Introduction to Chemical Recycling

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RECOVERY

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GreenBlue is an environmental nonprofit dedicated to the sustainable use of materials in society. We bring together a diversity of stakeholders to encourage innovation and best practices to promote the creation of a more sustainable materials economy.

The Sustainable Packaging Coalition (SPC) is a membership-based collaborative that believes in the power of industry to make packaging more sustainable. We are the leading voice on sustainable packaging and we are passionate about the creation of packaging that is good for people + 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. The Sustainable Packaging Coalition is a trademark project of GreenBlue Org.

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Introduction

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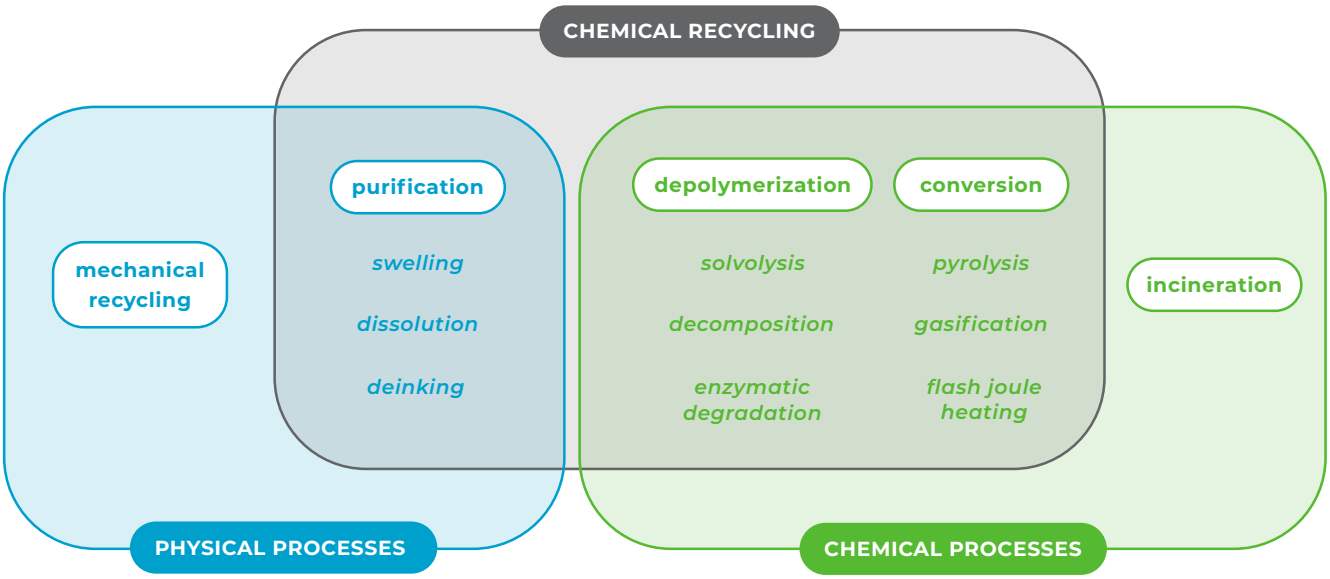
Chemical recycling encompasses a spectrum of physical and chemical processes for transforming plastic or polymer waste into new products. Chemical recycling is also sometimes referred to as molecular recycling, non-mechanical recycling, feedstock recycling, or advanced recycling—unless otherwise specified, these terms can be considered synonymous. Critiques exist for each of these terms, and the reality is that there is no perfect term to describe such a wide range of dissimilar technologies.

Currently, most plastic recycling globally happens via mechanical recycling. Mechanical recycling involves grinding and remelting plastic to produce new products. Plastic comes in many types, and to make recycled plastic products with good strength, flexibility, and other physical properties, each type of plastic must be recycled separately. The cleaner and more consistent the plastic being recycled is, the better the recycling process will work. When there's enough of the same type of used plastic to sort out from other materials and create a uniform stream—for example, high-density polyethylene (HDPE) milk jugs—mechanical recycling can produce recycled plastic that is nearly as good as new, although some degree of degradation of physical properties is inherent to mechanical recycling due to the grinding and heating steps. For used plastic streams made up of colored, contaminated, and mixed or variable types of plastic, however, mechanical recycling faces severe limitations. Although this used plastic can still be ground up and melted, fewer types of recycled plastic products can be made from this lower quality material. Chemical recycling offers opportunities to overcome these limitations, by:

- Removing color, additives, odor, and contamination,
- Providing additional supply of recycled material for food contact applications,
- Restoring physical properties, and
- Diverting more "hard-to-recycle" materials from landfill or incineration.

CHEMICAL RECYCLING IS A *SPECTRUM* OF TECHNOLOGIES.



Chemical recycling technologies fall under three main categories: purification, depolymerization, and conversion. The three categories of technologies can be differentiated by the chemistry involved and the types of products that result from each.

- **Purification** technologies use physical processes to remove inks, additives, and/or non-target plastics from the target plastic. Purification results in a cleaned-up version of the input plastic without changing the structure of the polymer it's made from.
- **Depolymerization** technologies use enzymes, catalysts, solvents, and/or other chemical substances to shorten the polymer chains that make up plastics. In cases where the polymer chains are deconstructed completely, the resulting monomer units can be used to produce new polymers.
- **Conversion technologies** also break down the polymer chains in plastics, but in contrast to depolymerization, conversion does not produce monomers that can be directly built back into new polymers. Rather, conversion involves many chemical reactions happening simultaneously at high temperatures, resulting in a mixture of many different hydrocarbon molecules. Depending on the mixture of molecules present, the output from conversion processes must go through numerous separation, refining, and chemical production steps to be used again to make plastics.

Technology Category	Purification	Depolymerization	Conversion
Chemistry	No chemical reaction	One major chemical reaction	Many chemical reactions
Outputs	Polymer structure is unchanged from inputs	Discrete monomers or limited set of shorter chain products	Complex product mixture

IS CHEMICAL RECYCLING TRULY RECYCLING?

Whether material reprocessing is done mechanically or chemically, recycling only occurs when an old material makes it into a new product. Conversion technologies have historically been used as a means of fuel production or energy recovery, not recycling. Today, driven by increased demand for recycled materials, conversion processes are being adapted to provide material for new plastic products. Still, a single process may produce recycled materials, fuels, or both—this distinction often depends more on the market the material enters than the technology itself. For this reason, it is critical to closely track materials through each stage of processing to properly account for the amount of recycled material produced and incorporated into new products. *Fuels derived from conversion processes, while preferable to new fossil fuel extraction, cannot be considered recycled material.*

Because of the diversity of technologies that fall under the chemical recycling umbrella, the yields, economics, and impacts of chemical recycling processes are also wide-ranging. Comparing impacts across technologies with different inputs and outputs is challenging, and public information on commercial-scale chemical recycling facility performance is limited. As a general rule, mechanical recycling is less impactful and less expensive than chemical recycling, but chemical recycling can provide higher-quality material and can tolerate more contamination. Thus, chemical recycling is best used for "hard-to-recycle" material streams and for applications and markets where high-quality plastic is essential. Increased transparency around impacts, proactive application of environmental justice and green chemistry principles, and collaboration to strengthen the entire recycling system (including collection, sortation, and mechanical recycling capabilities) will be crucial to the successful implementation of chemical recycling in the circular economy for plastics.

RESOURCES & GUIDES

Sustainable Packaging Coalition Position on Chemical Recycling

Product Stewardship Institute "Making Sense of Chemical Recycling"

Closed Loop Partners "Assessing of Molecular Recycling Technologies in the United States and Canada"

Plastic Recycling Technology Database

Closed Loop Partners Global Directory of Molecular Recycling Technologies

Recycling Technology Decision Tree

Notable Projects in Chemical Recycling

BOTTLE CONSORTIUM

Bio-Optimized Technologies to keep Thermoplastics out of Landfills and the Environment (BOTTLE) is an interdisciplinary research initiative focused on deconstruction, redesign, and upcycling of plastics. A recent project combined chemical and biological treatments to transform mixed plastics into useful chemical products.

CYCLYX 10 TO 90

Cyclyx's 10 to 90 initiative seeks to provide solutions for collecting and recycling all plastics. Cyclyx works to characterize plastic waste streams, source and aggregate plastics, and deliver those plastic streams to recyclers.

REMADE INSTITUTE

The REMADE Institute fosters partnerships among industry, academia, and national labs to develop and apply technologies for material recycling, recovery, and remanufacturing with lower associated costs, energy, and carbon emissions. The Institute has funded numerous research projects related to chemical recycling technologies.