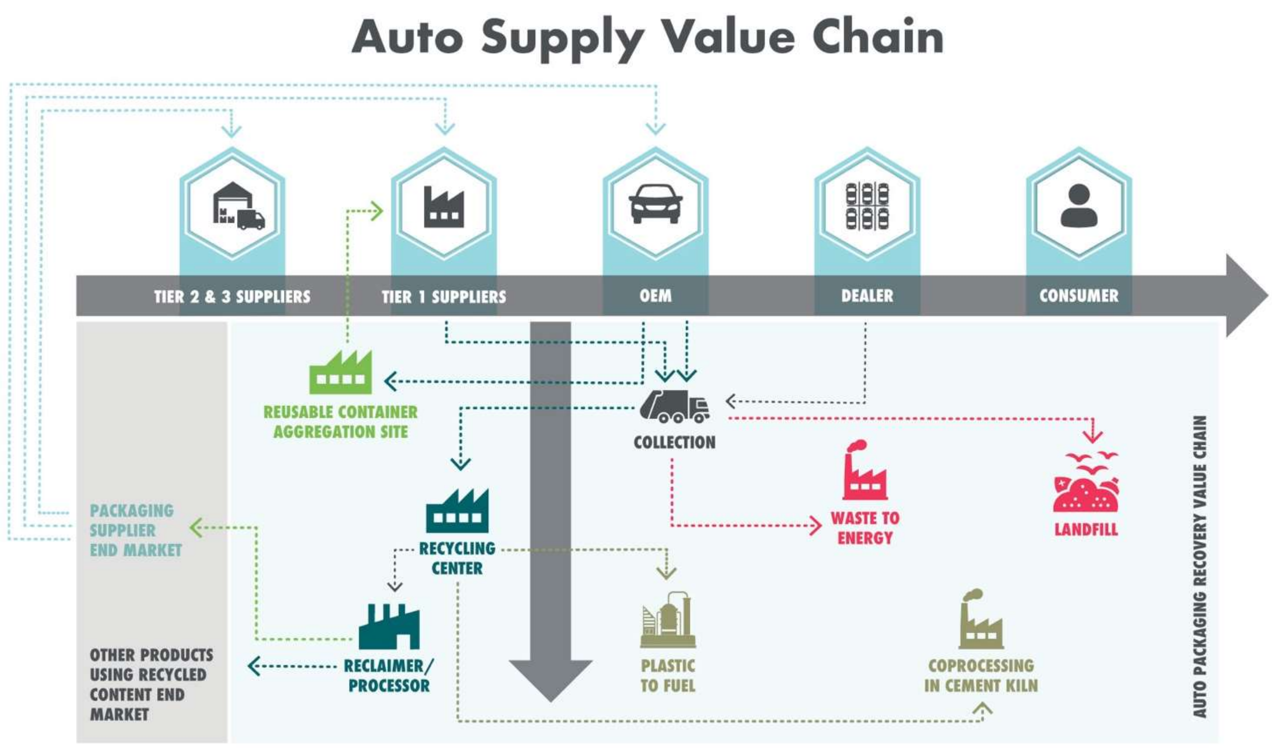

Figure 2. Auto Supply Value Chain

Auto Supply Value Chain

The auto supply chain is an extensive, multi-tiered system. Commonly lower tier suppliers (Tier 2 and 3) provide parts, which are assembled into components as they move up through the tiers, ultimately ending at the OEM, where the full auto assembly takes place.

Lower-tiered suppliers present more challenges for developing diversion opportunities, however, as they are often located a greater distance from the final assembly, and in many cases are imported from other countries.

The focus of this study was on Tier 1 and OEM facilities, though elements of this report could be informative to lower tiered suppliers as well.

TIER 1 SUPPLIER

Tier 1 suppliers produce vehicle components for shipment to automotive OEM assembly plants. Some Tier 1s are major multi-national enterprises, involved in many different commodity groups, such as engines and propulsion, transmissions, seating, brakes, wiring, EV batteries, suspension systems, and instrument panels. These larger Tier 1s are typically fully responsible for the component design, performance verification, parts sourcing, manufacturing engineering, and value chain management. Tier 1 suppliers can also be smaller in scope and complexity (but nevertheless very large firms), such as those supplying steering wheels, air bags, major stampings, wheels, and tires. Still smaller Tier 1 suppliers produce a broad array of parts including fasteners, simple plastic components, small stampings, housings, bushings, and forgings. Over the past 15-20 years, however, there has been a steady trend toward "modularization," whereby larger Tier 1s have expanded in responsibility to provide complex assemblies that are then shipped in-sequence to the OEM assembly plants; examples are seating systems (which include soft trim, cushions, frames, tracks, motors, and actuators), front end modules (fascia, cooling modules, headlights, ornamentation), and instrument panels (bolsters, clusters, switches and controls, and trim). This trend toward modularization has tended to shift formerly Tier 1 suppliers into the realm of "Tier 2-n," where they ship to other integrated suppliers rather than directly to OEMs.

ORIGINAL EQUIPMENT MANUFACTURERS

Original equipment manufacturers (OEMs) design, develop, produce, and ship automobiles and light trucks to the independent distribution network (dealers) across the country. Their manufacturing footprint includes numerous assembly plants and generally entails a smaller number of engine, transmission, stamping, and other component plants which then ship their output to the assembly plants.

Material Recovery Value Chain

The management of these plastics at the highest best use along the waste management hierarchy is the goal. Material recovery is itself a complex system that begins within the plant and follows materials through collection, aggregation, processing and production into a new product at an end market.

INSIDE THE PLANT

Office of Sustainability / Environmental Services / EHS

This department may have different names depending on the plant. This is the department that is most directly in charge of waste and related contracts. Any diversion program should be initiated and championed through this group.

Materials Handling and Logistics
This group may have different name depending on the plant. It is the department that manages the flow of inbound parts and ensures that they get to the assembly line. They typically are comprised of plant staff who manage the "grocery store" where components are staged and where "kits" are put together for line-side assembly. This group is important for any diversion happening during this initial unpacking phase, which includes significant amounts of clear plastic bags and wrap. The group also is likely to be integral in moving materials to and from the line, which could include recyclables.

Total Waste Management
Larger plants, such as OEMs, often have total waste management contractors that manage waste generated in the plant. In some instances, these contractors must coordinate with janitorial contractors and internal plant logistics departments to collect and move materials throughout the plant and to the loading dock for pickup. In plants demonstrating best practices, total waste management contractors have multiple staff on site and assign staff responsibility for handling, presorting into gaylords or onto pallets and, in some cases, baling materials in preparation for shipment to the recycler. These plants typically have a trailer staged at the dock available to load prepared recyclable materials and are swapped once it is full.

Smaller plants and lower performing sites may handle these practices internally and are often lacking space and staff to manage any sorting or preparation of materials within the plant. This limits the opportunities for diverting materials for recycling at their highest and best use and often defaults to putting all waste into the same pathway destined for landfill or lower value recovery, such as coprocessing.

Janitorial
This group is either internal staff or a contracted third party. They are typically responsible for moving waste from throughout the plant to the loading dock. In some instances, this group may load materials such as cardboard into balers. It is important that this group is engaged in any diversion efforts, as they are likely to engage with the materials at some point within the plant.

OUTSIDE THE PLANT

Hauler
All plants contract with haulers, also known as collection service providers, to manage elements of their waste to transport downstream. Most will contract with a hauler to transport mixed waste for disposal, while separating high volume materials such as cardboard for shipment to a recycler. High performing plants will separate certain types of higher value plastics as well, while lower performing plants put all plastic in the mixed waste compactor or dumpster and the hauler will transport that to a landfill or transfer station for disposal or low value recovery.

If truckload quantities of baled materials are generated, then it can be shipped direct to the end market and bypass the hauler and material recovery facility. This practice is only an option for the largest OEMs and is typically not available to smaller assembly plants and tiered suppliers.

Material Recovery Facility (MRF)
Most plants will have a recycling service contract to handle high volume and value materials such as cardboard. Those that cannot generate truckload quantities of baled material will have the material shipped to a MRF where the material is consolidated into truckload quantities and shipped to market. For plants that are sending unbaled or less than truckload (LTL) quantities of cardboard there is an opportunity to ship recoverable plastics with the cardboard to the MRF where it can be baled, aggregated and shipped.

Though MRFs have sorting capabilities to sort by resin using optical sorting or manual processes, it is unlikely they can use that infrastructure to sort mixed plastics from auto plants, as much of it is black plastic which is not recognizable to the sorting equipment and the resin type may not be apparent to the naked eye.

Recycling Processor / End Market
Once truckload quantities of baled materials are produced access to end markets is unlocked. These markets will pay for materials if truckload quantities can be generated, and that price typically includes pickup at the loading dock. Revenue from recyclables is optimized whenever full truckloads are shipped.

For plastics there are several types of end markets that can be accessed depending on the material type[1].

- **Closed loop end market –** these plants, such as Green Processing Company*[2] (rigid HDPE), JSP* (expanded PP), Padnos* (rigid PET, HDPE, PP) Petoskey Plastics (clear bags and stretch wrap), and others - will utilize select source-separated plastics as an input for making the same packaging.
- **Open loop end market –** these plants, such as ACI (clear or colored bags and stretch wrap), ADS (rigid HDPE), Trex (clear film and stretch wrap), Azek (clear film and stretch wrap), Edge Materials* (rigid HDPE & PP) and others will utilize source separated plastics as an input for other durable goods such as pipe or building materials.
- **Chemical recycling –** these plants, such as Nexus Circular*, Brightmark, Alterra, Freepoint, and others, will utilize mixed olefins to generate a pyoil which can be input into the refining process to make new fuel and resin. Based on the research, this category currently presents the only feasible opportunities for mixed plastics from the auto supply chain.

Appendix D offers more information on MRFs and Recycling End Markets.

Types of Plastic Dunnage

TWO PLASTIC PACKAGING WASTE GENERATION FLOWS	
End of Program	**Ongoing**
• **Description:** reusable containers at end of intended life • **Frequency:** very large batch, infrequent occurrences • **Current Management:** containers recycled mechanically (circular) through one -off bid process • **Problem:** Reusable dunnage "contamination" of mixed materials • **Opportunity:** explore chemical recycling of "mixed materials"	• **Description:** expendable dunnage & damaged reusable containers • **Frequency:** ongoing steady generation, • **Current Management:** varied but many manage lower on hierarchy through long-term waste contracts • **Problem:** lower volumes, range of materials with different opportunities, labor and space to source separate • **Opportunity:** define priority streams, volume threshold and ROI for single (large) plant; explore hub and spoke model

Figure 3. Packing Waste Generation Flows

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[1] Note that SP is not endorsing or recommending any particular recycling model or organization listed in this document but only providing information on some of the available resources that may be considered
[2] Asterix indicates members of Suppliers Partnership for the Environment

Reusable Packaging and Dunnage

Reuseable containers have been successfully deployed across the auto industry and are a standard requirement for OEMs if their supplier is within 500 miles. The outer containers are typically mono-resin (commonly rigid HDPE, some examples of expanded PP) and are valuable and sought after by recyclers when they come out of circulation. The responsibility for managing the reusable container fleet varies by OEM. In some instances, the supplier is responsible for managing inventory and in others, the OEM accepts responsibility and utilizes a shared pooling system across suppliers. There are pros and cons to each approach, with pooling presenting efficiencies in logistics, while introducing more potential for attrition, or loss of inventory.

In each scenario some of these containers become damaged throughout the program, while a majority are available for recycling at the end of the program, which is typically three to five years after program inception.

Plants exhibiting best practices collect damaged reusable containers throughout the program until they aggregate truckload quantities[ix] and then work with their suppliers and /or recyclers to recycle them, in some instances back into new reusable containers. The OEM or supplier responsible for the reusable inventory will typically accept bids to handle high quantities of these materials at a program's end and generated revenue through this transaction.

Overall, recycling of reusable containers presents an opportunity for plants to earn revenue and is a viable circular pathway for recycling at highest and best use that is commonly observed within the industry. These are likely already being recycled, however, and thus don't present new opportunities. Any instance where these containers are not recycled should be targeted as a high priority to intervene.

The outer container represents around 80% of the total reusable package when considering the internal reusable dunnage. Up to 20% of reusable packaging by weight are non-recoverable materials composed of mixed materials and formats. This fraction is typically sent to the landfill, either by the generator (OEM, Supplier or Packaging supplier) or the recycler, depending on the circumstances. Most of the materials by weight includes potentially valuable material, such as corrugated plastic (PP or PE). These materials have open loop recycling value potential, however, the presence of problem materials, such as fabric, metal rivets, nylon straps and nylon Velcro presents challenges. The most likely viable pathway for these materials would be chemical recycling if the system has pre-processing capabilities that can tolerate the problem materials. This includes recyclers such as Brightmark.

There is no clear estimate of the quantity of reusable containers and dunnage generated at the end of each program. One example of end of program material from the study identified over 180,000 lbs of inbound materials generated from one program at the end of life. About 150,000 lbs was recyclable HDPE containers and 18% was non-recyclable mixed materials. This 18% could be a candidate for chemical recycling if prohibitive materials such as Velcro, nylon or fabric are removed through pre-processing. Figure 4 lists the number of programs scheduled to come to an end each year over the next 10 years. Each of these events present great recycling opportunities.

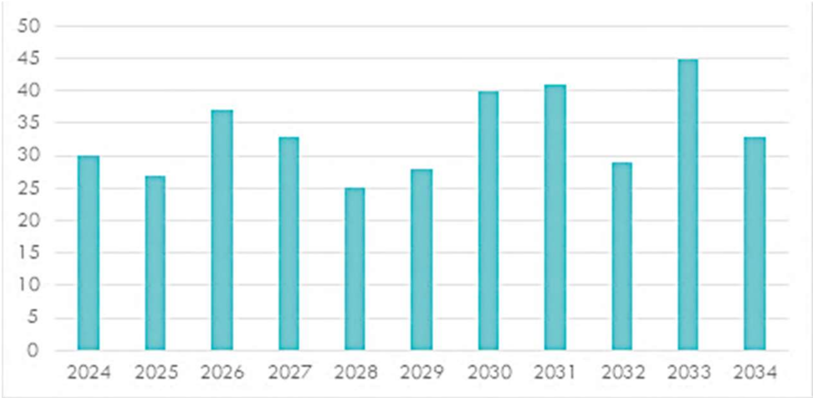

Figure 4. Annual North American Program End Dates 2024-2034

Expendable Packaging & Dunnage
Some auto supply packaging is expendable, or single use. This is most often the case when reusable packaging is not used, such as instances where there is a lack of inventory due to attrition and international shipments. Other instances include single use plastic trays, bags and even stretch wrap to secure pallets. These materials are generated on a more consistent, ongoing basis than the returnable dunnage and present opportunities for diversion within plants in fulfillment areas, often referred to as "grocery stores," and line side on the assembly line.

Based on the data obtained in the study expendable plastics represent between 4-15% of the total ongoing material waste stream by weight and 15-28% of the total packaging waste stream by weight. Wood and cardboard are the largest components of recurring packaging waste stream by weight.

Optimizing environmental benefits while navigating economic and behavioral constraints is the central challenge.

Types of Plastics:
Table 2 outlines common plastic packaging materials observed across Tier 1 and OEM sites and describes the recyclability, extent that it is recycled presently, and the ideal highest and best use from an environmental perspective. Logistics and constraints play an important role, however, which often limits the ability to achieve highest-best use. Recommendations, presented below, take these constraints into consideration.

Table 2. Recyclability of Common Materials

MATERIAL TYPE	RECYCLABILITY	CURRENTLY RECYCLED	POTENTIAL FOR CIRCULAR MECHANICAL RECYCLING	HIGHEST BEST USE
Damaged or end-of-program reusable containers (totes, knock downs, etc.)	Yes	Yes	High	Reused where possible or recycled into new reusable containers
Rigid plastics (P-Corr separators, trays – PET, PP, PE)	If single resin and free of contaminants	Sometimes	Low	Reused where possible or recycled into new rigid packaging
Clear LLDPE film (bags and stretch wrap)	If free of contaminants	Sometimes	Medium	Closed loop recycling into new film packaging, such as seat bags
Other films – (colored bags, VCI film)	Maybe	Not typically	Low	Open loop recycling into durable products or chemical recycling using pyrolysis
Foams – PP, PE and PS	If densified and single resin material	Sometimes	Low	Closed loop recycling into new packaging
Plastic (expendable or reusable dunnage) with mixed resin components	Maybe	No	No	Chemical recycling using pyrolysis
Other plastic (caps, rivet strips, strapping)	Maybe	Sometimes	No	Closed loop recycling into durables or chemical recycling using pyrolysis

Recycling Options:
Table 3 evaluates the suitability of the common materials against the available recycling technologies. The actual marketability depends upon access to end markets and minimum volumes (typically full truck load).

Table 3. Suitability of Common Materials for Various Markets

				Mechanical Recycling		Chemical Recycling		
	Plastic Packaging Material Types	**Commodity**[x]	**Selling Price ($/lb)**[xi]	**Closed Loop**	**Open Loop**	**Purification**	**Solvolysis**	**Pyrolysis**
Large Format Rigid Polyolefins (PE or PP)	**Colored / Black Plastic Reusable Containers**	Not indexed	.04-.10[xii]	X	X			X
Polyethylene (PE) films	**Clear Film and Bags (LLDPE)**	Films-clear (Grade A)*	0.15-20	X				X
	Colored Bags and Wrap (LLDPE)	Films (Grade B)	0.06-0.08	X	X			X
Rigid Plastic (PE, PET, PP, PS)	**Colored/black plastic trays (PS)**	PS/EPS	0.02-0.04					X
	Clear plastic trays- (PET)	PET -clear	0.16-0.19	X	X		X	
	Colored / black Plastic Trays – (PE)	HDPE color/ bulky rigid	0-0.02	X	X			X
	Corrugated Plastic (PP)			X	X	X		X
Foams	**Foam Packing Sheets (PE/PP)**	PE/PP foam	0.02-0.08	X				X
	Foam Blocks (PE/PP)	PE/PP foam	N/A	X				X

Conditions Needed for Success

1 TRUCKLOAD QUANTITIES OF MARKETABLE COMMODITIES

- Truckload quantities range from 20,000 – 40,000 lbs of materials. This comes down to the amount of waste generated and space for storage.
- If a plant generates truckload quantities and has space to store, seek to add infrastructure and staff to bale material and work directly with end markets. This can generate revenue.
- If a single plant does not generate this much material work with other plants and service providers to contract for less than truckload pickup services. This may come at a cost.

2 BUY-IN FROM MANAGEMENT

- Frame environmental benefits (such ghg impact from table 1).
- Align key performance indicators. These are discussed below.
- Include expected revenues, costs and environmental outcomes.

3 BUY-IN AND COORDINATION WITHIN THE PLANT

- Plant sustainability lead and material handling and logistics departments need to work in partnership for a program to succeed.
- Behavior of plant staff will make or break the ability to sufficiently divert materials. Engaging them and obtaining their support is paramount. Seek opportunities to create incentives and gamify diversion activities.
- Plant contractors, including waste management service providers and janitorial, should have clearly defined roles and responsibilities and should be included in any trainings done to launch a program..

4 WELL-DESIGNED INTERNAL COLLECTION PROGRAM

- The program should be designed to provide at least 3 months of runway to obtain materials, engage staff and train them.
- Collection containers and signs at all three phases – collection points, pooling points, final in-plant aggregation point – are required to ensure everyone is clear on what to divert
- Prior to launch all staff should be trained on new procedures.
- Success in diverting and quality of diverted materials should be monitored. If they are not meeting expectations additional training and communications should be deployed.

5 COORDINATION WITH DOWNSTREAM PARTNERS

- Work directly with end markets if truckload quantities are being generated. This presents more revenue opportunities and transparency over what is being produced with the recycled content.
- If using service provider make end market expectations clear. Recyclers likely already have their end markets of preference. If the goal is mechanical recycling with a local company, work with recycling contractors to make this desired outcome clear and negotiate with them to arrive at an agreement for downstream disposition.
- Establish reporting requirements. Reporting weights of materials sent for recycling is a minimum reporting requirement. If possible, seek reporting on weight by resin type and what type of recycling market and or product is made with the material.

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Common Challenges

WITHIN THE PLANT
• **LACK OF DATA** on the types and quantities of plastics. Decisions for diverting plastics require an understanding of the type and quantity of plastics being generated down to the resin and format – e.g., x lbs LDPE clear film per month or x lbs of HDPE rigid per year. The first question a recycler will ask is "what do you have and how much." Without an answer it is difficult to move forward on a plan. Plants typically do not have this data. Any plant wanting to establish a plastic recycling program should conduct a waste composition study to understand what they have. The best option would be to follow ASTM standard (ASTM D5231-92) to sort the entire disposal stream, breaking down each plastic by resin and format.
• **INTERNAL COORDINATION.** Obtaining buy-in across the plant from management to line side workers to staff or contractors managing the flow of materials to the loading dock is a challenge. In some instances, there are as many as six different groups involved in the program, including corporate sustainability team, plant sustainability lead, plant environmental services contractors, janitorial services contractors, plant logistics and line staff. Alignment across these stakeholders and understanding of roles, responsibilities and various motivating factors is a significant challenge that can define the success of a diversion program.
• **LACK OF STAFF DEDICATED TO DIVERSION.** Some OEM plants have total waste management contractors on site that play a more active role in diversion programs. This is uncommon among suppliers. It is important to have a specific role defined for overseeing the diversion program throughout the plant all the way to the back of the loading dock. This role should include ensuring that containers and signs are appropriately distributed throughout the plant, that staff are following instructions appropriately and that materials are appropriately sorted and prepped for shipment out of the plant.
• **SORTING.** There are many barriers to source separating at the plant level, from space constraints to staff buy in. Opportunities to manage unsorted plastics may be the most realistic opportunity for most plants.
• **SPACE.** Many plants lack space to perform any centralized sorting, baling and/or storing materials in order to create truckload quantities of materials.
• **BUY IN.** Even though it's "the right thing to do", it's not a core competency of the plants and workers and introducing new desired behavior to divert and segregate plastics is difficult. Especially with larger companies, the production rates outweigh the ability to slow the production line down to enable segregation and takt time is often noted as being a barrier.
• **EQUIPMENT.** Sorting new streams requires collection containers throughout the plant, carts to move materials to the loading dock and gaylords, pallets, dedicated compactors and/or balers to prep materials for shipping. These are not typically readily available and are investments that need to be made either by the plant or their contractors.
• **QUANTITY.** Most plants observed do not generate truckload quantities of plastics on a frequent basis. Without that it requires additional steps to transport loose, less than truckload (LTL) quantities and work with a third party to aggregate and ship to markets. These extra steps will typically cost more than the value of the material, shifting the practice from a revenue generating activity to a cost that the plant must pay.

- **LACK OF WILLINGNESS TO ADD COST.** There is often an assumption that diverting materials results in revenues. As noted above, this is generally only the case when truckload quantities of materials are generated. While it may be possible with cardboard and pallets, it is not likely with most plastics in most plants. The best chance at cost neutral would be associated with end-of-life reusable rigid containers and source separated clear bags and wrap. There may also be opportunities to ride along with cardboard. In many cases, however, successfully diverting all plastics may be an added cost to the plant.

BEYOND THE PLANT

COST OF LOGISTICS

- Transporting less than truckload quantities of materials adds significant costs to the system, which ultimately is born upstream by the waste-generating plants.

PROCESSING MATERIALS NOT DESIGNED FOR RECYCLING.

- Presence of "prohibitives" or materials of which certain recyclers have zero tolerance. In particular, some chemical recyclers, which are a potential outlet for mixed plastics, have no tolerance for non-olefin plastics, including common materials found either in the reusable and expendable dunnage, such as PET and Nylon, and engineered resins found in plastic scrap, such as ABS.
- Lack of transparency and reporting of downstream flow of materials. It is often a challenge to get downstream aggregation partners, such as MRFs, to provide information on the destination of recyclables collected from a plant. They may consider this competitive information and be unwilling to share it.

DEMAND FOR RECYCLED CONTENT

- Low demand for recycled content limits market opportunities. Creating more demand pull by committing to buy back packaging with recycled content can open additional opportunities.

PRIORITY OPPORTUNITIES

Based on the outcomes of this study the five greatest opportunities for recovery of plastic packaging based on a balance of environmental, economic and behavior considerations across the automotive supply chain are:

1. **OPTIMIZE REUSABLES.** The impact of inventory loss from reusable programs directly influences the amount of single use expendable dunnage generated throughout the system. Keeping tight inventory can reduce the need for "exception packaging," which is a prominent source of single use dunnage. This can be considered a waste prevention strategy that hits the very top of the waste hierarchy of preferred management options. Opportunities for managing this include setting a target on "leakage rate," or the amount of inventory loss over time, to use as a metric to track closely and from which to align performance. There are opportunities to further deploy systems using scanners, tags, and color coding to track down lost inventory. Further study is needed in this area.

2. **MAXIMIZE IMPACT OF EXISTING RECYCLING.** Prioritize closed loop mechanical options. A fair amount of plastic recycling is already taking place, particularly involving end of life reusable containers. However, there are instances where recyclers are bidding on reusable containers for use in downcycled products, such as pipes and other durable infrastructure. There are opportunities to direct these materials into more sustainable, circular pathways, by giving preference to a recycler that can demonstrate that the containers will be made into new reusable containers with the same intended use. Any instances where broken reusable containers are not being recycled should be immediately flagged as an opportunity. Plants should create a system to stack and store containers until a truckload is produced or coordinate with recyclers and other regional suppliers to aggregate truckload quantities.

3. **ALIGN WITH PURCHASING TO USE MORE RECYCLED CONTENT IN PACKAGING.** Closely related to the previous recommendation, more circular opportunities can be unlocked by engaging purchasing departments of the packaging supplies to commit to procuring packaging with increasing amounts of recycled content. In situations where there is revenue generated from recycling, there may be opportunities to turn that payment into a credit applied when purchasing back new containers. This can show clear net value and allow recycled content containers to be seen as more cost competitive by the purchasing agent. This may require coordination across OEMs, Tier 1 suppliers and their packaging suppliers. Further exploration of this concept is recommended.

4. **DIVERT CLEAR BAGS AND WRAP.** Of the expendable dunnage and packaging observed in the waste stream across all researched plants clear bags and pallet wrap, made from LDPE or LLDPE (low density polyethylene) was the most prevalent. This material is also commonly referred to as clear film. Source separating this film is the best chance to divert plastics without adding costs. The recycled commodity has a consistent market value ($.14/lb five-year average[xiii]) and has circular potential with a regional end market, Petoskey Plastics, that can incorporate recycled clear film into new packaging, such as seating bags. Seating plants would be a good initial target for this type of diversion program, though all plants generate meaningful quantities. Due to the light weight of these materials and need to generate truckload quantities to reach recycling markets, a hub with baling and storage capabilities is a likely partner. Existing infrastructure found in recycling facilities should be sufficient to manage this. Plants should work with local recyclers and/or engage with other plants in the region to develop a hub and spoke network that can generate at least 30,000 lbs of film per month. The appendix shows a map with recyclers and end markets.

5 **DIVERT MIXED PLASTICS.** Beyond reusable containers and clear film, a diverse range of resin and form factors of plastic packaging is used. This limits practical recycling opportunities based on low quantities of single commodity types and high level of sorting required at the plant to source separate. Plants typically do not have space or staff to perform this level of sorting. Markets for mixed plastics are the most likely pathway for these materials. These may be either open loop mechanical or chemical recycling. Most mechanical recycling markets accept rigid-only mixed plastics, while chemical recyclers typically include all film and rigid olefins, polypropylene (PP), polyethylene (PE) and polystyrene (PS), included in the mix. The presence of PET trays in expendable dunnage and nylon strapping, and Velcro in returnable dunnage, likely require an end market partner with pre-processing capabilities to remove these materials which are incompatible with recycling of olefins. Alternatively, utilizing a hub to pre-sort olefins from non-olefins would overcome this barrier; however, this step adds costs and would likely require plants to pay for the collection of this category of plastics.

PLASTIC RECOVERY PROGRAM CHECKLIST

CONSULT THE SP PACKAGING DESIGN GUIDE

The SP Guidance Document, "Sustainable Packaging Specification Recommendations for Automotive Manufacturing Operations Version 3, February 2024," provides a comprehensive list of best practice recommendations. The recommendations focus on opportunities to minimize automotive packaging waste and address barriers to recyclability in the design phase, including guidance related to a variety of commonly used plastic packaging and dunnage materials. The latest version of the guidance document can be found at: https://www.supplierspartnership.org/sustainablepackaging/

POLICY AND PROCESS

- Establish an internal monitoring program to track, measure, and formally approve package design conformance by environmental or sustainability team personnel. This includes carefully considering certain materials that present challenges to circularity, including:
  - Single use packaging
  - Packaging composed of multiple materials
  - Foams
  - Screws, nails, staples, clips
  - Metal brackets and banding
  - PVC
  - Non-clear film
  - Non-olefins
- Integrate goals and practices for packaging recycling into the company's sourcing policies and tactics.
- Keep in mind that certain regions have specific supply chain attributes, including access to recycling services, PCR feedstock and manufacturers able to utilize PCR (post-consumer recycled) content. materials that can be recycled, the ability to increase PCR (post-consumer recycled) content. Make sure the local/regional access and availability is there to support any sustainability policies for your goals.
- Use lean manufacturing principles in moving recyclables through system (including disassembly).

CHARACTERIZE YOUR WASTE

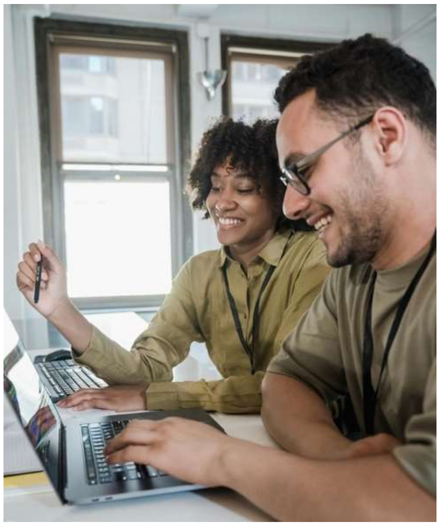
The opportunities for recycling in a specific plant relate to the type and amount of a specific plastics generated. Recyclability depends on a material's prevalence, the commodity value of that material and the costs of stewarding the material through the material recovery value chain. The first question that will come up when discussing opportunities with recycling collectors, processors or end markets are "what types of plastics are you generating and how much of each type?" To take the first steps towards designing a program, these questions should be definitively answerable. The best way to understand a material's prevalence is to conduct a waste characterization audit by sorting through all materials destined for disposal. This may require a third party researcher familiar with this study methodology. The most robust methodology to use is defined in ASTM standard D5231.[xiv]

The characterization of your "waste" is critical to this program – but the most important part is making sure it's comprehensive. The term Dumpster Diving isn't glamorous but making sure you're laying your eyes on what's currently being disposed of that could be recycled is an integral part of the waste characterization study and is a guiding pillar for program design.

PRIORITIZE OPPORTUNITIES

Once there are definitive numbers on the type and amount of plastic generated it is possible to identify and prioritize opportunities by considering its volume, value and environmental outcomes using Table 1 above. Based on observations from this study the most likely opportunities are broken or end-of-program rigid plastic reusable containers and source separated clear plastic bags and wrap. If you are in need of material identification, any local recycler can typically help with that and if they're stumped by a specific material, there are plastics producers/suppliers that can help or local Universities with Material Science programs. No fee is typically assessed for this service.

MAKE THE CASE TO MANAGEMENT



Generally, successful implementation of Sustainability initiatives, including programs for recycling and circular economy, requires the approval of a business case. The auto industry is intently focused on achieving profitability through the design, development, manufacture, sales, and service of its vehicles. Maximizing revenue and minimizing costs are paramount. As a result, endeavors that represent "the right way to do business," but lack a direct link to sales and variable costs, are less likely to gain full support of the management team and operational staff. Consequently, there are three primary ways in which Sustainability actions are justified.

1. **REGULATORY MANDATE**. Laws and rules are prominent throughout the industry, such as emissions standards, safety requirements, OSHA rules, and hazardous waste regulations. In these cases, there is understandably full support for compliance – essentially they are "must haves" vs. "nice to haves."
2. **FINANCIAL BUSINESS CASE**. If a Sustainability initiative can be cost-justified, then the project champion is more likely to garner management support. In the realm of recycling, this is the reason that cost-effective collection and processing is important, coupled with the existence of robust and profitable next-use markets. Cost-justification is also enabled by longer-term planning horizons, where ROIs can become favorable, and in firms where such traditionally "nonfinancial" issues are monetized; a good example of such an approach is the use of internal carbon pricing, which has been growing steadily as a practice among the private sector.
3. **CORPORATE SUSTAINABILITY GOALS**. Companies are now more frequently establishing and publicly reporting on non-financial ESG metrics. If a recycling project champion can clearly convey how the initiative will favorably impact a corporate sustainability goal, then they will more likely achieve support. The next sections covers KPI alignment in more depth. Zero Waste is one of the most frequently cited goals for major corporations. This entails making sure the materials leaving your facility are managed as valuable resources to the extent possible (or having an alternative end-of-life solution that does not include landfill). Aligning Zero Waste Goals with the Sustainable Materials Management Hierarchy (figure 1) should be the priority.

ALIGN KEY PERFORMANCE INDICATORS (KPIS)

Recycling projects need to define measurable and material metrics, or key performance indicators (KPIs). In so doing, the success of the project can be monitored, and more importantly, the justification for the initiatives will more likely be supported by the management team.

Overall, KPIs should:

- Align with corporate sustainability goals
- Align with desired recycling outcomes
- Encourage packaging recycling and reuse
- Empower local plant managers to invest in solutions
- Enable the identification and resolution of shortcomings

Using these corporate goals for reference, while also embracing the sustainable packaging guidelines published by SP, we can offer the following KPIs for possible use by a packaging recycling team:

(1) "INCOMING"

- Reduction of single-use packaging (volume and/or percent improvement)
- Use of recycled materials in packaging (volume and/or percent of total)
- Use of recyclable materials in packaging (volume and/or percent of total)

(2) "OUTGOING"

- Reduction of total plant waste (volume and/or percent improvement)
- Reduction of packaging waste (volume and/or percent improvement)
- Recycling rate for packaging materials (percentage)
- Rate of circular recycling for packaging materials (percentage)
- Leakage rate of reusable containers (percentage)
- Zero-waste-to-landfill plants (number of plants vs. total)

(3) GOVERNANCE

- Existence of a procurement policy for sourcing recycled and recyclable packaging materials
- Existence of a business process for approving single-use vs. recyclable packaging during product design phase
- Existence of goals, targets, and measurement method for gauging packaging waste performance

IDENTIFY AND ENGAGE PARTNERSHIPS ACROSS THE MATERIAL RECOVERY VALUE CHAIN AND WITH OTHER NEARBY PLANTS

Observations from this study indicate that most tiered suppliers and some OEM plants do not generate enough plastic materials on an ongoing basis to generate truckload quantities of materials, which is a key threshold. This means that a local recycler is needed to collect, aggregate and market materials from several sources. When developing a program, it is necessary to identify a recycling partner to conduct "milk run" pick-ups, aggregate and bale materials, and ship to end market. Typically, that partner will already have end market relationships. However, there are opportunities to engage preferred end markets in conversation with the local recycler. For example, if the recycler is sending clear bags and wrap to an open loop recycling process, such as aggregate lumber for decking, there are opportunities to request that they shift to a closed loop recycler that makes new bags with the recycled content. See Appendix D for a list of recyclers and plastic end markets in Michigan.

It may be difficult to direct downstream supply chain partners on end market decisions as a single generator of material with less than truckload quantities, but higher quantities of materials provide more leverage in those conversations. Engaging and coordinating with other local plants within a geography and working together can present added opportunities.

IDENTIFY AND ASSIGN ROLES AND RESPONSIBILITIES

A successful recycling initiative requires that all stakeholders are identified and that their respective priorities and responsibilities are confirmed; typically, the following categories of participants in an industrial facility will be involved:

WASTE MANAGER (also environmental services) – principally responsible to managing the process for collection and proper disposal of plant refuse.

PACKAGING ENGINEER (also material handling engineer) – oversees design and procurement of the dunnage and containers required for conveyance of components from supplier plants to assembly facilities.

MATERIAL HANDLING (also materials logistics management) – manages movement of materials within the plant from incoming docks to lineside; may also be responsible for return of waste and defective materials for disposition.

OPERATIONS MANAGEMENT – supervise production processes; these individuals usually play a supporting role in ensuring recyclable materials are collected at line side.

INDUSTRIAL ENGINEER – they will need to acknowledge the potential Takt time impact on any operator involvement in material collection.

SERVICE PROVIDERS – on-site total waste managers and other supporting services, such as janitorial staff and baling station operators. They will be involved in collecting materials throughout the plant and preparing for shipment.

SUPPORTING FUNCTION STAFF – organizations including finance, purchasing, legal, and HR/labor relations may also need to be consulted when developing a recycling/reuse plan.

PLAN AND DESIGN THE PROGRAM

CREATE A PLAN

A complete plan should be developed and circulated to gain support and approval within the plant. This should include at least three months' lead time to get equipment (collection containers, transport carts, etc), service providers and staff aligned. The planning phase should include:

- Discussions with vendors and end markets to determine available pathways and associated costs / revenues.
- Articulation of roles and responsibilities, designation of space within the plant to manage material before shipping to recyclers and processes for moving materials from the floor to the dock, and incentives for positive support and action
- Standard operating procedures

CONDUCT TRAINING

Engage a third party with experience to conduct a training. This could include an initial kickoff to announce the plan and reasoning followed by a demonstration of the plan in action. Let the program begin and have a follow up training with initial observations on performance and identify areas for improvement. Empower staff to have periodic updates on performance and announce incentives for areas of the plant demonstrating high performance. Establish the Third Pary Trainer's roles and responsibilities. Training and support for project management would be preferred as the on-site team has day-to-day responsibilities that sometimes are prioritized over the program for discovering recyclable material opportunities.

ENSURE CLEAR COMMUNICATION AND MESSAGING

A key mandate must be communication at every level of the program. This starts with the use of clear signage at each stage in the process within the plant, from the line to the intermediate pooling point to the back of the dock. Use pictures where possible instead of just words. Try to keep as simple and clear as possible. Figure 5 is an example of effective signage used in the pilot.

It is also essential to have effective communication with partners outside of the plant, especially if one of the steps was unable to be completed at the stated time. For example, if materials were not able to be collected from the end-of-line and properly placed on the dock for the recycler or hauler to pick-up, immediate communication needs to occur, so time and resources is not wasted. Also, the Recycler/Hauler needs to be held accountable to provide timely updates on material weights, if there were any exceptions (materials that were unable to be identified or caused system failure), and provide any general areas of improvement that they see.

Figure 5. Sample Communications Messaging, Clear Film and Other Plastic Packaging

TRACK, EVALUATE AND ADAPT

As the deep dive into the work begins, keep in mind that this is a program that needs frequent checks and monitoring. Different shifts of personnel, different products received, different materials presenting themselves that could be recycled, all indicate the need for very frequent communication after the initial company-wide kick-off discussion.

The program should review data on a regular basis to track performance in relative to the KPIs. Data on diversion quantity, quality and value of material down to the resin and form factor (e.g., HDPE rigid tray, LLDPE clear bags and wrap) is important for tracking market opportunities and seeking recovery at highest and best use based on the hierarchy. Ability to adapt and iterate should be built into the program, for example, to understand and respond to changing material composition within the industry.

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CONCLUSION

The automotive supply chain does many things well when it comes to environmental sustainability and materials management, but there are opportunities to do more with plastics dunnage and packaging that is currently not being reused or recycled. The goal is to use the sustainable materials management waste hierarchy as a guidepost to balance environmental, economic and behavioral elements and prioritize the most impactful interventions. There are non-trivial challenges that may present barriers improving the sustainable management of these materials. Some of these challenges can be overcome by better understanding the plastics in the waste stream and coordinating within the plant, among other plants and across the material recovery value chain to pursue the highest priorities. This guide describes a framework and approach that can be taken through this complex system to divert plastic waste and access recycling markets that reflect the highest, best use of those materials. Though there is no one-size fits-all approach to handling this plastic waste, this report can help Tier 1 suppliers and OEM plants to evaluate opportunities that fit their circumstance considering economic, environmental, and behavioral aspects, and outlines how clusters of plants may work together to overcome common barriers.

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APPENDIX A: RESEARCH ENGAGEMENTS

Table 4. Research Participants

ROLE	CATEGORY	ORGANIZATION NAME	INTERVIEW	SITE VISIT	FIELD TRIAL
Tier 1 Supplier	Body, Interior, Powertrain	Magna International Inc.	1	5	3
Tier 1 Supplier	Chassis	American Axle		1	1
Tier 1 Supplier	Electronics	Bosch Group	1		
Tier 1 Supplier	Interior, Electronics	Lear Corp	1	1	1
Waste Handling	Total Waste Management	VMX International	1		1
Waste Handling	Total Waste Management	MPS	1		
Waste Handling	Total Waste Management	RecycleMax	1		
Waste Handling	Total Waste Management	Envita	1		
Waste Handling	Recycling Collection / Aggregation	GFL Recycle Center	1	1	1
Waste Handling	Recycling Aggregation	Goodwill Greenworks		1	1
Waste Handling	Recycling Collection / Aggregation	WM		1	
Waste Handling	Recycling Processing	Petoskey Plastics	1		
Waste Handling	Recycling Processing	JSP	1		
Waste Handling	Recycling Processing	Edge Materials	1		
Waste Handling	Recycling Processing	Green Processing	1	1	
Waste Handling	Recycling Processing	Padnos	1		
Waste Handling	Recycling Processing	ACI Plastics	1		
Waste Handling	Recycling Processing	Nexus Circular	1		
Waste Handling	Recycling Processing	Covanta	1		
Waste Handling	Recycling Processing	EFS	1		
Packaging Supplier	Packaging	Orbis	1		
Packaging Supplier	Packaging	Primex	1		
Packaging Supplier	Packaging	Bradford	1		
Packaging Supplier	Packaging	Schaefer	1		
Packaging Supplier	Packaging	ITB	1		
Packaging Supplier	Packaging	Packaging Products Inc	1		
OEM	Assembly Plant	GM	1		
OEM	Assembly Plant	Ford	1	1	
OEM	Assembly Plant	Stellantis	1	1	1
Other	Researcher	Shane Litchey	1		
TOTAL			**30**	**12**	**8**

APPENDIX B: 2024 FIELD TRIAL CASE STUDY

Description and Overview

Early stages of research indicated that most Tier 1 and OEM plants were not able to generate truckload quantities of materials to send direct to market due to a combination of challenges as described above. Therefore, a hub and spoke model of aggregation across a group of plants clustered within close geographic proximity was identified as the most likely viable option for managing these materials. To test this concept a field trial pilot was developed involving five plants in the Detroit area representing different auto companies and capabilities including Tier 1 and OEM sites. The pilot also included a logistics partner to run collection routes, two different waste handlers and engagement with several end markets to obtain market feedback of the collected samples. RRS was engaged to perform characterization of the collected materials.

The trial was designed to gather quantitative data on plastic waste generated and qualitative data on the attitude and behavior associated with adopting of a diversion program. The design simulated a launch of a new diversion program, including segregation containers spread throughout the plant, designed signage indicating what can and cannot be diverted and aggregation points at the loading dock. There were two distinct diversion streams collected during the trial 1) clear bags and stretch wrap and 2) all other mixed plastic packaging. Reusable containers and dunnage were not a part of the trial, as they are not generated on a regular, ongoing, basis.

It was a six-week trial during early 2024.

Field Trial Outcomes

Quantitative Data
Figures 6 and 7 show the breakdown of material type collected during the trial. A majority of material by weight was clear bags and film. The mixed plastics were low in quantity and diverse in both resin and format. End market feedback indicated that the largest component of this stream – the clear bags and wrap – was suitable for closed loop or open loop mechanical recycling.

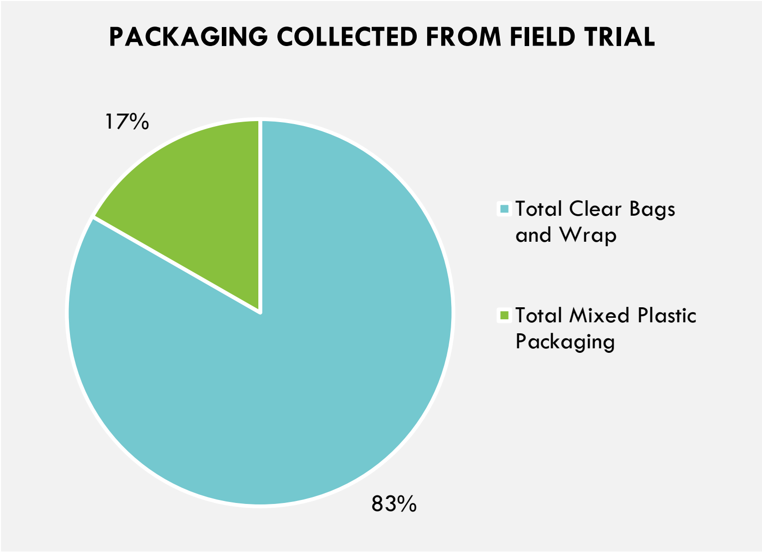

Figure 6. Packaging Collected from Field Trial

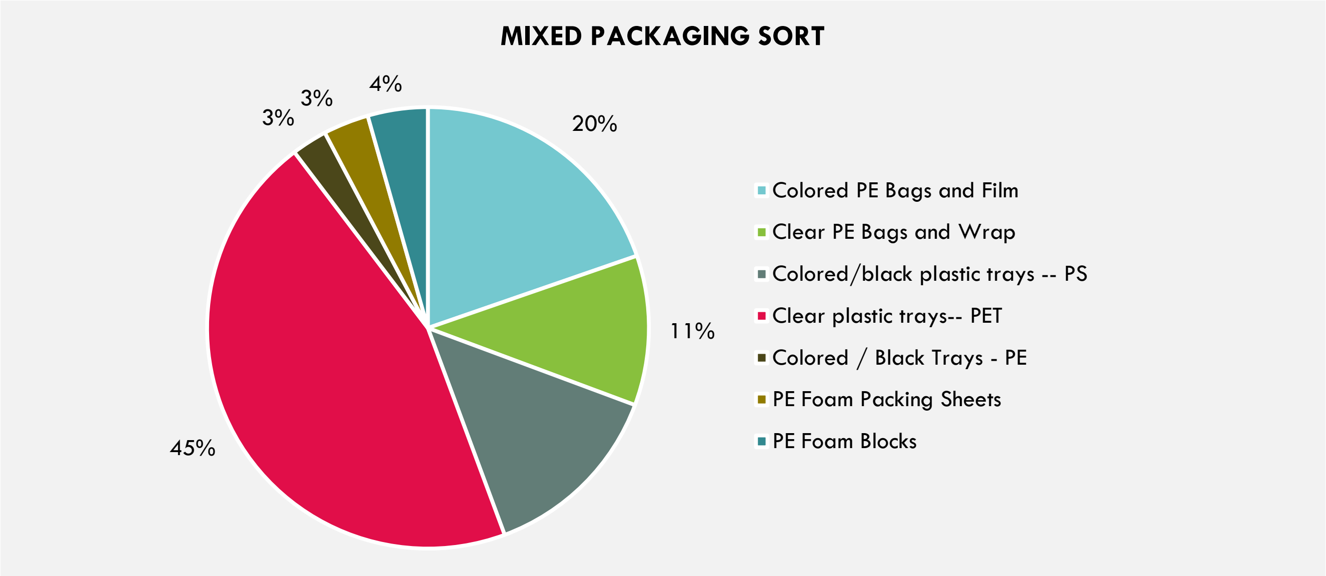

Figure 7. Mixed Packaging Sort, Field Trial

Qualitative Data

- Launching a diversion program requires a lot of coordination and communication across the plant. Time to plan and engage with staff is essential to success.
- The plant in general focuses on productive labor and managing waste is not a priority for the average line employee. This relates to Takt time, as the operator has only so much time to produce a part. Employees can't take the time to walk away to dispose or recycle so it must be line-side if possible. Even making decisions on what stream to throw if there are multiple options presents a challenge. Unless the collection is instantaneous, the operator tasks ideally need to explicitly include collection in required work tasks if they are expected to comply.
- Less than truckload collection is a significant challenge, especially if the vehicle is not equipped to load at the dock level.
- Similarly, the flow of a plant is towards shipping of productive goods. It proved to be difficult to move materials in the other direction to load recyclables onto trucks where typically waste materials are just tossed in a compactor.
- Fighting for floor space – plant engineers typically do not consider placement of receptacles (trash or recycling) when they're laying out a line and thus there is always a fight for space to place bins for diversion.
- A key is getting a business case to the Purchasing and Finance teams, though the business case doesn't necessarily need to be revenue-positive, if it can align with Sustainability goals. The case should have data to demonstrate that the activity increases recycling rates and ideally can attribute that to direct recycling or circularity goals or, better yet, net emissions reduction goals.
- It takes clear communication and signage, not just at the line side collections, but also at pooling points in the plant where materials are consolidated for movement to the dock and finally in the dock area.
- The material that was collected was mostly free of contamination.

Lessons Learned

- Keep the program clear and simple. Use preliminary research on the waste stream to identify one or two diversion streams throughout the plant. Anymore and it gets too complicated and there is not sufficient room for additional receptacles.
- Prepare! The prep work is key. Although we were all optimistic, including the participant companies, on the ability to collect the materials that were part of the study, there were a variety of reasons as to why the collection proved more difficult than originally anticipated.
- Know that line side preparation for Tier 1 companies is critical. Having appropriate, discernable bins to collect the recyclable material provides a necessary process. Participant companies that did not have line side bins utilized a centralized collection area which wasn't as successful due to the extra effort it took to move the collected material to the centralized location.
- Train the personnel and including them in the journey, letting them know the Why, Where, and What of the effort should have been conducted long before we set the pilot dates. Having a third party expert develop and conduct a training program prior to launch alongside the participant company program lead would allow for clarity and alignment among all parties to set expectations and establish roles and responsibilities.
- Have pre-printed materials distributed to the participant companies showing material differentiation, specific bins and gaylords, locations for material placement within the facilities.
- Encourage the facilities to have a process document so all are on the same page with the process. A participant company collected the material but then it was difficult for them to get the gaylords from the central location to the dock. Early communication and weekly communication are necessary.
- Make the case to all staff, not just management. Success depends on all staff participating in the program. Appeal to diversion as something to take pride in. It's a small step to contribute to the big efforts the world needs to support our children and grandchildren.
- Motivate staff to engage in this process; this is incredibly important. Establish incentives around performance, such as the quantity diverted, or the quality of the stream can create more buy-in and why it is a priority
- Gamify it. Try putting a backboard on the recycling bin to make it into a skills challenge.

APPENDIX C: EXISTING WASTE RELATED KEY PERFORMANCE INDICATORS

Sustainability reports among selected automotive OEMs and Tier 1 suppliers provide the following salient highlights of their publicly disclosed objectives:

GM (2022 Report)

- By 2030, substantially reduce waste generation through prevention, reduction, recycling and reuse
- Divert more than 90% of our total operational waste from landfills, incinerators, and energy recovery facilities by 2025
- Have 100% returnable, viably recyclable, reusable, or compostable packaging by 2030

Ford (2023 Report)

- Reach true zero waste to landfill across our operations
- Eliminate single-use plastics from our operations by 2030
- Suppliers in North America and Asia Pacific are required to use packaging that has a neutral, if not positive, environmental footprint, achieved by using 100% recycled, renewable or recyclable materials

Stellantis (2022 Report)

- Design industrial processes that allow minimal use of raw materials and ensure 100% waste recycling in local loops of circular economy
- Total waste normalized (kg/vehicle produced); achieve 36 kg by 2030
- Percentage of waste recovered out of total waste generated; achieve 90% by 2030
- Percentage of plants with zero waste sent to landfill; achieve 75% by 2030

Toyota (2023 Report)

- Our packaging target for fiscal years 2022 to 2026 is to reduce procurement of single-use packaging materials by 25% from FY2018 levels (11,989 metric tons was their 2018 baseline)

Magna (2022 Report)

- Percentage of waste generated by Magna that is recycled (2022 was 87.2% excluding energy recovery)

Lear (2022 Report)

- Use returnable, reusable and recyclable packaging where practicable
- Landfill-free facilities (28 in 11 countries in 2022)
- Waste volume reduction (2% reduction 2022 vs. 2021)

APPENDIX D: LIST OF RECYCLERS RELEVANT TO MICHIGAN PLANTS

Material Recovery Facilities

These sites are potential hubs in a hub and spoke network. They have baling and marketing capabilities. Work with them to aggregate truckload quantities. There are opportunities to designate specific end markets if enough material is flowing through them. An interactive version of the map with additional site information can be found at https://nextcyclemichigan.com/mrfs-base-map.

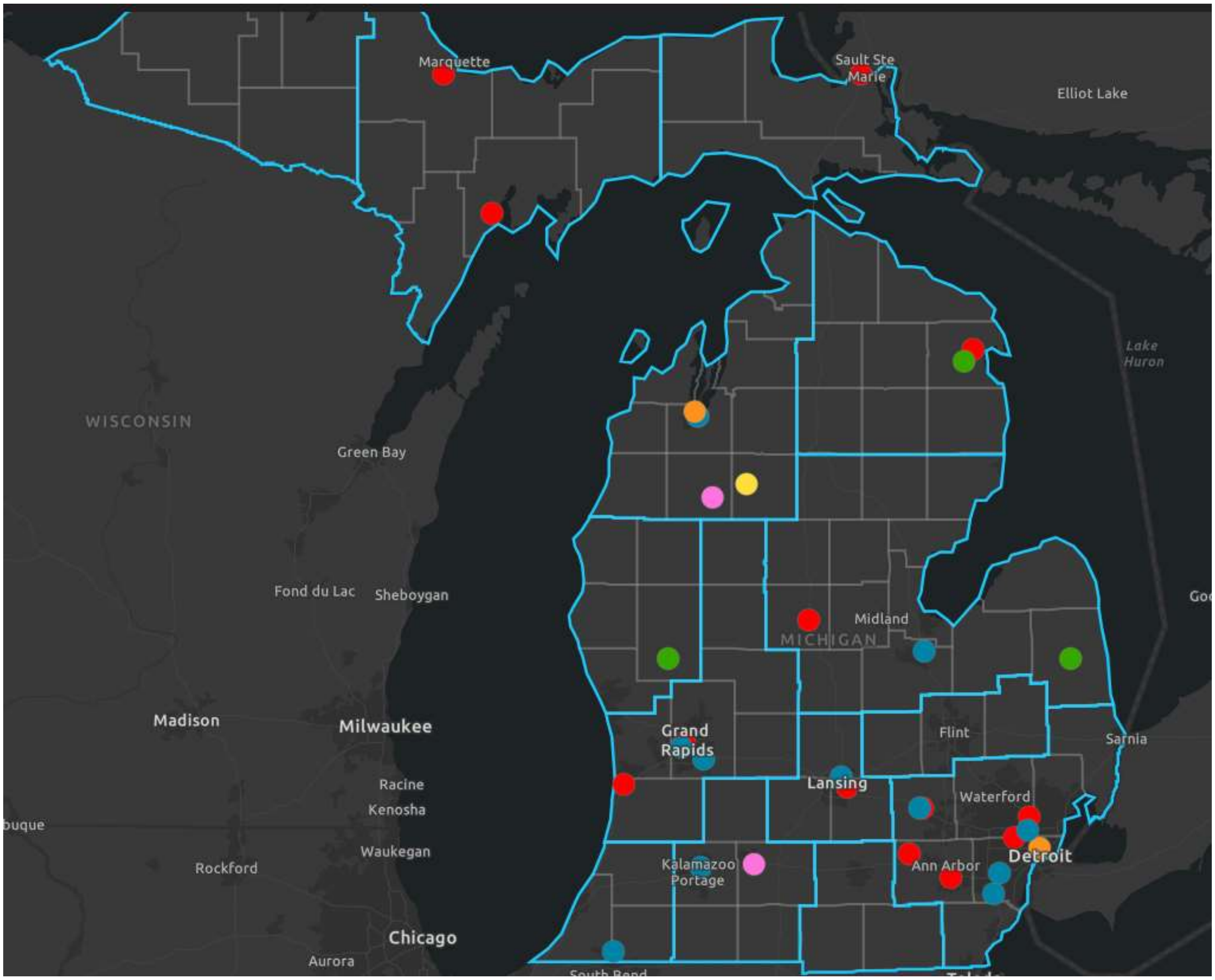

Figure 8. Potential Hub and Spoke Sites in Michigan

Michigan-based Mechanical Recycling Plastic End Markets

These sites are potential end markets for plastics that are source separated, such as end of life returnable containers or clear bags and wrap. An interactive version of the map with additional site information can be found at https://nextcyclemichigan.com/end-markets-base-map.

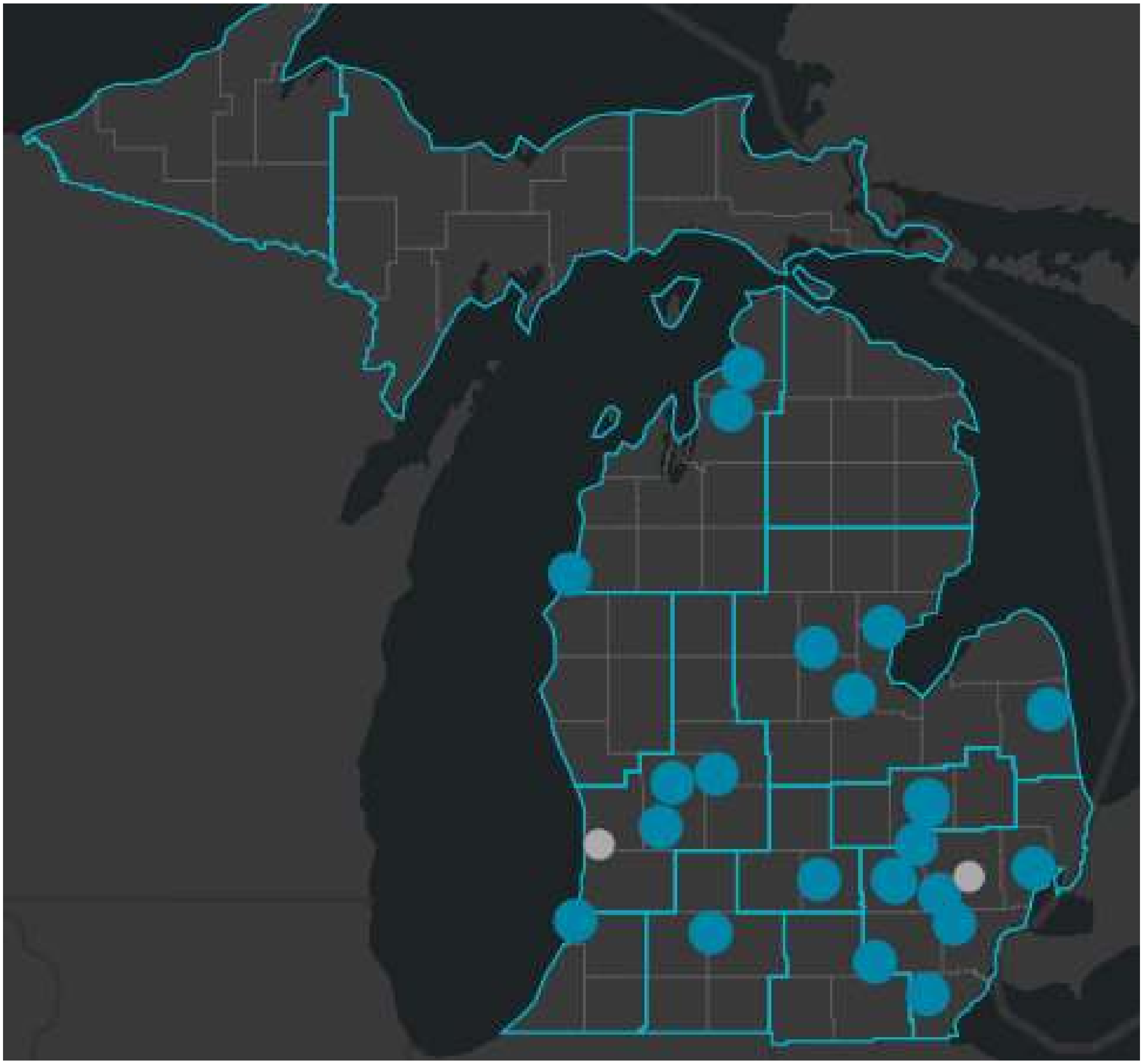

Figure 9. Michigan-based Mechanical Recycling Plastic End Markets

Additional Notable End Markets

Table 5. Additional Notable End Markets

NAME	LOCATION	RECYCLING TYPE	MATERIALS SOURCED
Green Processing Company*	Ontario, Canada	Mechanical Recycling	Rigid Reusable Containers
EFS Plastics	Ontario, Canada	Mechanical Recycling	Mixed Plastics
Alterra	Akron, Ohio	Chemical Recycling – Pyrolysis	Mixed Olefins
FreePoint Eco-Systems	Hebron, OH	Chemical Recycling – Pyrolysis	Mixed Olefins
Nexus Circular*	Atlanta, GA	Chemical Recycling – Pyrolysis	Mixed Olefins
Brightmark	Ashley, IN	Chemical Recycling – Pyrolysis	Mixed Olefins

*SP Members

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END NOTES

[i] RRS analysis of historical data from recyclingmarkets.net
[ii] 2023 MichAuto Mobility Report, https://michauto.org/automobility-asset-map/
[iii] https://napcor.com/wp-content/uploads/2020/05/LCA-2018-APR-Recycled-Resin-Report.pdf
[iv] Results are highly dependent on product being substituted, LCA model assumptions and methodology. Value quoted is based upon recycled PET to textile: https://www.sciencedirect.com/science/article/abs/pii/S0921344910001618
[v] Limited data as technologies are in early stages of maturity. Results are highly dependent on process and target resin, Values quoted are based upon data reported from an LCA of PureCycle's solvent based purification of PP process https://www.purecycle.com/blog/purecycle-releases-favorable-life-cycle-assessment-results-for-european-facility
[vi] Limited data as technologies are in early stages of maturity. Results are highly dependent on process, LCA methodology and target resin, Values quoted are based upon data reported from an LCA of Eastman's methanolysis process for PET. PRT Methanolysis LCA Summary Report.pdf (eastman.com)
[vii] Limited data on mature plastic to plastic pyrolysis. Results are highly dependent on modeling methodology, process yield and feedstock mix, baseline gird mix and alternative waste treatment
[viii] Meta Study on LCA of chemical Recycling, Sphera, 2023, Commissioned by BASF
[ix] These types of materials are often stored outside while aggregating truckload quantities.
[x] Assumes truck load volumes, baled , picked up, (800+lb bales for films)
[xi] Prices reflect market range for Chicago (Midwest/Central) as obtained from Recyclingmarkets.net on June 7, 2024,
[xii] No index pricing available, pricing typically quoted per project. Listed price based on interviews.
[xiii] RRS analysis of historical data from recyclingmarkets.net
[xiv] D5231 Standard Test Method for Determination of the Composition of Unprocessed Municipal Solid Waste https://www.astm.org/d5231-92r16.html