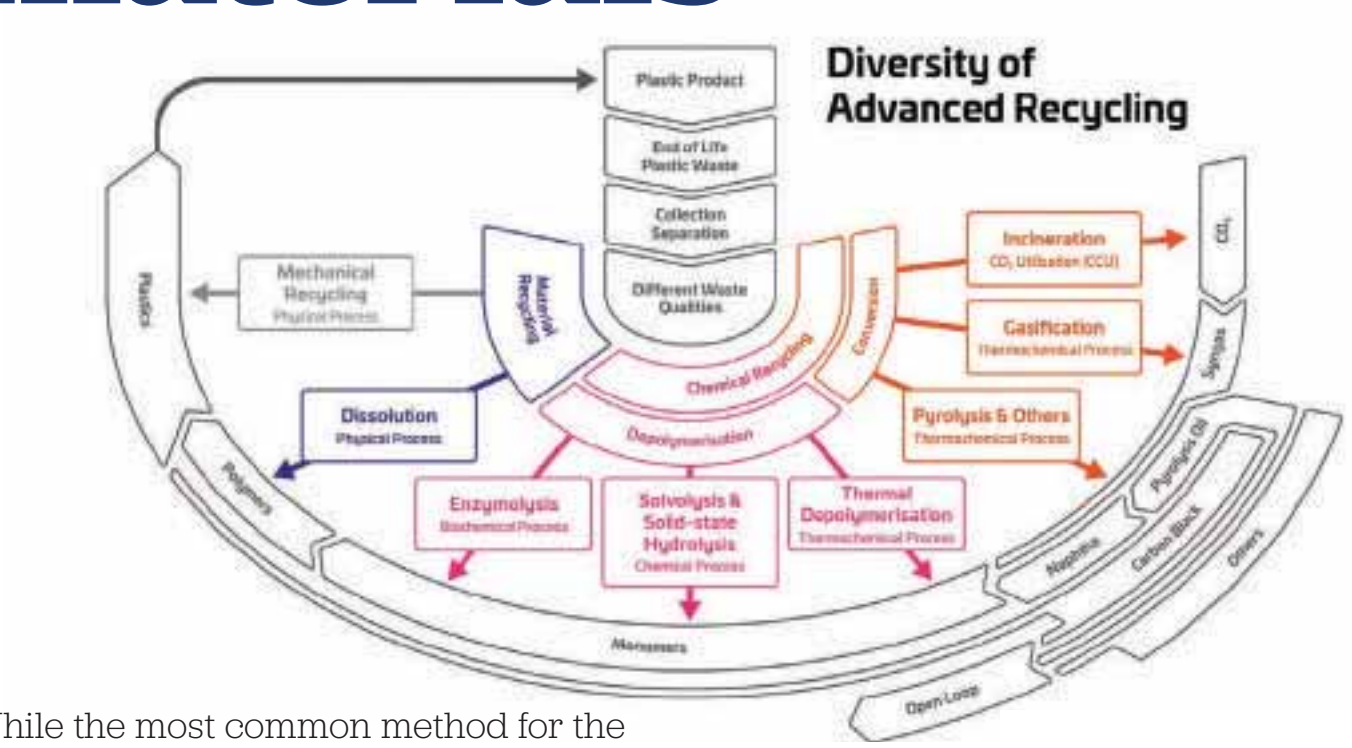
Providing new paths to high-quality recycled materials



While the most common method for the recycling of plastic waste is mechanical recycling, it is certainly not the only option. Here, **Lee Ellen Drechsler**, senior vice president of corporate sustainability technologies at Procter & Gamble, provides insight into physical recycling and how this can provide another route towards achieving high-quality recycled materials. "We believe having multiple technology options to deliver quality recycled resins will keep more useful plastics in service and decrease dependence on virgin petroleum feedstocks."

As a company founded on delivering superior cleaning products, Procter & Gamble possesses deep knowledge of how to remove unwanted soils and impurities from the many materials found in people's homes. We have reapplied this expertise to address the challenge of recycling waste plastics, developing multiple solutions to "clean" plastics using extraction and filtration in the presence of solvents as cleaning agents.

Figure 1 shows where this dissolution recycling approach fits into the range of available plastics recycling techniques. Our ground-breaking work on solvent-based purification recycling has inspired multiple industrial partnerships to expand the toolbox of recycling solutions for polyethylene (PE) and polypropylene (PP), two of the most used plastics worldwide.

Today, these polyolefins are difficult to recycle for reuse in high-purity, high-performance applications since they can absorb contaminants that are often not removed during mechan-

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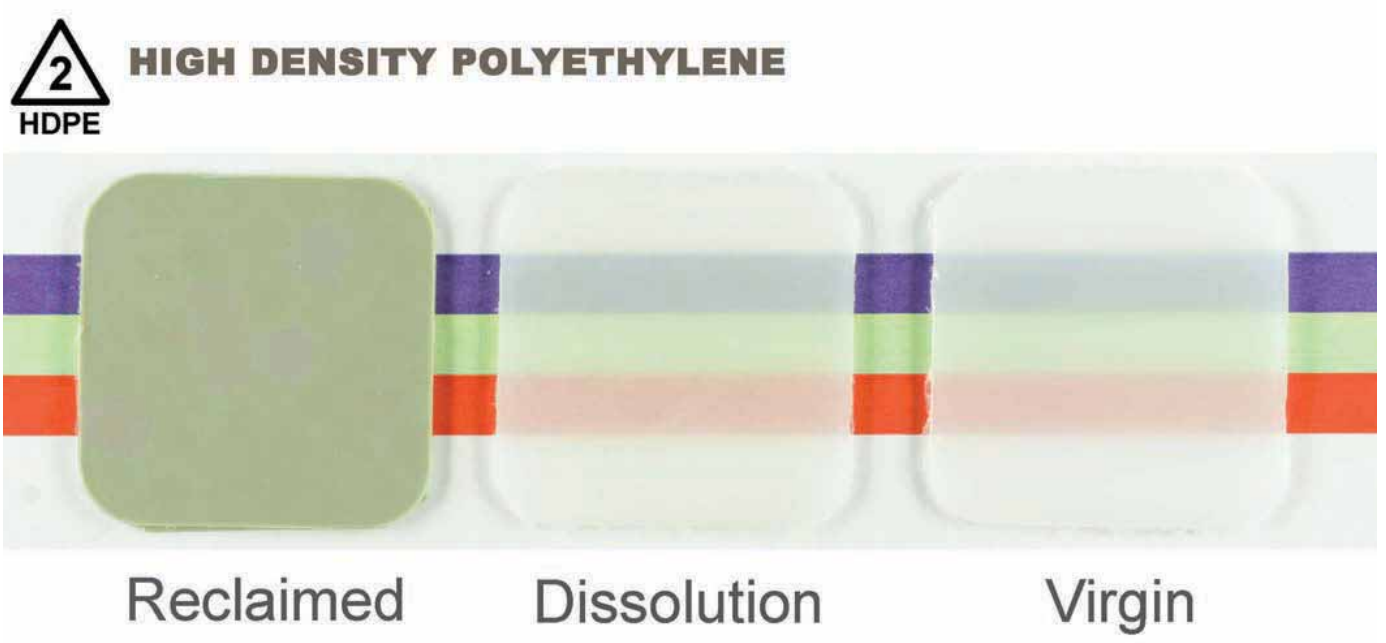

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Figure 1: General overview recycling technologies (nova Institute webpage: www.renewable-carbon.eu/publications/product/diversity-of-advanced-recycling-2024/)

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ical recycling. Solvent-based purification recycling targets these absorbed contaminants and helps extract them from the inside-out without deconstructing the plastic itself.

This innovation is now being demonstrated at scale for PP but is not yet included in all standard definitions of recycling or called out as an option in some packaging regulations where post-consumer recycled (PCR) material usage is required. Building awareness of solvent-based purification recycling and its beneficial role within the range of solutions for driving plastic circularity is critical to broad adoption. This is an exciting opportunity to move the needle on polyolefin recycling rates and offer circularity to plastic applications with demanding purity requirements.

Solvent-based purification recycling encompasses two approaches: solvent washing applied to mechanical recycling and full dissolution recycling. While both remove contaminants from the interior of waste polyolefin materials, they result in recycled outputs with different levels of purity. The next section describes these differences in detail, including target applications and carbon footprint considerations that enable solvent-based purification recycling to fill a critical gap in advancing the circular economy for plastics.

> **We are committed to establishing these solvent-based purification recycling technologies at scale, as we believe having multiple technology options to deliver quality recycled resins will keep more useful plastics in service and decrease dependence on virgin petroleum feedstocks.**

Solvent washing technology (Flexloop)

Mechanical recycling of polyolefins is a well-established technology and the workhorse of the plastics recycling industry. There have been multiple modifications to mechanical recycling processes over time, including the introduction of hot water washing and decontamination extrusion. The next step toward higher purity of mechanically recycled plastic is replacing, or augmenting, water washing with a selective solvent washing step to extract impurities from the interior of waste plastic. In the solvent washing process, the solvent is recovered, cleaned and used again.

Solvent washing is intermediate between mechanical recycling and full dissolution recycling. It removes surface contamination, including printing inks and paper labels, and extracts migratable compounds such as processing additives present in the bulk plastic. However, solid particles such as colorants compounded within the bulk plastic are not removed. The first applications will focus on flexible polyolefin films with the potential for reapplication to rigid materials.

Solvent washing offers a lower carbon footprint than other advanced recycling processes, similar to that of mechanical recycling. It can be installed by established mechanical recyclers as an add-on module, minimizing capital investment and making integration easier. We are currently pursuing licensing arrangements to industrialize solvent washing and look forward to advancing this technology.

Dissolution recycling technology (VersoVita)

For deeper cleaning of waste polyolefins, a multi-step dissolution recycling process has been developed. This process starts with feedstock preparation to maximize concentration of the target polyolefin and remove surface dirt. Then, the plastic is melted and injected into a solvent extraction process under temperature and pressure conditions that swell the polymer sufficiently to mobilize extractable impurities and move them into the solvent-rich phase. This is followed by a polymer dissolution step under different pressure and temperature conditions that enables filtration and

Figure 2: Comparison dissolution recycling of PP and PE with virgin plastic

adsorption removal of solid contaminants. Finally, solvent separation from the cleaned plastic and solvent recovery completes the process.

The result is a near-virgin quality recycled polyolefin that is ready for compounding and reuse in applications with demanding purity and optical clarity requirements. Figure 2 shows the transformation of waste polyolefins into pure, high-clarity recycled polymers via dissolution recycling.

Both solvent washing and dissolution recycling technologies are plastic-to-plastic recycling processes with no need for mass balance. The polymer chains themselves are not changed by the purification steps. Both technologies offer a lower carbon footprint than virgin resin production and chemical recycling processes because polymer bonds are not broken and solvents are recovered.

To date, P&G has licensed dissolution recycling technology to PureCycle Technologies Inc. for application to PP, which they are now commercializing as PureFive Ultra-Pure recycled resins. You can read more about PureCycle operations on their website, including progress of the first commercial plant in Ironton, Ohio, toward its nameplate production capacity of 49ktons/yr. PureCycle has also announced expansion plans for Europe in the NextGen district, Port of Antwerp-Bruges.

Additionally, in March 2024, Dow Chemical and P&G announced a joint development partnership focusing on dissolution recycling of PE including those grades used for rigid (HDPE) and flexible (LDPE, LLDPE) packaging. A collaborative program is underway to demonstrate the process at pilot scale and then progress to commercialization.

Conclusion

Solvent-based purification recycling technologies are physical processes that deliver higher-purity recycled polyolefins compared with current mechanical recycling methods. Solvent-based purification also offers lower carbon footprint than both virgin petroleum resin production and chemical recycling methods. As industrial demand for higher-quality PCR resins grows, continued innovation is necessary in both sorting for better controlled feedstocks and novel plastic cleaning processes such as solvent-based purification described here. It is important to recognize that all approaches including mechanical recycling, dissolution recycling and chemical recycling can be complementary and all have a role to play in fully realizing the circular economy of plastics. Ultimately, purity, performance and cost requirements will determine the preferred recycling route for each recycled plastics application.

We are committed to establishing these solvent-based purification recycling technologies at scale, as we believe having multiple technology options to deliver quality recycled resins will keep more useful plastics in service and decrease dependence on virgin petroleum feedstocks.