Chemical Recycling Q&A

An educational resource designed to help our members and other stakeholders understand chemical recycling technologies relevant to packaging.

INTRODUCTION

The Sustainable Packaging Coalition (SPC)'s mission is to bring together sustainable packaging stakeholders to catalyze actionable improvements to packaging systems and lend an authoritative voice on issues related to packaging sustainability.

Chemical recycling is one part of the solution to reduce plastic waste and the use of natural resources. It supports accelerating the industry and SPC mission. However, chemical recycling facilities and processes need to be developed with care, and companies should pay attention to possible unintended consequences.

This Chemical Recycling Questions & Answers (Q&A) document is an educational resource that helps our members and other stakeholders understand chemical recycling technologies relevant to packaging. It clearly articulates the SPC's approach to chemical recycling in addition to informing readers about other SPC's resources related to chemical recycling as well as the Chemical Recycling Collaborative and its ongoing projects.

We believe that education is key to facilitate industry alignment and drive action toward similar goals. The engagement of informed stakeholders has the best potential to increase the effectiveness of chemical recycling and recycling systems overall.

Chemical Recycling Questions & Answers

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Chemical Recycling

QUESTIONS & ANSWERS

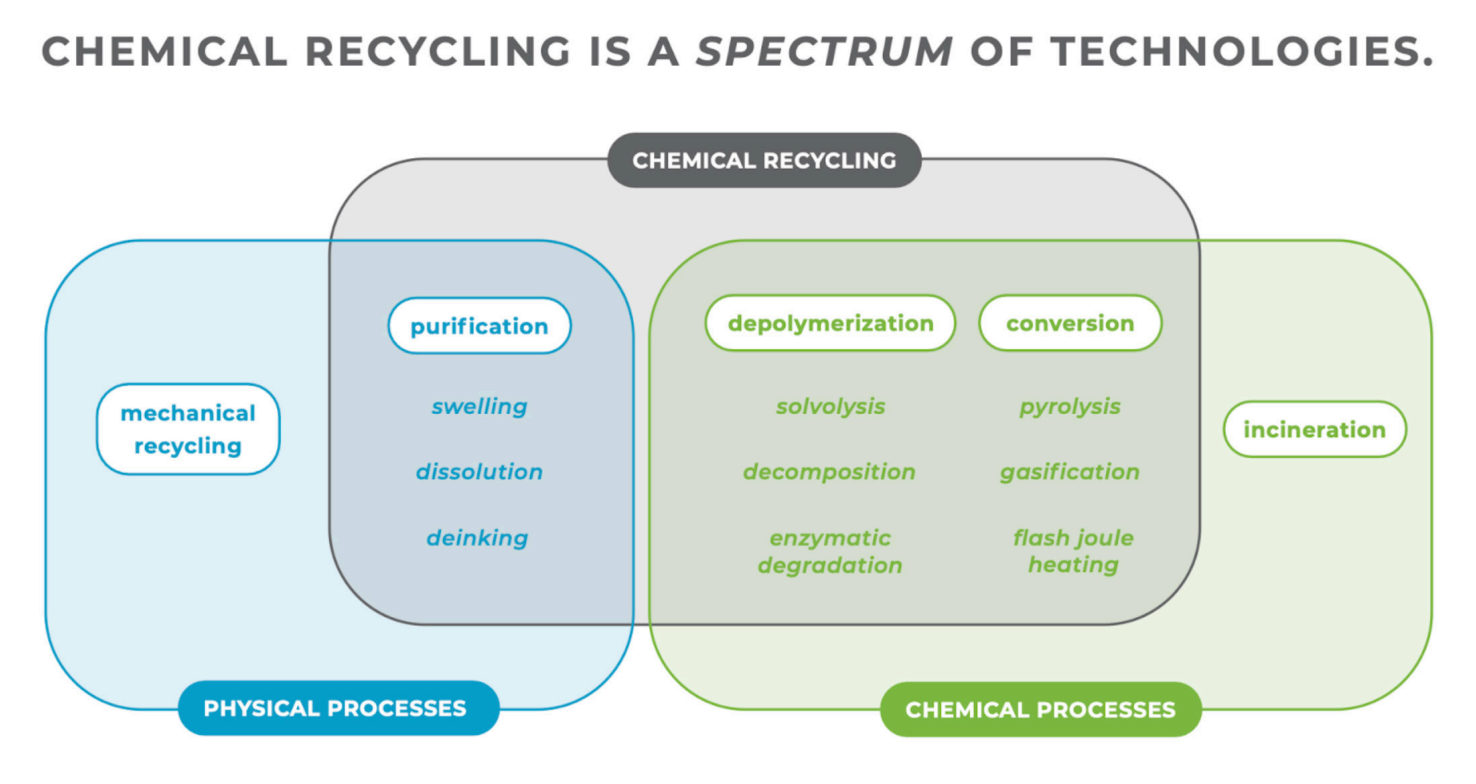
What is Chemical Recycling?

Chemical recycling refers to a spectrum of physical and chemical processes for transforming plastic or polymer waste into new products. Chemical recycling is also referred to as advanced recycling, molecular recycling, non-mechanical recycling, or feedstock recycling.

What are the three different kinds of chemical recycling technologies?

Chemical recycling technologies fall under three main categories: Purification, Depolymerization, and Conversion.

The three categories of technologies are differentiated by the chemistry involved and the types of products that result from each.



What are the main differences between the three chemical recycling technologies?

Purification, also known as dissolution, is a physical process that uses solvents to remove contaminants, such as inks and additives. As it does not break the polymer, the output polymer structure is unchanged from input.

Depolymerization, also known as chemical depolymerization, uses chemicals, such as enzymes and catalysts, for one major chemical reaction which shortens input polymer into either monomers or a set of shorter chemical compounds that can be then used to produce new polymers.

Conversion, also known as thermal depolymerization, involves many chemical reactions happening simultaneously at high temperatures that revert the input polymer back into a mixture of different hydrocarbon molecules that may or may not be used to produce new polymers.

What are examples of chemical recycling technologies and what are the materials that are better suited for technology?

Although most types of plastic can be recycled using one or more mechanical or chemical recycling technologies, some examples are listed below.

- Purification or dissolution technologies can be used for various types of plastics, but each process targets just one type of plastic, so the best inputs for purification are streams that contain a large majority of the target plastic resin. An example of purification is removing contaminants from a polyethylene (PE) or polypropylene (PP) packaging to produce purified polyethylene (PE) or polypropylene (PP) pellets, respectively.
- Depolymerization or chemical depolymerization includes methanolysis, hydrolysis and glycolysis and is best suited for condensation polymers such as, but not limited to, polyethylene terephthalate (PET) and polyamides (PA). For instance, with this technology, PET packaging input is shortened into building block chemicals, such as mono ethylene glycol (MEG) and dimethyl terephthalate (DMT), that can be then used to produce PET again.
- Conversion or thermal depolymerization, which encompasses pyrolysis and gasification, is best suited for hydrocarbon polymers, including PE, PP, and sometimes polystyrene (PS). It may also accept mixed plastics, though yields may be reduced in that case. Mixed polyolefins flexible packaging can be used as an example of waste input that, after many chemical reactions during a pyrolysis process, will be reverted into pyrolysis oil. Pyrolysis oil can be used as feedstock for a range of products, including fuels, monomers, or eventually, polymers. Gasification can produce synthesis gas (or syngas) that can be used in hydrogen or methanol production, that may or may not be used to produce new polymers.

What is the impact of contaminants in chemical recycling inputs?

Although chemical recycling has the potential to accept a wider range of plastic waste, like most manufacturing processes, the quality of the input affects the quality of the output product. For example, some pyrolysis processes target PE, PP and PS, and any material other than these would be considered contaminants. In chemical recycling processes, contaminants generally result in lower process yields and affect the quality of the product.

Are there specific materials that are detrimental to chemical recycling processes?

Polyvinyl chloride (PVC) is detrimental to most chemical recycling processes, as it contains halogens that may bond with hydrogen and become an acid which can be corrosive and damage equipment.

Oxygen-containing materials such as PET and Ethylene-vinyl alcohol copolymer (EVOH) are usually detrimental to pyrolysis as the process requires a low-oxygen environment.

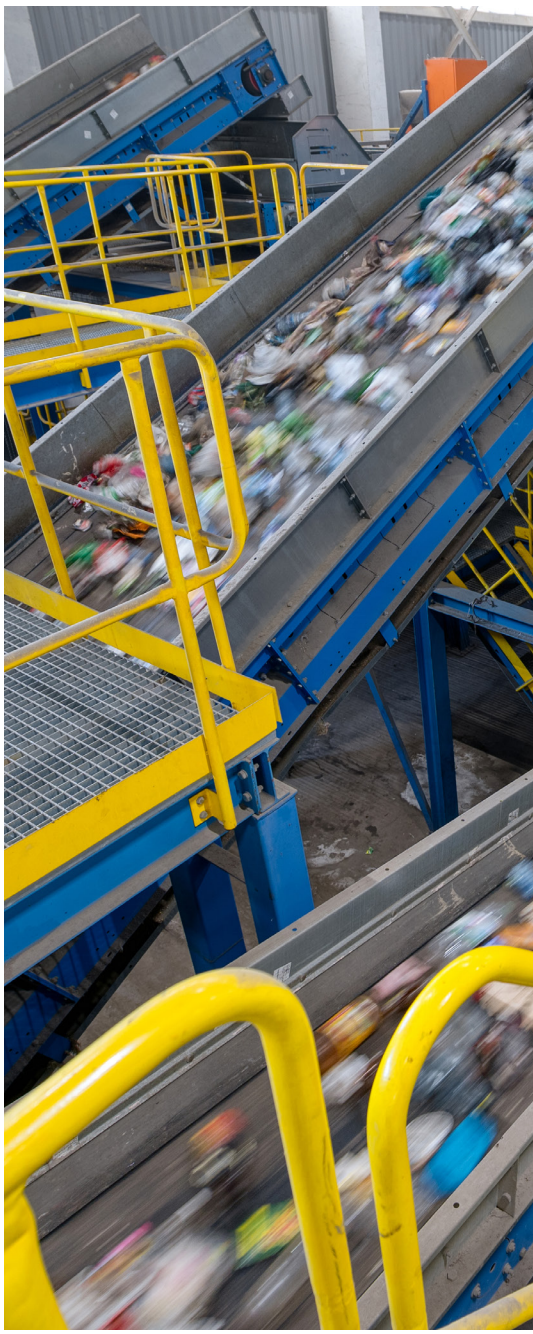
Each process has its own feedstock specifications based on how sensitive it is to contaminants such as moisture, paper, and metals.

Although chemical recycling can accept a wider range of plastic waste, materials like PVC can be detrimental to most chemical recycling processes.

What is the difference between pyrolysis and incineration?

Incineration is a waste treatment process that burns materials. At high temperatures and an oxygen-rich environment, the oxidation of the carbon and hydrogen occurs, producing carbon dioxide (CO2).

On the other hand, pyrolysis is a thermal process that happens in a low or no oxygen environment. As a result, it breaks polymers into basic chemicals that can be used to produce a range of products, including new polymers.



How are various US state policies defining chemical recycling technologies?

As of 2024, 25 states in the US have passed legislation related to chemical recycling, which ensures chemical recycling facilities are properly regulated as manufacturing operations, instead of waste treatment facilities.

What is chemical recycling's role in the circular economy?

Chemical recycling should be used as an end-of-life strategy for material streams that are considered hard-to-recycle, diverting plastics from landfills or incineration. It also reduces dependence on virgin fossil plastic by providing an additional supply of high-quality recycled plastics.

Chemical recycling can be a complement to mechanical recycling when used to process waste that is not accepted by mechanical recyclers or when used to replace virgin resin in highly regulated end-markets, such as food and pharmaceuticals.

Nevertheless, SPC reinforces that the design for recycling should still be a priority in order to increase recyclability of packaging through mechanical recycling. SPC then discourages chemical recyclers from using feedstock that is currently used by mechanical recyclers to avoid competition between the technologies. We suggest that easier-to-recycle plastics enter mechanical recycling while mixed, or hard-to-recycle are captured by chemical recycling.

How do chemical recyclers have access to plastic waste currently?

Challenges remain around the collection and sortation of plastic waste to be used as feedstock in either mechanical or chemical recycling. Currently, infrastructure is lacking and most chemical recyclers access plastic waste through off-take agreements with waste suppliers, instead of using residential waste collected through curbside programs. In some cases, chemical recyclers get their feedstock from mechanical recyclers, finding a new destination for materials that could not be processed mechanically.

What are the main advantages and disadvantages of chemical recycling versus mechanical recycling?

In terms of advantages, some chemical recycling processes can accept a broader range of plastic waste (e.g. multi-material products or mixed plastics) as feedstock, which supports the reduction of plastic pollution.

Furthermore, chemically recycled resins are often similar to the properties and performance of virgin resins. Therefore, it is more suitable to a larger range of end-markets and applications than mechanically recycled products, including food contact applications, pending regulatory approvals. Unlike mechanical recycling, by using chemical recycling, plastics can be endlessly recycled; thus replacing virgin resins and reducing consumption of natural resources.

However, important disadvantages include elevated investment and production costs, despite expectations of reduction when scale is gained. Conversion processes typically have low yields, especially when discounting the portion of materials going to fuels. The environmental impact from the manufacturing and production processes of chemical recycling are typically greater than those of mechanical recycling, although more beneficial than virgin production. That said, while greenhouse gas (GHG) emissions may be higher, chemical recycling prevents plastic pollution and reduces consumption of virgin resins.

Concerns exist over Environmental Justice (EJ) for chemical recycling in regards to responsible end-markets and manufacturing. Third-party certification can be seen as a relevant solution to address EJ in chemical recycling.

How are materials tracked through chemical recycling processes?

With chemical recycling, it is often difficult to keep certified materials physically separated from other materials; thus, mass balance is often used. Mass balance is a chain of custody method that reconciles the amount of plastic waste inputs with the amount of recycled plastic products.

In other words, the amount of certified material entering a facility is known and an equivalent volume of the product leaving the operation can be sold as certified, even though it may not appear in each individual product. You can learn more about mass balance in the video, on the right.

Does SPC have additional resources on chemical recycling?

Yes! In 2023 SPC published its Chemical Recycling Position Statement and a 101 Introduction to Chemical Recycling. This Chemical Recycling Q&A has been published to provide additional information on the topic by clarifying pressing questions from the industry. In addition, a Chemical Recycling topic will soon be added to the SPC's Knowledge Library.

Mass balance claims use an accounting process (sometimes referred to as a credit system) to assign claims to particular product batches. The allocation can be made at different equivalencies to help support customer needs. The flexibility afforded by mass balance accounting enables market growth for both mechanical and chemical recycling pathways. Learn more about mass balance by clicking here.

What is the role of chemical recycling within the SPC?

Chemical recycling topics are explored within a dedicated Collaborative, or working group, for SPC Members. The Chemical Recycling Collaborative, together with the Flexible Packaging Recovery Collaborative, are part of the SPC's Recovery Pillar.

The SPC's Recovery Pillar provides our Members with education and guidance on packaging material recovery, particularly recycling. We help the packaging value chain find solutions for a package's end-of-life. The Pillar views recovery as part of an integrated cycle, including collection, sortation, as well as mechanical and chemical recycling technologies.

The SPC suggests Members first explore ways of recycling their packaging mechanically, including redesigning packaging to improve recyclability, to then consider chemical recycling technologies if mechanical recycling is proven not to be viable for feedstock, end-market, or regulatory reasons.

Together with our Members, we identify problems and solutions to take collective action to advance the recovery of packaging materials, which includes chemical recycling.

INTERESTED IN GETTING MORE INVOLVED? JOIN US!

As a SPC Member you are welcome to join the SPC's Chemical Recycling Collaborative. The group is currently working on a Regional Healthcare Plastics Recycling Program in partnership with the Healthcare Plastics Recycling Council (HPRC) and the Alliance to End Plastic Waste (AEPW) with the objective of demonstrating a cross value-chain program to divert hospital single-use plastics from landfill or incineration to chemical recycling.

Email us at collaboratives@greenblue.org!