Guide to Recycled Plastics for Packaging, Part II – Sourcing & Qualification

This guide aims to empower brands and their suppliers with the knowledge necessary to replace virgin fossil plastic in their packaging with recycled plastic.

The ultimate goal of the guide is to advance the use of recycled plastics in packaging in order to reduce demand for virgin fossil plastics.

GUIDE

PACKAGING DESIGN

SPC's Mission

The Sustainable Packaging Coalition is a membership-based collaborative that believes in the power of industry to make packaging more sustainable. As the leading voice on sustainable packaging, we are passionate about creating packaging that is good for people and good for the environment.

Our mission is to bring packaging sustainability stakeholders together to catalyze actionable improvements to packaging systems and lend an authoritative voice on issues related to packaging sustainability.

SUSTAINABLE PACKAGING COALITION®

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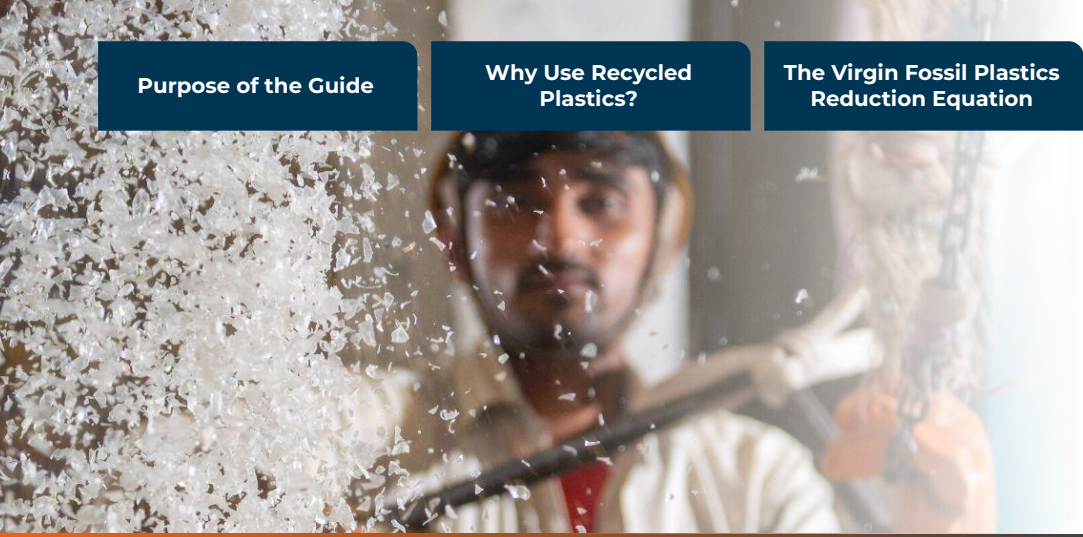


The “Why”

Purpose of the Guide

This guide aims to empower brands and their suppliers with the knowledge necessary to replace virgin fossil plastic in their packaging with recycled plastic.

The ultimate goal of the guide is to advance the use of recycled plastics in packaging in order to reduce demand for virgin fossil plastics.

Why Use Recycled Plastics?

OUR ECONOMY MUST MOVE AWAY FROM DEPENDENCE ON FOSSIL EXTRACTION.

Most plastic (including plastic packaging) is currently made from fossil sources. In fact, according to the U.S. Department of Energy's 2023 Strategy for Plastics Innovation, *98% of plastic packaging is made from fossil feedstocks.*

It's imperative to reduce the production of "virgin" plastic from fossil sources. Aside from elimination, there are two strategies to move away from fossil sources for plastic: biobased plastics and recycled plastics.

Total Plastic Used − **Recycled Plastic** − **Biobased Plastic** = **Virgin Fossil Plastic**

1. Reduce Overall Plastic	2. Reduce Virgin Plastic	3. Reduce Fossil Plastic
Legislation such as California's SB 54 calls for source reduction (or absolute reduction) of plastic use.	The Ellen MacArthur Foundation Global Commitment tracks progress of its signatories to reduce virgin plastic use, including both absolute reduction and use of recycled plastics.	Biobased plastics are most likely virgin materials but they do reduce demand for fossil feedstocks.

The SPC encourages all three of these actions, in this order, to reduce the use of virgin fossil plastic in packaging.

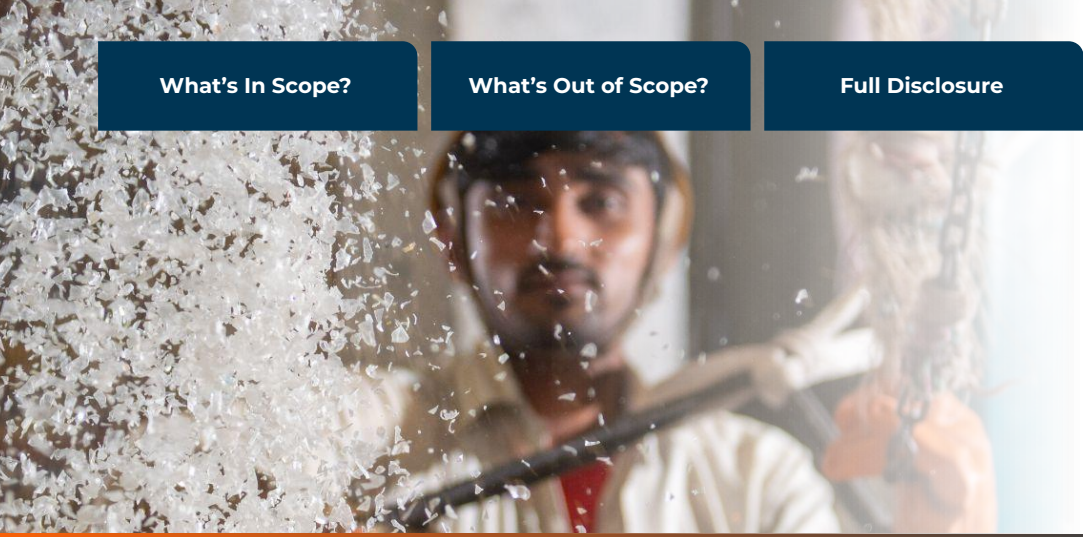
1. Reduce overall plastic
2. Reduce virgin plastic
3. Reduce fossil plastic

More Reasons Why

The primary reason to use recycled plastics is to reduce the demand for fossil feedstocks. And there are several more good reasons beyond that!

Recycled plastics often bring environmental benefits over the equivalent virgin plastics, such as reduced embodied energy and carbon emissions from manufacturing. Waste plastic that is made into new products and packaging is prevented from becoming air, land, or water pollution.

Using recycled materials is also becoming more than a business strategy or voluntary sustainability target: increasingly, it's a legal requirement. It is recommended that companies proactively take steps to use more recycled plastics in packaging than required.



The "What"

What's in Scope?

This guide focuses on issues and opportunities related to incorporating recycled plastics into new packaging.

This guide addresses the following areas:

- sourcing considerations based on supply chain roles;
- recycled plastic quality, performance, and suitability for different packaging applications, including food contact applications;
- methods for tracking recycled plastic through the supply chain in order to make substantiated sustainability claims; and
- policy covering recycled plastics, such as recycled content minimum requirements.

The geographical scope of the guide is centered on the United States, although some global examples are included for additional context.

What's Out of Scope?

Goal setting, material selection, and life cycle assessment (LCA) should happen before embarking on efforts to introduce recycled content into plastic packaging, so these topics are out of scope for the guide.

To get ready to make the most of this guide, SPC specifically recommends that you:

1. Set sustainability goals for your packaging portfolio, and establish baselines according to those goals.
2. Using LCA and packaging performance tools, select the base packaging material to be used for each product or application in your portfolio.

Why should material selection happen ***before*** any efforts to incorporate recycled content?

Research from the Oregon Department of Environmental Quality indicates that the level of recycled content is not a good indicator of sustainability or relative "greenness" when comparing across different material types. However, once a material has been selected, increasing the amount of recycled content "almost always reduces overall environmental impacts."

1. This guide is not legal advice. It is intended as a starting point on what you need to know about using recycled plastics in packaging. Although the guide touches on issues of compliance, it is the responsibility of each company to conduct their own due diligence and understand their own legal obligations.

2. Examples of specific companies or brands using recycled plastics in their packaging are drawn from the respective company/brand websites and/or associated articles and announcements. They are not independently audited or verified by SPC.

3. Lists or examples of suppliers (of resins, additives, packaging materials, technologies, etc.) included in the guide are not comprehensive, nor are they an endorsement of the companies mentioned.

This is Part II of a three-part guide on recycled plastics in packaging. Part II dives into recycled plastics quality, processing, and material health considerations, including resin-specific information. The two remaining parts cover high-level tips for using recycled plastics and the policy and certification landscape.

Understand “Fit for Use” for the Relevant Packaging Formats and Applications

The “How”

Understand “Fit for Use” for the Relevant Packaging Formats and Applications

Due to the diversity of plastic packaging materials and formats as well as the variety of companies involved in getting plastic all the way from diversion from the waste stream to incorporation in new packaging, it is not possible to address or provide specific guidance on all scenarios. This section provides a starting point for you to think through the quality requirements for the applications in your packaging portfolio and where and how recycled plastics might meet those requirements.

Fit for Use Checklist

1. **What are the quality and performance requirements for the application?**
    a. How is the package manufactured, and what is an appropriate melt flow or intrinsic viscosity for that manufacturing process?
    b. Will the package be in direct contact with food or beverages? If so, has your supplier obtained a no objection letter, and if so, what are the conditions of use? What other information can they provide about the source of the material, decontamination steps, and testing conducted?
    c. How strict are color, clarity, or other aesthetic demands?
2. **Are there any recycled content mandates for this packaging format?**
    a. Is your company considered a producer in any of the regions where a recycled content mandate exists?
3. **Does your company have sustainable sourcing goals or voluntary commitments to recycled material targets?**
    a. Does your purchasing policy include a certification component?

Plastics Quality & Specifications

Topics covered in this section:

- What factors impact the quality of recycled plastics?
- Fit for use recycled plastics
- Specifying and qualifying recycled plastics

The quality of plastics—that is, their appearance, their processability, their durability, their flexibility or rigidity, and their eventual degradation—depends on the molecular structure of the plastics. The molecular structures of virgin plastics are diverse. Plastics can be customized to an extreme degree, which is what makes them useful in such a wide range of applications.

Recycled plastics are also diverse and widely useful, even though they are often different from virgin plastics. Understanding where the differences arise among plastics can help you identify which sources of recycled plastic will be able to provide material suitable for your company's packaging.

What Factors Impact the Quality of Recycled Plastics?

Different types of plastic resin (different polymers) have different properties, but chemical identity of a resin is not the only thing that dictates its properties or performance. On a material science level, there are two main factors that distinguish recycled plastics from virgin fossil plastics: **molecular weight distribution** and **additive mixture.**

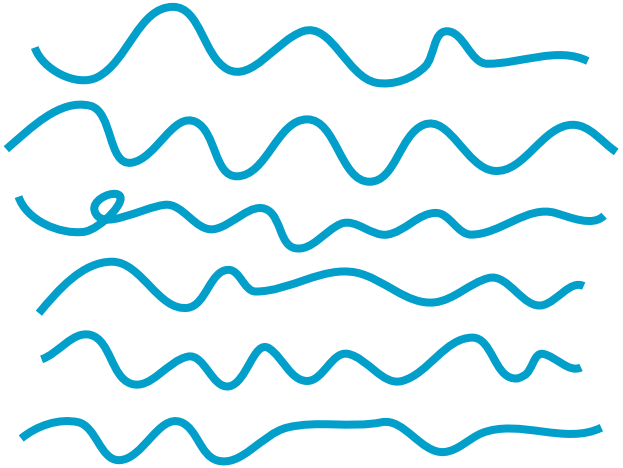
The processes used to sort, clean, and recycle plastic determine how much the molecular weight distribution and the additives present will affect the quality of recycled plastic and how similar the recycled plastic will be to virgin plastic.

Impacts on Quality: Molecular Weight Distribution

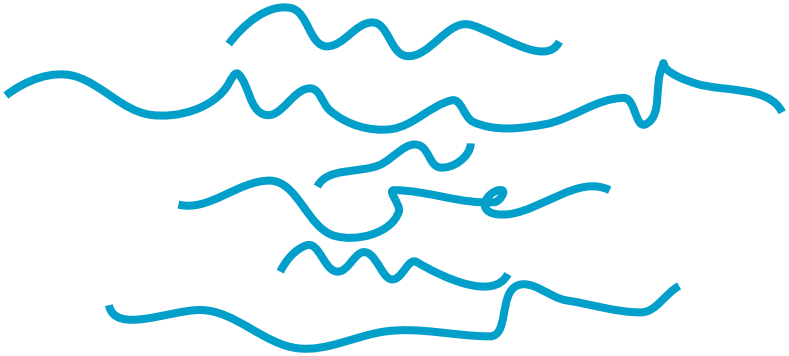
Plastic made from virgin fossil sources is produced under carefully controlled conditions. Typically the polymer chains in a batch of virgin plastic all have a very similar length. Different batches of plastic will have different average chain lengths, or molecular weights, tailored to different end uses. Molecular weight determines the viscosity and melt flow of a plastic resin.

Recycled plastic is a mixture from different batches of virgin plastic with different histories. There can be a wide range of chain lengths present in one batch of recycled plastic, and the plastic's melt flow will depend on the composition of the incoming material stream. Plastic recyclates also exhibit varying degrees of polymer degradation, including chain length reduction and polymer cross-linking, caused by repeated exposure to heat (such as during manufacturing and recycling), UV light, and other external factors. Wide spec virgin resin—when a batch of resin is off from its target molecular weight or some other parameter—is still more consistent than recycle.

A batch of virgin plastic has a relatively consistent polymer chain length or molecular weight.



Recycled plastic has a mixture of polymer chain lengths depending on its source.



Impacts on Quality: Additive Mixture

When virgin plastics are made, there are tens of thousands of different additives that can be added along the way, including performance additives and processing aids. In virgin plastics, additives are tailored to the end use. In recycled plastics, these additives create a mixture with unknown composition. Additives may react with or interfere with each other, affecting the performance and processing of recycled plastics.

- processing aid
- additive for heat resistance (food grade)
- additive for chemical resistance (non-food grade)
- clarifier (food grade)
- clarifier (non-food grade)
- colorant

Impacts on Quality: Recycling Process

Regardless of recycling process, the level of uniformity of incoming plastic (both material and format) dictates how well recycling will work.

For best results, the stream of plastic coming into mechanical recycling should have similar melt flow and other properties. For instance, an incoming stream of exclusively bottles can be made into new bottles more easily than an incoming stream of mixed formats. Mechanical recycling cannot remove additives, although some additives may degrade or be volatilized under recycling conditions.

Purification technologies can remove additives but cannot change the molecular weight of recycled plastics. Sorting feedstocks into consistent streams allows recycled plastic outputs to retain the physical properties associated with their initial uses.

Depolymerization and conversion technologies can each remove additives and reprocess multiple formats with different molecular weights together. New batches of plastic with the desired molecular weight are then made from the monomers or base chemicals that are the initial outputs of these processes.

Example of Effects of Material Source

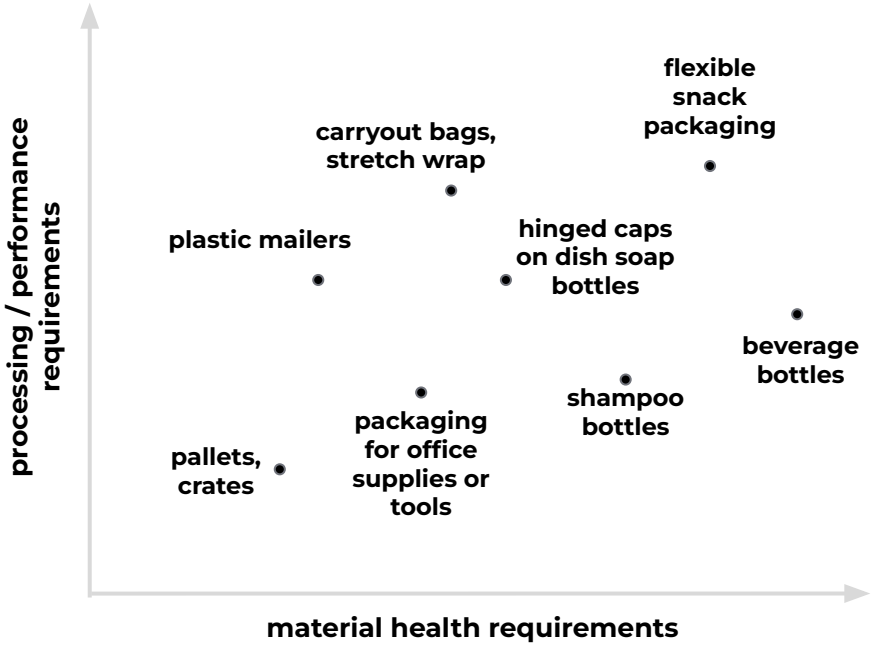
Even using the same recycling process, characteristics of the output material may differ depending on the material's source. Here, large variations in color are visible among six batches of mechanically recycled rPET from different sources. Note that pellet color is not necessarily representative of the color of a processed item, in this case molded plaques.

Fit for Use Recycled Plastics

Because virgin fossil plastic is the status quo, often people assess the quality of recycled plastic based on how its attributes compare to the attributes of virgin resin. An expectation that recycled plastic will match virgin resin on every parameter will make sourcing recycled plastic extremely challenging. Luckily, not every test result needs to be identical to the virgin resin result for a recycled plastic to be fit for use.

Fit for use for recycled plastics means finding a balance in terms of material quality so that packaging performance is maintained but over-specification and over-engineering are avoided. Performance in the desired application is more important than a recycled plastic stream's individual attributes.

Work to understand which minimum specifications are critical to performance, as well as which attributes or inconsistencies can lead to performance issues. Your packaging suppliers can help you determine fit for use.



Fit for Use Examples

There's no single definition of "good quality" or "high quality" plastic, because packaging requirements vary by application.

From a sustainability standpoint, the most important measure of material quality is whether a package can maintain performance. In other words, "high quality" plastic is plastic that is fit for use.

Fit for use can be approximated by considering material health and processing/performance requirements. For example, compared to rigid packaging, flexible packaging is more susceptible to a low level contaminant causing mechanical failure, so the processability requirements for flexibles are higher. Compared to a poly bag for clothing, a rigid tray that comes in contact with food has lower processability requirements but higher importance on ensuring low levels of any hazardous contaminant.

Recycled Plastics in Reusable Packaging

Switching from single-use packaging to reusable packaging is often thought of as a separate goal from using recycled content, but progress toward both can happen together! Especially since reusable packaging needs to be durable enough withstand repeated uses, it can be a great fit for recycled plastics as processing is typically easier for rigid, thick-walled structures.

Examples of recycled plastics being incorporated into reuse and refill packaging models include:

- Refillable Dove deodorant sticks (Unilever) are made with 98% rPP.
- Bio-D refillable home care product bottles made by Berry Global are 100% PCR rHDPE.

Specifying & Qualifying Recycled Plastics

The plastics supply chain is complex, including for recycled plastics. Not only are distinct players involved for each plastic resin, the relationships between buyers and their suppliers vary based on application, location, volume, and other factors.

Additionally, each company involved in plastic recycling for packaging typically has its own specifications for the quality of incoming material it will accept as well as its own quality metrics for its products, making it difficult for buyers to compare quality across suppliers and for suppliers to find new markets. Industry harmonization of specifications for recycled plastics at different stages of the supply chain is an ongoing need.

Material Pathways and Specifications

Material collected for recycling may reenter the supply chain either through MRFs (sometimes accompanied by secondary sortation at PRFs) or through other collection mechanisms such as deposit return programs, store drop-off, take-back programs, and commercial partnerships.

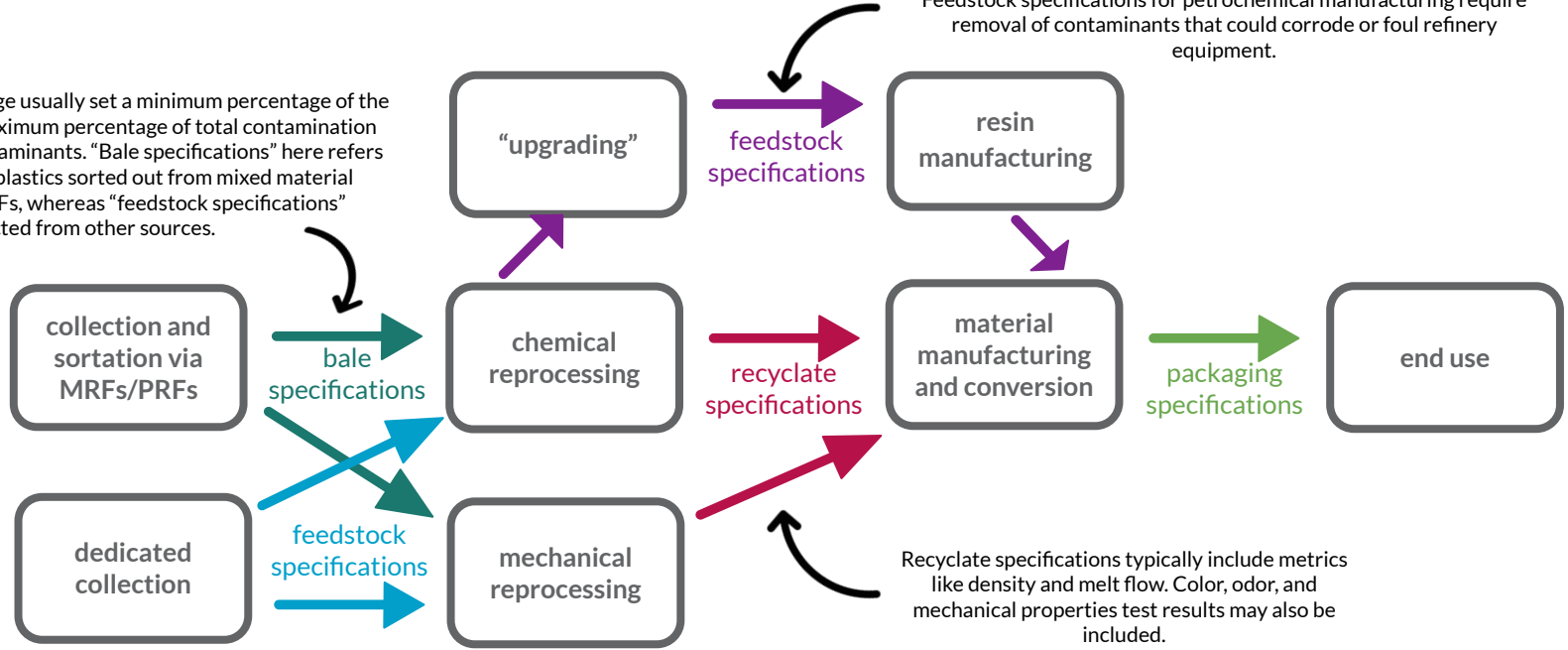
The collected and sorted material may enter either mechanical or chemical reprocessing. Mechanical and chemical reprocessors may produce recyclate that feeds directly into material manufacturing and conversion for new packaging.

In instances where chemical reprocessing produces chemical intermediates rather than recycled resin, these intermediates may be sold to petrochemical companies and integrated into existing resin manufacturing processes. Sometimes an “upgrading” step is required to remove contaminants to meet the feedstock specifications of these petrochemical companies.

Feedstock specifications for petrochemical manufacturing require removal of contaminants that could corrode or foul refinery equipment.

Specifications at this stage usually set a minimum percentage of the target material and a maximum percentage of total contamination and/or of particular contaminants. “Bale specifications” here refers to quality guidelines for plastics sorted out from mixed material streams at MRFs and PRFs, whereas “feedstock specifications” applies to material collected from other sources.

This figure illustrates the interplay of feedstock specifications along common plastic recycling pathways.



Recyclate specifications typically include metrics like density and melt flow. Color, odor, and mechanical properties test results may also be included.

Finding Suppliers

Brands wanting to source recycled plastics for packaging may buy directly from recyclers/reprocessors, from resin suppliers offering resin grades with recycled content, or from packaging material manufacturers or converters that have purchased recycled plastics.

Resources and tools to help with finding suppliers include:

- The RMS Certificate Database
- U.S. Plastics Pact's list of recyclers and reclaimers
- APR's directory of PCR suppliers
- Stina's Plastics Markets supplier search
- Circular's PCR marketplace
- Plastics News lists of plastics recyclers/brokers and compounders

For food grade plastic, the U.S. FDA maintains a database of companies that have received no objection letters. Keep in mind that no objection letters are voluntary and not applicable to all recycling technologies and that not all "food grade" plastic is equal quality.

Qualifying Recycled Plastics

Information provided on technical data sheets such as melt flow, density, color, moisture level, and mechanical properties gives some insight into how a material will perform, and an experienced supplier can help with interpreting this information. However, trialing the material is the ultimate indicator of performance as well as any process changes that may be needed.

Qualifying recycled plastic requires decisions about what changes suppliers and end users are willing to make to accommodate any differences in the material. For example, if a recycled plastic stream is more brittle than its virgin counterpart, are the companies involved willing to consider redesigning molds to minimize stress on areas prone to cracking? Recycled plastic may also introduce differences that are aesthetic in nature rather than having an impact on packaging performance. In these instances, are brands able to tolerate color variations or off-white material? Would slowing down production and increasing filtration to reduce inclusions in film packaging be preferable, or can customer expectations about film aesthetics and the acceptable level of inclusions be managed? There is no right answer to these questions, and every company or brand must decide for themselves how to manage trade-offs and what constitutes fit for use.

Sourcing & Qualification Checklist

1. **How much recycled material will you need to meet legislative mandates and your company's goals?**
   a. Do you have access to an assured supply? Will you need to qualify multiple sources?
2. **Onboarding a new supplier or material**
   a. Ask the supplier how they maintain quality and consistency from batch to batch
   b. Ensure you have access to the relevant data sheets and/or certificate of analysis
   c. Get assurance from your supplier about the source of the material and the processing steps it has been through, or conduct your own audits to confirm
3. **Ongoing auditing**
   a. Material streams can change over time, so make sure that resins as well as finished packaging items are tested on a regular basis

Material Health & Food Grade Recycled Plastics

Topics covered in this section:

Packaging that does not touch food

Packaging that touches food

Material health is a fundamental tenet of circularity. Ideally, hazardous substances should be eliminated in the design phase, so that all materials in use can safely circulate multiple times. Currently, however, tens of thousands of substances are used in plastics manufacturing, some with known health concerns and many others with little to no data on their hazard profiles. It's important that any hazardous substances present do not contaminate new products through recycling. Material health should be considered for all packaging, but it is especially pertinent when recycled materials are used in food contact packaging.

Packaging That Does Not Touch Food

Material health is an important consideration when using recycled plastic in any application, especially for consumer goods. Unfortunately, there is no industry standard for what constitutes safety for recycled plastics. “Food grade” is sometimes used as a proxy for generally high quality plastic; however it’s important to recognize that guidance on recycled plastics from the U.S. FDA (and analogous agencies in other countries) only applies to packaging that directly comes in contact with food intended for human consumption. Applications such as secondary and tertiary food packaging and packaging for personal care products, cleaning and household products, and even pet food don’t necessarily have the same material health requirements as (human) food contact packaging.

Best Practices for Non-Food Contact Recycled Plastics

Food grade plastic is in short supply, so use it where it's needed.
If you have been using food grade recycled plastic for aesthetic reasons such as color and clarity, seek out material that meets your aesthetic requirements but is not food grade.

Testing: the more the better.
Every batch of recycled plastic has different contaminants at different levels. Ask your supplier for information on the types of testing they have conducted and how frequently they test their incoming materials or outgoing products. Your company may want to conduct additional internal testing. Ultimately the level of testing that will satisfy your company's requirements is a company-by-company decision based on the intended applications and an assessment of risk.

Packaging That Touches Food

Much of the plastic that is currently recycled was initially food safe material. There are two main ways that hazards can be introduced into the recycled plastics stream and make it unsuitable for food contact uses. First, contaminants may come from plastics or additives that were never initially intended for food contact. For example, plastics used in electronics often contain hazardous additives such as brominated flame retardants, and while the plastic resins in these products may be able to be recycled, these sources of plastic would be contaminants in recycled plastics meant for food contact. Second, food-safe plastics can be contaminated by consumer use cases. For example, a consumer may store pesticides, cleaning products, or motor oil in a repurposed plastic container and later place the empty container in the recycling. While chemical recycling processes can remove additives, mechanical recycling relies on careful source control, sorting, and/or cleaning to produce food safe recycled plastics. Suitability of recycled plastics for food contact applications can be determined by carrying out testing based on the intended conditions of use.

Key Concept: Conditions of Use

Conditions of use for a package refers to package filling and storage conditions as well as the type of food that will be contained in a package. The various resins and additives that make up plastic packaging have unique chemical properties, and each combination will respond differently to different circumstances. For example, a material that works well for room temperature filling and short-term storage may not be suitable for retort packaging or long-term storage. Likewise, packaging meant for acidic liquids will have more demanding requirements compared to packaging for dry foods.

Examples of Food Types and Conditions of Use

refrigerated storage / frozen storage

ready-prepared foods intended to be reheated in container

hot filled or pasteurized

moist bakery products

acid, aqueous products

dry solids

Testing for Food Contact Suitability

Challenge testing (also called surrogate contaminant testing) is meant to demonstrate that a recycling process can successfully remove contaminants originating from consumer use. Challenge testing involves:

1. *intentionally contaminating virgin plastic with "surrogate" contaminants that represent a range of the types of chemicals that could be found in consumer products, and*
2. *subjecting the contaminated plastic to a cleaning and recycling process to determine whether any residual contamination remains in the recycled plastic.*

After recycling, if contamination in the plastic exceeds acceptable levels, then alternative ways to use the plastic in food contact applications include blending it with virgin plastic to dilute the contamination, restricting the conditions of use of the final package, or putting a barrier layer between the recycled plastic and package contents. Effectiveness of a barrier layer between recycled plastic and food can be determined via **migration testing** following the same procedures used for demonstrating the safety of other food contact substances. Migration testing can also be used to show that even if recycled plastic is contaminated, the contaminants will not enter food to any substantial degree.

Better Sorting Bolsters Supply of Recycled Plastics for Food Contact Packaging

Sorting Issue	Technologies & Innovations	Examples
Most material recovery facilities (MRFs) sort out only a few types of plastic based on resin and color, and they are not equipped to sort out food packaging from non-food plastic packaging. However, a feedstock stream that is exclusively food packaging is often one of the requirements for producing recycled plastics for food contact applications.	*Technologies such as artificial intelligence (AI) and digital barcoding are being implemented in sorting to increase the supply of recycled plastic for food contact applications. Digital barcoding allows sorting by SKU, enabling food packaging to be sorted immediately from non-food packaging. Artificial intelligence systems can be trained to recognize a range of packaging attributes to sort plastics more precisely or to remove contamination.*	• Digimarc digital watermarking system • AMP Robotics AI sortation

Best Practices for Food Contact Recycled Plastics

Understand what a no objection letter is and isn't.
Not all "food grade" plastic is equal. Pay attention to the processing and storage conditions listed in no objection letters. Consider a no objection letter as a first step, not a final assurance of safety.

Testing: the more the better.
Every batch of recycled plastic has different contaminants at different levels, which is why challenge testing uses virgin plastic contaminated with known substances instead of an actual specific batch of recycled plastic. Still, testing the actual material in question is also useful. Ask your supplier for information on the types of testing they have conducted and how frequently they test their incoming materials or outgoing products. Your company may want to conduct additional internal testing. Ultimately the level of testing that will satisfy your company's requirements is a company-by-company decision based on the intended applications and an assessment of risk.

Remember that not all recycled plastic has the recycled content physically present.
If sourcing the right quality of recycled plastic is an issue, look for certified recycled plastics where the mass balance accounting method is used.

Processing Issues & Innovations

Topics covered in this section:

- Non-target polymer contamination
- Melt flow & viscosity
- Color
- Additives & contaminants

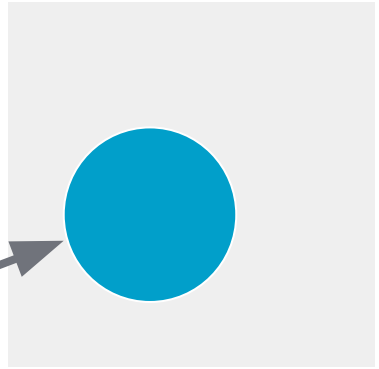
Issues that can be detrimental to recycled plastic processability or suitability for desired applications include contamination from other types of polymers, unsuitable or inconsistent melt flow, unwanted color, and contamination from additive degradation or other sources. This section summarizes these issues and provides examples of the technologies and innovations on the market to combat these issues.

Non-Target Polymer Contamination

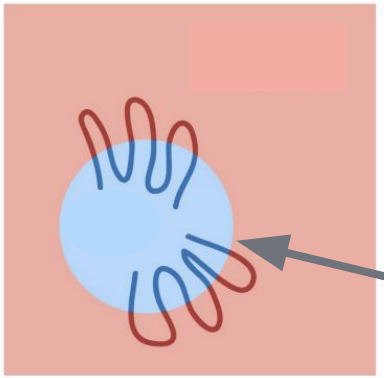
Processing Issue	Technologies & Innovations	Examples
Even low levels of non-target polymer, such as PP or PET contamination in a recycled PE stream, will lower mechanical toughness and increase brittleness. Although different polymers may be able to be physically mixed, they will not mix completely on a molecular level. The interfaces between microscopic area where the polymers haven't mixed together are where mechanical failures often occur.	Compatibilizers are polymers or other molecules that have an affinity for both the main material and the low-level contaminant material. Compatibilizers bridge the interfaces between different types of polymers that otherwise won't mix together completely. The same approach can be used to adhere materials that otherwise would not stick together. Compatibilizers are especially important for maintaining mechanical properties of recycled polyolefins.	• Dow compatibilizers: RETAIN for PE/EVOH, INTUNE for PE/PP • Kraton multi-resin compatibilizers

How Does Compatibilization Work?

weak interface between different materials is susceptible to mechanical failure



without compatibilizer



with compatibilizer

interface between different materials is strengthened by compatibilization

Melt Flow and Viscosity

Processing Issue	Technologies & Innovations	Examples
Different formats (bottles, thermoforms, tubs, pouches, etc.) and manufacturing methods (extrusion, blow molding, injection molding, etc.) have different requirements, most notably melt flow or viscosity.	In some cases viscosity modifiers can be used to adjust melt flow or viscosity. Process conditions can be changed to some degree to accommodate the incoming material stream.	• iMFLUX inline adjustments for injection molding

Color

Processing Issue	Technologies & Innovations	Examples
Not only does color influence the aesthetics of recycled plastic, high levels of colorant can also change the density and processability of a resin. For clear or natural plastics, yellowing over multiple heat cycles is another concern.	Brighteners, clarifiers, and toners can help diminish unwanted coloration and/or haze of recycled plastics. Other additives can prevent yellowing. Inline monitoring can improve color consistency.	• Avient rPET toners • REPI rPET anti-yellow additives • Milliken PP clarifiers • Ampacet inline color measurement

Examples of Yellowing in Recycled Plastics

Heat history, UV light exposure, additives, and contaminants all affect the degree of yellowing in recycled plastics. Yellowing may be associated with increased brittleness. Yellowing is more visibly pronounced in thicker items.

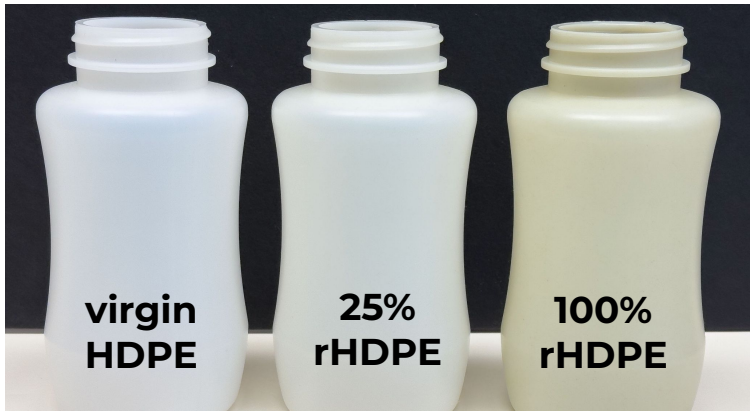


image courtesy of PTI

image courtesy of PTI

Additives & Contaminants

Processing Issue	Technologies & Innovations	Examples
The breakdown of additives, non-intentionally added substances, and/or contaminants such as paper labels can cause odors, defects, and issues with processing equipment.	Performance additives such as antioxidants can prevent degradation. Otherwise, equipment and process upgrades including filters, improved sorting and washing processes, and devolatilization are employed to deal with odor and contamination.	• Baerlocher chemical stabilizers • Gneuss devolatilization extruder • Fraunhofer Institute rHDPE odor extraction • CEFLEX quality recycling process

Resin and Format-Specific Considerations

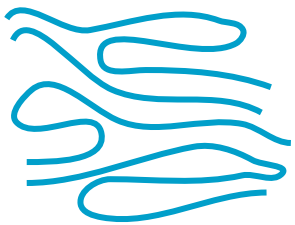
Topics covered in this section:

- Recycled polyolefins (PE & PP)
- Recycled PET

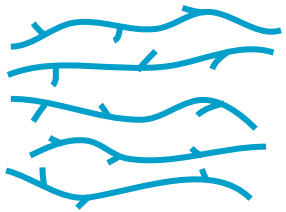
The ability to use recycled content varies by plastic resin, due to technical differences as well as market dynamics. Plastics that are recycled at lower levels will not be sorted into multiple streams or grades, whereas higher volume recycled plastics have more options available in terms of quality. This section delves into technical aspects of fit for use for common packaging formats and includes numerous examples of how recycled content is used in these formats today.

Recycled Polyolefins (PE & PP)

Polyethylene (PE) and polypropylene (PP) are structurally similar hydrocarbon polymers. Blending different types or grades of polyolefins can either enhance or diminish performance.

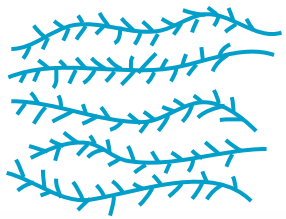


HDPE



LLDPE

LDPE



PP

Polyethylene comes in several varieties—such as low-density PE (LDPE), high-density PE (HDPE), and linear low-density PE (LLDPE)—which have different densities based on the amount of branching present in the polymer chains.

Recycled Polyolefin Properties & Processing

Polyolefins can be mixed with each other to some extent. Blending different grades of PE with different molecular weight distributions and/or different levels of branching can enhance properties as well as processability. Conversely, mixing different polymers or grades can also diminish properties. For instance, too high a level of PP in PE weakens the material. This means the level of sorting—for example, how much PP is present in a PE bale—makes a big difference in the material quality, although this issue can be addressed to some extent using compatibilizers.

When it comes to using recycled polyolefins, matching recyclate melt flow/viscosity to the desired application is a key challenge. Extrusion, blow molding, thermoforming, and film production require relatively high viscosity (low melt flow), injection molding requires an intermediate viscosity, and thin wall injection molding requires low viscosity resin. Due to their all-carbon backbones, the polymer chains in PE and PP cannot be extended once the polymers are made. “Viscosity breaker” additives can shorten the polymer chains and decrease viscosity, but there isn’t yet an effective way to increase viscosity (or decrease melt flow) of polyolefins.

Recycled Polyolefin Sourcing & Suppliers

The most readily available recycled polyolefin is HDPE, due to its relatively high recycling rate. Natural HDPE comes at a price premium compared to color HDPE.

An increasing number of processes can produce food grade PE or PP, although decontamination of these plastics is challenging. A 2021 report estimated food grade HDPE PCR production capacity in the U.S. and Canada as no more than 118 million kilograms. Envision's EcoPrime HDPE resin has been used in multiple food and personal care product packaging applications, for brands including Kashi and Pureology. PP from KW Plastics is used in Lush cosmetics packaging. Revolution is an example of a company that has received a no objection letter for its LLDPE mechanical recycling process.

In addition to mechanical recycling, polyolefins can also be recycled via purification and conversion technologies. The melt flow rate of material obtained from purification will depend on the input stream, whereas material from conversion is remanufactured from basic chemical building blocks and can be tailored to the end use just like with virgin plastic. PureCycle has received a no objection letter for its PP purification process. SABIC, ExxonMobil, LyondellBasell, Circulus, INEOS, and BASF have each supplied polyolefins derived from conversion processes for food and/or personal care product packaging. Companies using recycled polyolefins derived from conversion technologies include Nestlé, Unilever, Estée Lauder, Del Monte Foods, and Tupperware.

Examples of Recycled PE & PP Across Packaging Formats

Blow molding: Seventh Generation laundry detergent bottles (Unilever) now use 100% PCR rHDPE. This increase from 80% in earlier detergent bottles was enabled by mold redesign and availability of higher quality PCR.

Injection molding: Seventh Generation laundry detergent bottle closures and spouts (Unilever) made by TricorBraun use 100% rPP. Knorr bouillon tubs (Unilever) use 100% rPP sourced from pyrolysis. Refillable Dove deodorant sticks (Unilever) are made with 98% rPP.

Extrusion: Burt's Bees lotion tubes (Clorox) made by Berry Global use about 60% rPP.

Film production: Floeter has used >50% rHDPE and 100% rLDPE (>80% PCR) in two products in their Airwave ClimaFilm air cushions line. EcoEnclose offers 100% PIR rPE poly bags. Annie's cereal liners (General Mills) are made with 35% PCR rHDPE. A study by Microsoft and partners found that stretch film with 25% PCR and 25% PIR performed comparably to virgin LLDPE wrap, although achieving 100% PCR in this application was deemed "unlikely to be realistic." Poly mailers can be made with 100% PCR.

Recycled PET

Unlike polyolefins, PET has a polymer backbone containing both carbon and oxygen atoms, which makes PET polymer chains easier to deconstruct or to extend.

Recycled PET Properties & Processing

Bottle-grade PET has relatively long polymer chains and high viscosity, and bottle-to-bottle recycling preserves those characteristics. Thermoforms use lower viscosity PET than bottles so the material has to be “upgraded” to use for bottles, meaning the polymer chains have to be extended.

Chain extension using a process known as solid stating is a common practice in PET recycling. PET is decontaminated using heat and vacuum, and under these conditions the ends of different polymer chains can undergo a chemical reaction with each other, forming longer chains and increasing the resin’s viscosity.

Recycled PET Sourcing & Suppliers

Recycled PET is widely available, although packaging applications do face competition from fiber markets.

The large majority of no objection letters from the U.S. FDA are for PET recycling, as PET is easier to decontaminate than other polymers. A 2021 report estimated food grade PET PCR production capacity in the U.S. and Canada at 660 million kilograms. DAK, Indorama, Merlin Plastics, and many other companies supply mechanically recycled food grade PET.

In addition to mechanical recycling, PET can also be recycled by depolymerization technologies. Because these technologies break the plastic down to its monomers and remanufacture it, properties of the recycled plastic can be tailored to the end use just like with virgin plastic. The U.S. FDA has stated that PET depolymerization processes in general produce recycled PET suitable for food contact applications, so the agency no longer evaluates or issues no objection letters for these processes. rPET from Loop Industries has been used by L'Oréal, and Carbios has supplied rPET to L'Oréal, PepsiCo, Nestlé Waters, and Suntory Beverage & Food.

Examples of Recycled PET Across Packaging Formats

Blow molding: There are plentiful examples of 100% rPET bottles and jars, including Evian water bottles (Danone), Smartwater water bottles (Coca-Cola), Buxton and Mineré water bottles (Nestlé), Ice River Sustainable Solutions water bottles, Pepsi soda bottles (Suntory PepsiCo Beverage), Dial hand soap refill bottles (Henkel), Pril dish soap bottles (Henkel), Seventh Generation dish liquid bottles (Unilever), Hellmann's mayonnaise jars (Unilever), and Love Beauty and Planet hair and body care product bottles (Unilever).

Thermoforming: 100% rPET can also be used in thermoformed boxes and trays. Examples include Organic Girl salad clamshells, The Vegetarian Butcher burger trays (Unilever), and cups and food containers from rPlanet Earth. Often the recycled plastic used in thermoforms comes from bottles, but notably, Driscoll's berry clamshells have incorporated about 10% rPET sourced from thermoforms.

Injection molding: Origin Materials bottle caps are made with 100% rPET.

Film production: Label liners from UPM Raflatac contain 90% post-consumer rPET.

Appendix

- Key Terms & Concepts
- Literature & Links
- Acknowledgements

Key Terms & Concepts

Molecular weight distribution
Wide spec virgin resin

Mechanical recycling, purification, depolymerization, and conversion

Conditions of use
Challenge testing

Compatibilizers

Literature & Links Index

- Reasons to Use Recycled Materials
- Life Cycle Impacts of Recycled Plastics
- Recyclability and Design for Recycling
- Recycled Plastics Properties & Processing
- Chemical Recycling
- Specifications & Quality Standardization
- Material Health & Food Contact Recycled Plastics

Literature & Links

Reasons to Use Recycled Materials

- U.S. Plastics Pact PCR Toolkit: Why Use PCR?

Life Cycle Impacts of Recycled Plastics

- APR “Life cycle impacts for post-consumer recycled resins: PET, HDPE, and PP”

Literature & Links

Recyclability and Design for Recycling

- APR "APR Design Guide for Plastics Recyclability"
- How2Recycle “The How2Recycle Guide to Recyclability”

Literature & Links

Recycled Plastics Properties & Processing

- U.S. Plastics Pact PCR Quality Considerations
- Australian Packaging Covenant Organisation Recycled Content Guide
- ACS Macro Letters “100th Anniversary of Macromolecular Science Viewpoint: Needs for Plastics Packaging Circularity”
- Plastics Today “Assessing the Blowmolding Suitability of rPET Resins”
- PTI “How Light Impacts Recycled Polyethylene Terephthalate (rPET) Characteristics”
- SpecialChem Additives Database
- Plastics Technology “Compatibilizers Aid Recycling & Upcycling of Mixed Resins”

Literature & Links

Chemical Recycling

- SPC "Introduction to Chemical Recycling"
- SPC Position Statement on Chemical Recycling

Literature & Links

Specifications & Quality Standardization

- Plastic Technology “Specifying PCR? Find Answers to These Eight Questions”
- APR Model Bale Specifications
- APR Guide for Plastic Sorting
- Eunomia for the Alliance to End Plastic Waste "Defining Recyclate Quality Target Specifications to Improve Plastic Packaging Circularity"
- Eunomia for the Alliance to End Plastic Waste “Feedstock Quality Guidelines for Pyrolysis of Plastic Waste”
- Plastic Recycling Corporation of California (PRCC) PET Marketplace

Literature & Links

Material Health & Food Contact Recycled Plastics

- U.S. FDA "Guidance for Industry – Use of Recycled Plastic in Food Packaging: Chemistry Considerations"
- Stina for Environment and Climate Change Canada "Assessing the State of Food Grade Recycled Resin in Canada & the United States"
- Starlinger press release: "India's first 100% rPET beverage bottle"
- Sustainable Plastics "Pepsi, Nestlé debut first 100% rPET bottles in Thailand"

Acknowledgements

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Lucy Pierce, GreenBlue
Elizabeth Ritch, GreenBlue
Nina Goodrich, GreenBlue
Kim Carswell, GreenBlue
Laura Thompson, GreenBlue
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