The APR Design® Guide for Plastics Recyclability is the most comprehensive resource outlining the plastics recycling industry’s recommendations in the marketplace today. The content is regularly updated to ensure APR’s Recyclability Categories represent today’s North American plastics recycling infrastructure. Although it is designed as an online resource, with links to all relevant information, a PDF of the complete document can be downloaded as well.

The APR Design® Guide specifically addresses plastic packaging, but the principles can be applied to all potentially recycled plastic items.

APR encourages package designers to utilize The APR Critical Guidance and Responsible Innovation programs, as well as the APR Design® Guide to create the most recyclable packaging. Assistance is available through APR or one of the APR member, independent laboratories found in the member directory.

The intended audience for the APR Design® Guide for Plastics Recyclability is the package design engineer for use in designing packaging that complies with the capabilities of the recycling infrastructure. Before accessing the APR Design® Guide for Plastics Recyclability the user should thoroughly understand the fundamentals of its concept as described in the scope, definition of recyclability and recyclability categories outlined below.

SCOPE

This guide covers plastic items entering the postconsumer collection and recycling systems most widely used in industry today. Collection methods include single stream and dual stream MRF’s, deposit container systems, mixed waste facilities, and grocery store rigid plastic and film collection systems. The impact of package design on automated sortation process steps employed in a single stream MRF, as well as high volume recycling processes is of primary consideration.

Items recovered in recovery systems where they are source-selected and sent to a recycler specializing in this particular item are specifically excluded from this guide.

APR’s DEFINITION OF RECYCLABLE

An item is “recyclable per APR definition” when the following three conditions are met:

- At least 60% of consumers or communities have access to a collection system that accepts the item.
- The item is most likely sorted correctly into a market-ready bale of a particular plastic meeting industry standard specifications, through commonly used material recovery systems, including single-stream and...
dual stream MRFs, PRF’s, systems that handle deposit system containers, grocery store rigid plastic and film collection systems.

- The item can be further processed through a typical recycling process cost effectively into a postconsumer plastic feedstock suitable for use in identifiable new products.

**APR’s RECYCLABILITY CATEGORIES**

The APR Design® Guide is itemized by design features commonly used with packaging applications. The recycling impact of each design feature is discussed within the Guide. The APR’s guidance on the design feature is developed considering this impact and broken down into four categories which should be thoroughly understood:

- **APR DESIGN GUIDE® PREFERRED**: Features readily accepted by MRFs and recyclers since the majority of the industry has the capability to identify, sort, and process a package exhibiting this feature with minimal, or no, negative effect on the productivity of the operation or final product quality. Packages with these features are likely to pass through the recycling process into the most appropriate material stream with the potential of producing high quality material.

- **DETRIMENTAL TO RECYCLING**: Features that present known technical challenges for the MRF or recycler’s yield, productivity, or final product quality but are grudgingly tolerated and accepted by the majority of MRFs and recyclers.

- **RENDERS PACKAGE NON-RECYCLABLE PER APR DEFINITION**: Features with a significant adverse technical impact on the MRF or recycler’s yield, productivity or final product quality. The majority of MRFs or recyclers cannot remove these features to the degree required to generate a marketable end product.

- **REQUIRES TESTING**: In order to determine compatibility with recycling, testing per an APR testing protocol is required.

**DISCLAIMER**

This document has been prepared by the Association of Plastic Recyclers as a service to the plastic industry to promote the most efficient use of the nation’s plastic recycling infrastructure and to enhance the quality and quantity of recycled postconsumer plastic. The information in this document is offered without warranty of any kind, either expressed or implied, including WARRANTIES OF MERCHANTABILITY OR FITNESS FOR A PARTICULAR PURPOSE, which are expressly disclaimed. APR and its members accept no responsibility for any harm or damages arising from the use of or reliance upon this information by any party. Participation in the Recognition Program is purely voluntary and does not guarantee compliance with any U.S. law or regulation or that a package or plastic article incorporating the innovation is recyclable or will be recycled.
BACKGROUND: Polylactic acid (PLA) is one of several structures and polymers using resin identification code (RIC) #7. PLA is typically used in applications requiring stiffness, resistance to cracking, clarity and ease of modification. It is easily formed into sheet and is thermoformable. PLA is often chosen as a packaging material because it is made from renewable resources and is compostable in an industrial composting facility. PLA properties can be enhanced with colorants, impact modifiers, and other additives. Each modification to base PLA must be considered for its effect on the recycling stream. This section of the Design® Guide applies to rigid PLA.

At this time, PLA collection systems are limited in North America so this material does not currently meet the collection accessibility criteria established in “APR’s definition of recyclable” or by the FTC https://www.ftc.gov/sites/default/files/attachments/press-releases/ftc-issues-revised-green-guides/greenguides.pdf. Anticipating the development and growth of future PLA recycling programs, however, the APR recommends the following guidelines.

BASE POLYMER

The use of postconsumer PLA content is preferred. Depending on the application, a blended recipe of post-consumer and post-industrial PLA is encouraged for products up to the maximum amount technically and economically feasible.

PLA and PLA resin variants which have a crystalline melting point between 140°C and 170°C are preferred. Flake from thermoformed parts, trim scrap, or cast sheet is amorphous. Flake from oriented film or oriented sheet will be a mixture of amorphous or crystalline fractions, while fibers like staple or spunbond are crystalline. Amorphous PLA flake requires drying at low temperatures (43-55°C) to prevent sticking in dryers. It is the process, the shape and degree of crystallinity, and the percentage of regrind that will determine if the recycled PLA material will need to be pre-crystallized prior to drying and melt extrusion. Recycling crystalline PLA material allows drying at temperatures in the range of 65-85°C. Non-crystallized resin and material with a lower melt point may become sticky in the reclaimer’s pre-extrusion dryer and could prevent the material from flowing through the process. Contaminant materials of a higher melting point remain solid in the reclaimers’ extruder, catch on and may cause blockages in melt screens and contamination in the final product.

The density of PLA is 1.24 g/cm³ and so it sinks in water.
BARRIER LAYERS, COATINGS & ADDITIVES

Non-PLA layers and coatings require testing to determine the appropriate APR recyclability category.
The use of non-PLA layers and coatings can be detrimental to recycling of PLA if not implemented according to
APR test protocols. Layers and coatings must either separate and be removed from the container wall in the
recycling process or have no adverse effects on the polymer in future uses. When used, their content should be
minimized to the greatest extent possible to maximize yield, limit potential contamination, and reduce
separation costs.

Test protocol: TBD

Additives require testing to determine the appropriate APR recyclability category.
The APR recognizes that other types of additives may be required for the performance of a particular package
but are not addressed in this document. Additives such as de-nesting, anti-static, anti-blocking, anti-fogging,
anti-slip, UV barrier, impact modifiers, stabilizer and heat receptor agents and lubricants should be tested to
determine their compatibility with recycling.

Test protocol: TBD

Optical brighteners are detrimental to recycling.
Like many other additives, optical brighteners are not removed in the recycling process and can create an
unacceptable fluorescence for next uses of the recycled polymer containing the brighteners. It is difficult to
identify material with this negative effect until extremely late in the recycling process where a great deal of
added cost has been imparted into a material of low value due to the additive.

COLOR

All non-dark colors are preferred.
As PLA recovery and recycling is in an early development stage and clear packaging applications are not an initial
target for recycled PLA, there is a wider tolerance for pigmented polymer than if a clear packaging application
was being pursued for this material. However, lighter colors will have more value and a compatibility with a
wider variety of end uses.

Colors with an L value less than 40 or an NIR reflectance less than or equal to 10 percent require testing to
determine the appropriate APR recyclability category.
NIR (near-infrared) sorting technology used in MRF’s and reclaimers is not capable of identifying many dark
polymers because the colorant absorbs light and manual sorting cannot distinguish one dark polymer from
another. Some dark shades may be detected by NIR but these must be tested to determine their sorting
potential. Other separation techniques such as float-sink cannot be employed since many dark polymers sink
with PLA. Therefore, dark packaging is considered a contaminant.

Benchmark Test: Evaluation of the Near Infrared (NIR) Sorting Potential of a Whole Plastic Article
DIMENSIONS

Size and shape are critical parameters in MRF sorting, and this must be considered in designing packages for recycling. The MRF process separates items by size and shape first, then by material. Screens direct paper, and similar two-dimensional lightweight items, into one stream; containers and similar three-dimensional heavier items into another stream; while broken glass and smaller but heavy items are allowed to drop by gravity to yet another stream, which may or may not be further sorted. Large, bulky items are typically manually sorted on the front of the MRF process.

**Items more two-dimensional than three-dimensional render the package non-recyclable per APR definition.** Aside from not being captured in the plastic stream, they cause contamination in the paper stream. Items should have a minimum depth of two inches in order to create a three-dimensional shape for proper sorting. This issue is unrelated to the polymer type. The APR encourages and anticipates developments in MRF design and technology to improve capture and recovery of thin plastics; however, at the current time this technology either does not exist or is not yet installed in the majority of MRFs.

**Items smaller than 2 inches in 2 dimensions require testing to determine the appropriate APR recyclability category.** The industry standard screen size loses materials less than two inches to a non-plastics stream, causing contamination in that stream, or directly to waste. These small packages are lost to the plastic recycling stream. It is possible that some small containers travel with larger ones when either the screens wrap with film or they are operated above their design capacity. Film wrapping reduces the effective size of the screen and over-running provides a cushion of large items on which the smaller items travel. The design guidelines use clean screens operating at their design capacity for the determination of the recyclability category. The APR anticipates and encourages technology development to improve the process of small package recovery but currently these items are not recovered.

**Test Protocol:** Evaluation of Size Sorting Potential for Articles with at least Two Dimensions less than 2 inches

**Items greater than two gallons in volume are detrimental to recycling.** Recycling machinery, particularly automatic sorting equipment, is not large enough to accept items larger than two gallons. Because larger containers jam the systems, most MRFs employ manual sortation before the automatic line to remove the large items. These items are recovered in a stream of bulky rigid containers that are sold and processed as polyethylene since the vast majority of bulky rigid items are comprised of this polymer. Other polymers either negatively affect or are lost by the polyethylene processing.

CLOSURES & DISPENSERS

PLA closures are preferred.
Since these are the same material as the target polymer they will be recycled with it and add to the material yield.

PLA PACKAGING
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Polypropylene and polyethylene closures are preferred.
Because these polymers float, they are most easily separated from the container in conventional separation systems. Additionally, the PLA recycling process may capture floatable polyethylene and polypropylene to create an ancillary stream of marketable material. Care must be taken when modifying the polyethylene or polypropylene to ensure the modifier does not increase the overall density to the point that it sinks.

Closure systems without liners are preferred.
Due to size and thickness, most liners are lost in the recycling process thereby slightly decreasing yield. Closures without liners do not experience this loss.

EVA and TPE liners in plastic closures are preferred.
Both EVA and TPE float in water and will be separated in the recycling process with the floatable polyethylene and polypropylene. Since EVA and TPE are compatible with these polymers, and in fact enhance their properties, they are preferred.

Closures containing metal or metal foils require testing to determine the appropriate APR recyclability category.
Metal is difficult to separate from PLA and adds both capital and operating costs to conventional reclamation processes. Even a small amount of metal left in the recycled PLA stream will block extruder screens in remanufacturing. Large metal items attached to PLA packages may cause the package to be directed to the metal or waste stream in the recycling process, causing yield loss. Small metal components such as spray dispenser springs unravel in the recycling process and blind screens, adding significant cost for removal at the end of the process.

Benchmark Test: Evaluation of Sorting Potential of Plastic Articles Utilizing Metal, Metalized or Metallic Printed Components
Definitive Test: Closure Test

Closures made from thermoset plastics are detrimental to recycling.
These materials are heavier than water and sink in the float-sink tank with PLA. They are extremely difficult to separate from the recycled polymer flake, requiring a costly and inexact polymer flake sorter currently not envisioned in the PLA reclaiming operation.

PET closures render the package non-recyclable per APR definition.
PET sinks in the float-sink tank with the PLA and is difficult to remove with other methods, thereby causing contamination in the final product. The recycled PLA process is very intolerable to even minute amounts of PET.

Closures containing silicone polymer are detrimental to recycling.
Silicone generally sinks in the float-sink tank with the PLA and is difficult to remove with other methods, thereby causing contamination in the final product.

The use of PVC closures or closure liners render the package non-recyclable per APR definition.
PVC sinks and is extremely hard for the recycler to remove. The recycled PLA stream is very intolerable to even minute amounts of PVC.
LABELS, INKS AND ADHESIVES

Removing adhesives is a significant component to the cost of recycling. The most recyclable packages use the lowest quantity of recycle-friendly adhesive. Lower adhesive usage reduces processing cost and potential contamination risk.

**PLA labels are preferred.**  
Since these are the same material as the target polymer they will be recycled with it and add to the material yield.

**PP or PE labels are preferred.**  
If a PLA label is not available or suitable, then PP or PE labels are preferred since they float in water and separated from the PLA in the float-sink tank with the closures. Since they are the same general polymer as most of the closures they do not contaminate or devalue this stream. Care should be taken to ensure that any modifiers to the label material do not increase its density above 0.95. Minimizing label size is advantageous to both processes.

**Laminated labels require testing to determine the appropriate APR recyclability category.**  
Labels that break into small, very thin pieces of material are more difficult to manage in the recycling process because they behave erratically in a float-sink tank. Therefore, labels that stay intact are preferred. Carry-over of delaminated labels into the recycled PLA can result in contamination.

**Test:** TBD

**Full container sleeve labels require testing to determine the appropriate APR recyclability category.** Full container sleeve labels cover a large amount of the container surface with a polymer that is not the same as the container body. Because of this, a sleeve label designed without considering recycling may cause a false reading on an automatic sorter and direct a PLA container to another material stream where it is lost to the process. Furthermore, some sleeve label materials cannot be removed in the recycling process and contaminate the RPLA produced. Sleeve labels that have been found compliant with the APR test protocols should be selected.

**Benchmark Test:** Evaluation of the Near Infrared (NIR) Sorting Potential of a whole Plastic Article

**Pressure sensitive labels require testing to determine the appropriate APR recyclability category.** Pressure sensitive labels generally require complete adhesive coverage which is greater than other typical label methods. This raises the importance of the compatibility of the type of adhesive with the recycling process. Adhesives resistant to washing in the recycling process allow labels to remain on the container and become contaminants in the final product. Adhesives that have been found compliant with the APR test protocols should be selected.

**Test:** TBD
Label structures that sink in water because of the choice of substrate, ink, decoration, coatings, and top layer require testing to determine the appropriate APR recyclability category.
Label components that sink with the PLA end up in the recycled polymer stream as contaminants.

**Test: TBD**

**High melting temperature plastic labels that sink in water are detrimental to recycling.**
High temperature melting plastic labels sink in the float sink tank remain solid in the PLA extruder. Such plastic labels are considered a contaminant to the RPLA stream and should be avoided. The recycled PLA process is very intolerable to even minute amounts of PET.

**Paper labels are detrimental to recycling.**
The PLA reclamation process may involve a wash that removes glue and other label components to the levels required to render the RPLA usable. Paper, when subjected to these conditions, becomes pulp which is very difficult to filter from the liquid, thereby adding significant load to the filtering and water treatment systems. Individual paper fibers making up pulp are very small and difficult to remove so some travel with the PLA. Paper fibers remaining in the RPLA carbonize when the material is heated and re-melted, causing quality degradation and a burnt smell to the polymer. Paper fibers could also cause quality issues, such as non-melted particles in the melt stream and final article. Non-pulping paper labels that resist the wash process sink in the float-sink tank, thereby causing RPLA contamination. These, although removed when the polymer is melt filtered, carbonize causing the same effect. (For pressure sensitive paper labels reference the pressure sensitive label category).

**Metal foil, metalized and metallic printed labels require testing to determine the appropriate recyclability category.**
Sorting equipment in the recycling process is designed to detect and eliminate metal from PLA. Even very thin metallized labels may be identified as metal by the sorting equipment and cause the entire package to be rejected as waste, thereby creating yield loss. If not detected, they pass through the process with the PLA and cause contamination issues in the final product.

**Benchmark test:** Evaluation of Sorting Potential for Plastic Articles Utilizing Metal, Metalized or Metallic Printed Components

**PVC labels render the package unrecyclable per APR.**
This material is extremely difficult to remove in the recycling process due to its similarity in density to PLA. The recycled PLA process is very intolerable to even minute amounts of PVC.

**Adhesives require testing to determine the appropriate APR recyclability category.**
Adhesives that wash off cleanly from PLA and remain adhered to the label are preferred. Label adhesive that is not removed from PLA, or which re-deposits on the PLA during the wash step, is a source of contamination and discoloration when PLA is recycled.
The recycling process is designed to remove reasonably expected contamination from the surface of the container to a degree necessary to render the polymer economically reusable in further applications. In practice, some adhesives are resistant to this process so are detrimental to recycling. In extreme cases, an adhesive and label cannot be separated from the PLA and may render a package not recyclable.

Test: TBD

Label inks require testing to determine the appropriate APR recyclability category. Some label inks bleed color in the reclamation process, discoloring the polymer in contact with them and may diminish its value for recycling. Label inks must be chosen that do not bleed color when tested under this protocol.

Test: TBD

Direct printing other than date coding requires testing to determine its compatibility with the recycling system. Historically, inks used in direct printing tend to bleed or otherwise discolor the polymer during the recycling process or introduce incompatible contaminants. In either case, the value of the recycled polymer may be diminished. Some inks used in direct printing do not cause these problems. The specific ink must be tested to determine its effect.

Test: TBD

ATTACHMENTS

PLA attachments affixed to PLA containers are preferred. Attachments made of the base polymer are recovered and recycled with the base polymer without causing contamination or yield loss, thereby generating the highest value.

Tamper evident sleeves and safety seals require testing to determine the appropriate APR recyclability category. If tamper resistance is required in specific product applications, it should be an integral design feature of the container. Unless the tamper sleeve is made of PLA, the use of tamper-resistant or tamper-evident sleeves or seals is discouraged as they can act as contaminants if they do not completely detach from the container or are not easily removed in conventional separation systems. If non-PLA sleeves or safety seals are used, they should be designed to completely detach from the container, leaving no remains on the bottle. The material used should float and separate from the PLA in the float-sink system.

Test: TBD
Non-PLA attachments such as handles require testing to determine the appropriate APR recyclability category. These should not be adhesively bonded to the package and should readily separate from the package when ground. They should be made from materials that float in water such as PP or HDPE. If adhesives are used to affix attachments, their selection should consider the adhesive criteria within this document.

Test: TBD

Metal and metal containing attachments require testing to determine the appropriate APR recyclability category. Examples include metal foils and metalized substrates that sink in water. In the recycling process these items are either identified and removed along with their PLA component in the early stages, thereby causing yield loss, or they pass into the recycling process causing a contamination issue. Since they are heavier than water they sink with the PLA in the float-sink tank. Many of these items are too small to be removed with machinery designed to remove metal such as eddy current and optical separators.

Benchmark Test: Evaluation of Sorting Potential of Plastic Articles Utilizing Metal, Metalized or Metallic Printed Components

Paper attachments are detrimental to recycling. The PLA reclamation process may use a wash to remove glue and other contaminants to the levels required to render the RPLA usable. Paper, when subjected to these conditions, becomes pulp which is very difficult to filter from the liquid, thereby adding significant load to the filtering and water treatment systems. Individual paper fibers making up pulp are very small and difficult to remove so some travel with the final polymer. Paper fibers remaining in the RPLA carbonize when the material is reused causing quality degradation.

Welded attachments are detrimental to recycling. A certain amount of a welded attachment cannot be separated from the main polymer in the recycling process. These attachments, even when ground and made of floatable materials, cause contamination and yield loss issues in both cases: when the PLA they are attached to causes the ground section containing both polymers to sink, or when the ground section floats.

RFID's (radio frequency identification devices) on packages, labels or closures are detrimental to recycling. Unless they are compatible with PLA recycling and are demonstrated not to create any disposal issues based on their material content, the use of RFID's is discouraged as it limits yield, introduces potential contamination, and increases separation costs.

PVC attachments of any kind render the package non-recyclable per APR. The use of PVC attachments of any kind on PLA packaging is undesirable and should be scrupulously avoided. This includes thermoforms of PVC that may be visually confused with PLA thermoforms. Very small amounts of PVC can severely contaminate and render large amounts of PLA useless for most recycling applications. In
addition, PVC is very difficult to separate from PLA in conventional water-based density separation systems due to similar densities (densities greater than 1.0) that cause both to sink in these systems.

**PET attachments of any kind affixed to a PLA container render the package non-recyclable per APR.** The use of PET attachments of any kind on PLA packaging is undesirable and should be scrupulously avoided. Very small amounts of PET can severely contaminate and render large amounts of PLA useless for most recycling applications. In addition, PET is very difficult to separate from PLA in conventional water-based density separation systems due to similar densities (densities greater than 1.0) that cause both to sink in these systems.

**RESIN IDENTIFICATION CODE, RIC**

PLA currently falls under the #7 category in the Resin Identification Code. In addition to the #7 appearing on the package, the letters “PLA” are encouraged to help in identifying PLA in the mixed plastics recycling stream. The symbol and lettering should be of the proper size as detailed in ASTM D7611 is encouraged.