The Case for Polypropylene

A White Paper by:

Prepared for Winpak Ltd.

November 2021

Circular Matters

Contents

Figures

Until January 2020, polypropylene packaging could be labeled and communicated to the consumer as “recyclable” without the need for any further clarifications or disclosures by consumer-packaged goods companies. At that time, changes in recycling markets and questions about how MRFs were responding to those market changes led to the need to change packaging labeling and instruct consumers to “check locally” to see if their recycling program accepted polypropylene packaging for recycling. This has led to a discussion of whether other plastic resins considered by some to be more recyclable than polypropylene should replace the use of polypropylene in packaging. This White Paper provides an overview of polypropylene’s unique performance properties, the extent to which it is currently recycled, end-use trends for recycled polypropylene, and steps that can be taken to improve recycling collection access and recycling rates and ensure the continuing use of polypropylene in packaging.

- Phillip Crowder, Director, Corporate Sustainability, Winpak

1. Introduction

Companies that have joined the Ellen MacArthur Foundation’s and the United Nations Environment Program (UNEP)'s New Plastics Economy Global Commitment commit to ensuring that by 2025 some 100 percent of the plastic packaging they use is reusable, recyclable, or compostable. Signatories include companies representing 20 percent of all plastic packaging produced globally and include major global brand companies. To make good on their commitments, these companies are changing some plastics they use in packaging from resins that are recycled at lesser levels to more readily recycled alternatives. Greenpeace has claimed that “only some PET #1 and HDPE #2 plastic bottles and jugs can be legitimately labeled as recyclable in the U.S. today.” Greenpeace has also claimed that “companies cannot legitimately claim or label PP#5 tubs and containers as recyclable.”[1] In 2021 the California Statewide Commission on Curbside Recycling and Market Development published a report to CalRecycle with recommendations regarding a Statewide Standardized Acceptance List of Recyclable Materials (CA Statewide Recyclable List). This list did not include polypropylene as a recyclable material.

2. Background and History of Polypropylene

What is Polypropylene and When was it Developed

Employees of the Phillips Petroleum Company discovered polypropylene in 1951 while attempting to convert propylene into gasoline; however, the orientation of the molecules wasn’t controlled, and polypropylene produced in this way wasn’t considered to have useful properties. Isotactic polypropylene, in which the orientation of propylene monomer molecules is controlled, was discovered in 1954 by Italian chemist Giulio Natta and his assistant Paolo Chini, working in association with the Montecatini Company (now Montedison SpA). They employed catalysts of a type recently invented by the German chemist Karl Ziegler to achieve controlled orientation. Ziegler and Natta were later awarded the Nobel Prize for Chemistry for their catalyst discoveries.

[1] Greenpeace, “Circular Claims Fall Flat: Comprehensive U.S. Survey of Plastics Recyclability, February 2020.

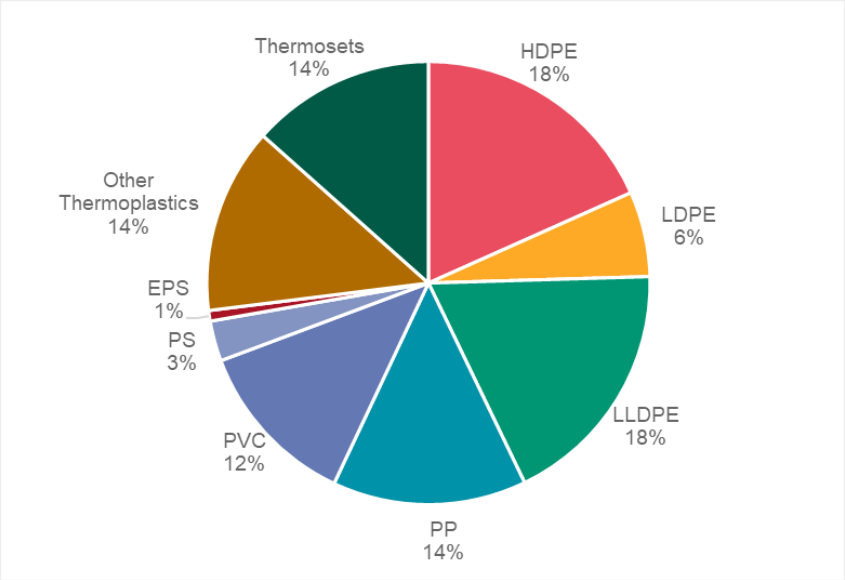
Flowing from these discoveries, commercial production of polypropylene began in 1957; however, it wasn't until the early 1980s that production and consumption of polypropylene (PP) increased significantly.[2]

PP is made from propylene, a gaseous compound obtained by the thermal cracking of natural gas or the naphtha fraction of petroleum, with subsequent processing to produce a single pair of carbon atoms linked by a double bond and a single bond to a third carbon atom. The chemical structure of the propylene molecule is CH2=CHCH3. Under the action of polymerization catalysts, thousands of propylene molecules link together to form the controlled orientation chainlike polymer we call PP.

How Much is Produced

Eleven North American companies make PP including Braskem PP Americas, Inc., ExxonMobil Chemical Company, Flint Hills Resources, Formosa Plastics Corp. U.S.A., INDELPRO, INEOS Olefins & Polymers, LyondellBasell Industries, Phillips 66, Pinnacle Polymers, Sasol Chemicals North America, and Total Petrochemicals USA. PP production from these companies has been steady from 2010 to 2020, averaging 16.9 billion pounds per year, with virtually all consumed in North America.[3] When compared to overall plastics production, PP composes 13.7 percent of plastics made in North America. Figure 1 depicts the breakdown of plastics sales in North America by different resin types.

Figure 1: North American Plastics Sales



Source: "2021 Resin Review," the American Chemistry Council, June 2021.
Other Thermoplastics includes PET, ABS, engineering resins, SB Latex, and other thermoplastics.

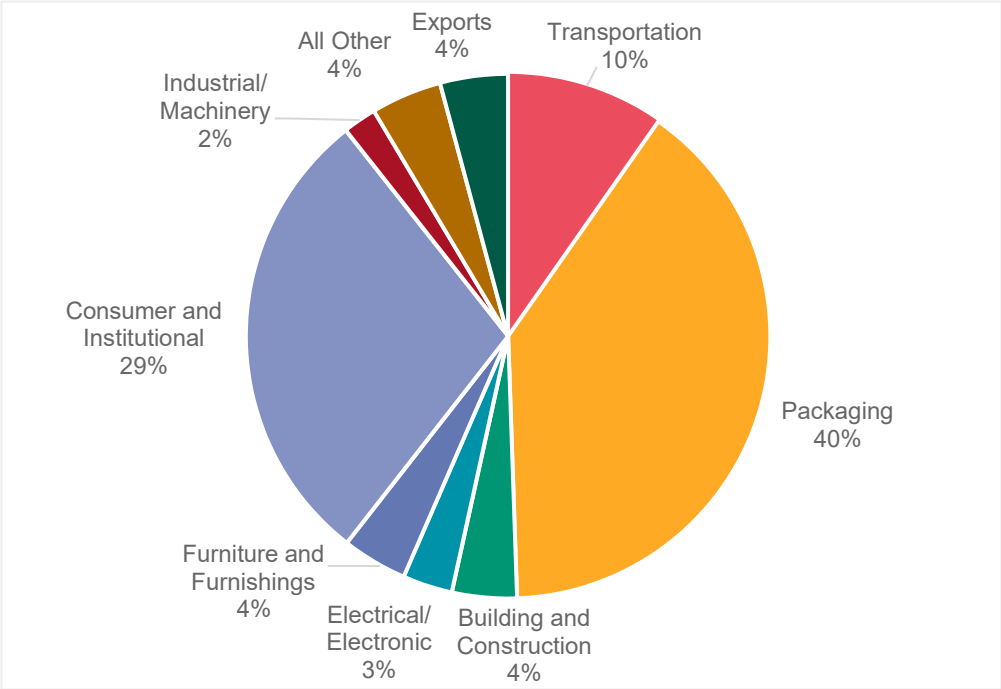
[2] Encyclopedia Britannica December 6. 2017, "polypropylene," accessed August 27, 2021, from https://www.britannica.com/science/polypropylene

[3] Production and use data in this section come from "2021 Resin Review," the American Chemistry Council, June 2021.

Polypropylene Uses

Figure 22 shows the proportions of uses for PP in North America, including the U.S., Canada, and Mexico. Although the North American marketplace functions as a single market for plastics resin sales, approximately 70 percent of consumption is in the United States.

Figure 2: Major Market Uses of Polypropylene in North America



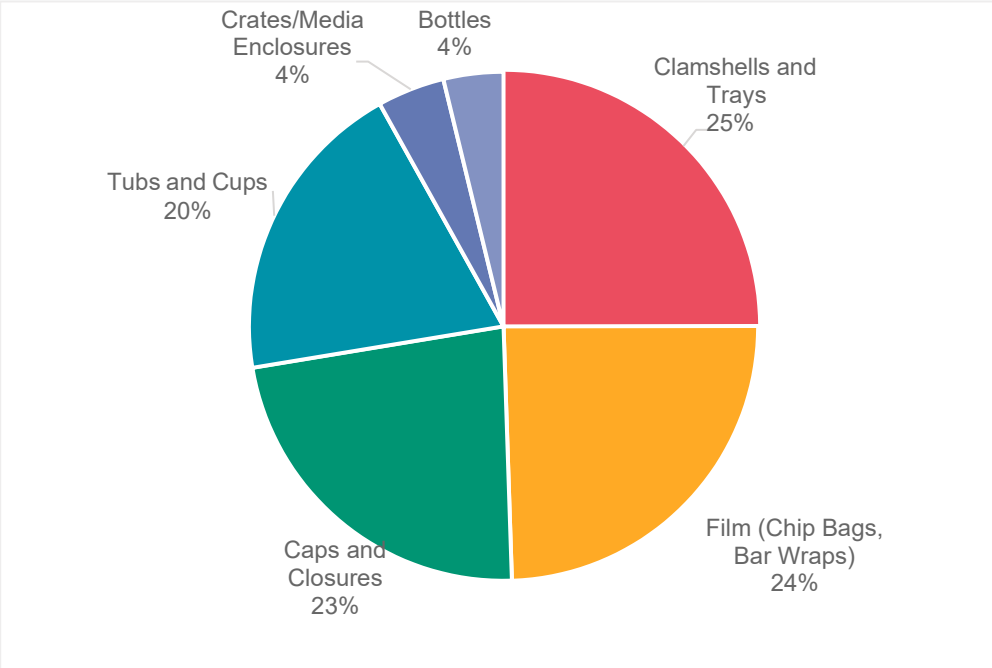
Source: "2021 Resin Review," the American Chemistry Council, June 2021.

The three major markets for PP are in packaging, consumer and institutional goods, and automotive, together consuming approximately 80 percent produced.

- The leading use for PP is in packaging. PP packaging includes rigid packaging such as caps and closures, dairy containers, food and drink cups, take-out/deli containers, clamshells, specialty bottles (e.g., medicine and syrup bottles), small portion cups, and plastic paint cans. It also includes flexible plastic packaging applications such as chip bags, bar wrappers, zippered fruit bags, labels, and as a layer in multilayer structures with other plastic resins.
- Consumer and institutional goods include housewares such as laundry baskets, storage bins and totes, hangers, rakes, plant containers, outdoor resin chairs, carpet backing, artificial turf and nonwoven fibers used in disposable masks, diapers, baby wipes, and medical blue cloth.
- Transportation uses for PP are many and include lead-acid battery casings, bumpers, and other under-the-hood parts.

Most of the scrutiny regarding the recyclability of PP is focused on packaging. Figure 33 shows the proportions of uses for PP in packaging in North America, including the U.S., Canada, and Mexico.

Figure 3: Polypropylene Used in Packaging in North America



Source: "2021 Resin Review," the American Chemistry Council, June 2021.

3. Characteristics of Polypropylene That Make it a Preferred Resin

Polypropylene has many advantages that are difficult or impossible for other resins to match, including:

- Physical properties:
  - Low moisture vapor transmission
  - Ability to be metallized through a vapor deposition process
  - Fatigue resistance (living hinge), allowing flip caps that resist breaking free from container
  - Environmental stress crack resistance when containing chemicals
  - Optical clarity in biaxially oriented films, thermoforming applications, and stretch blow molded containers
  - Low density, allowing for lightweight parts and packaging
- Mechanical properties:
  - Good stiffness
  - High impact resistance
- Thermal properties:
  - High melting and heat deflection temperatures, allowing PP to be used for hot fill and microwave reheating applications and under-the-hood auto parts

- Weldability
  - Low thermal and electrical conductivity (insulation properties)
- Chemical properties:
  - Inertness toward acids, alkalis, and most solvents
  - Ability to be sterilized by heat, gas, and radiation, which is important for medical packaging

PP's balance of properties means it cannot be easily replaced by another resin type in many applications, especially those that require thermal stability, chemical stability, fatigue resistance, and thin wall molding applications.

In highlighting benefits, PP has one of the lowest densities compared to other common packaging resins like LDPE/LLDPE, HDPE, PS, and PET. This means yields are typically improved using PP. As shown in Figure 4, PP's density of 0.90 g/cm³ is approximately 2 percent to 50 percent less than other resins. In addition to a density advantage, PP also has one of the lowest greenhouse gas (GHG) emissions profiles of common plastic resins. As seen in Figure 5, most polyolefins (PP, LDPE, HDPE) have favorable carbon footprints (~2.00 $kgCO_2/kg$) versus competing plastic resins. Polypropylene's carbon footprint,is ~40 percent lower than PET and ~55 percent lower than PS per values reported in the Ecoinvent 3 database. For companies looking to accomplish sustainability goals around reducing overall packaging volume and GHG emissions, PP is an ideal choice.

Figure 4: Density Comparison of Common Packaging Resins

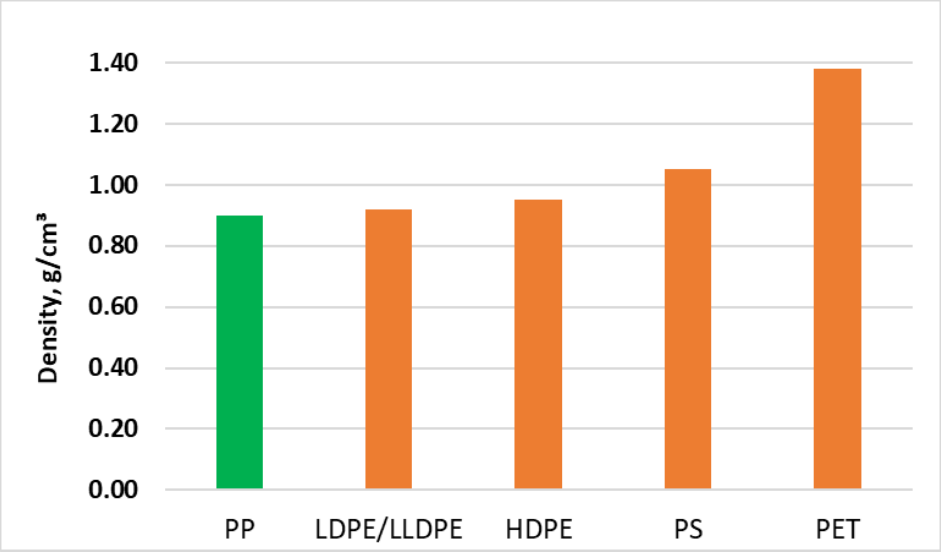
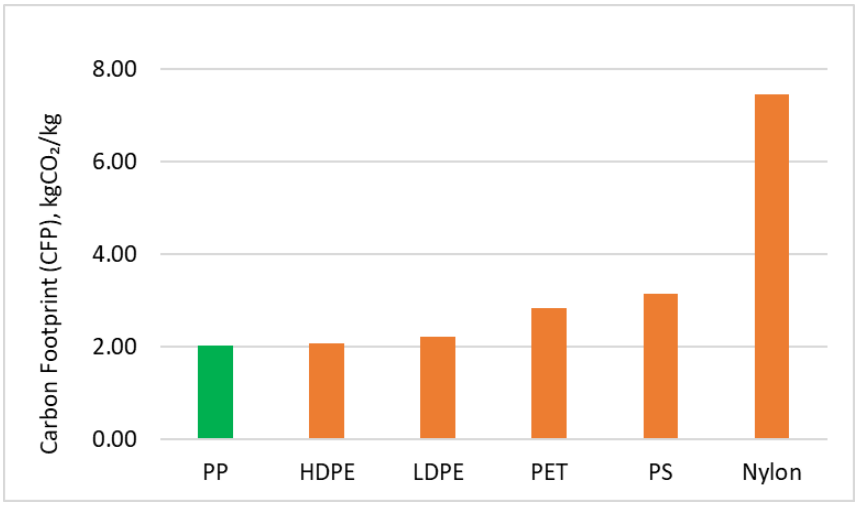
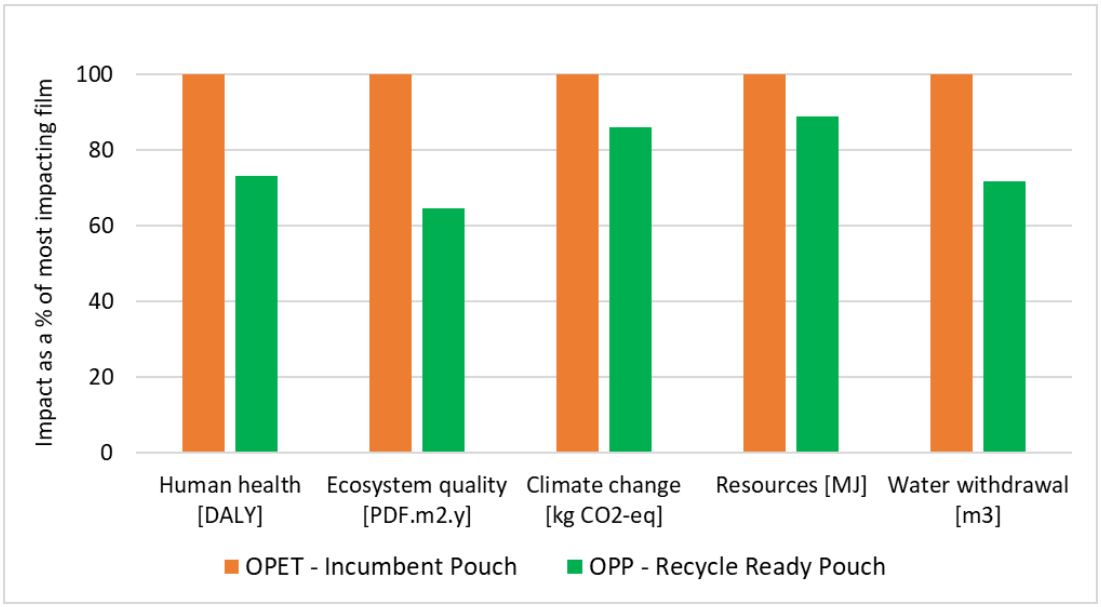


Figure 5: CFP Comparison of Common Packaging Resins



And these favorable attributes for PP then translate into a reduced environmental impact for complete packages. In the flexible film space, the past couple years have seen packaging innovations like 'recycle ready' pouches come to market. Besides having mechanical, optical, and barrier properties closely matching traditional structures, these high-PP content pouches have reduced climate impact due to lower resource (energy, water) use and lower GHG emissions (Figure 6).

Figure 6: LCA Comparison of PP Recycle Ready Pouch vs Traditional Incumbent

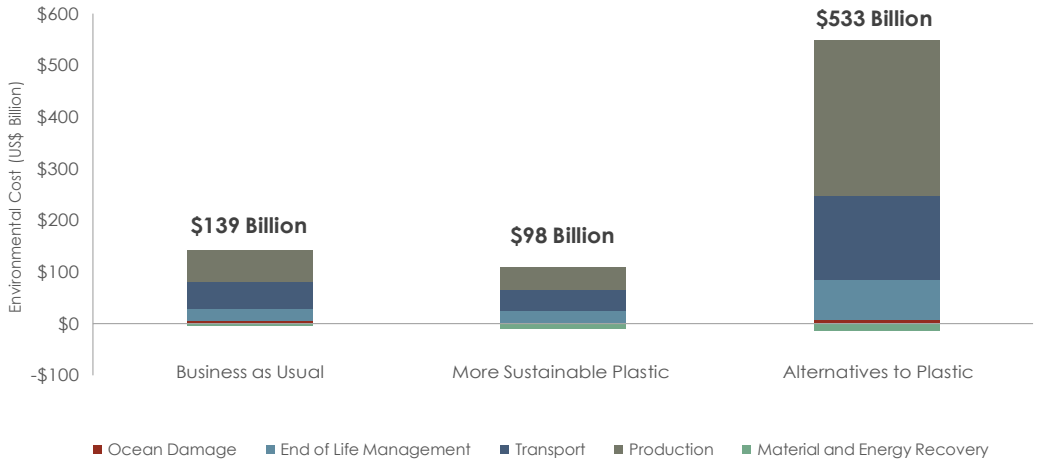


Circular Matters

Aside from favorable characteristics versus other resin types, PP (and plastics in general) has a favorable profile when considering packaging alternatives like glass, metal, and fiber-based packaging. A research paper prepared by Trucost demonstrated that the environmental cost of alternatives to plastics would be 3.8 times higher than even a 'business as usual' approach.[4] This includes substantial increases in environmental costs/impacts in transportation, production, and end of life management associated with alternative materials as seen in Figure 7. And why are these environmental costs higher with alternative materials?

- On average, over four times more alternative material by weight is needed to replace plastic
- Climate change impacts, such as GHG emissions, increase substantially
- Transportation needs increase dramatically along the value chain due to heavier weight and reduced cube efficiency of these alternative materials
- Food waste and/or product loss may be higher with alternative packaging materials resulting in both wasted resources and higher GHG emissions

Figure 7: Environmental Cost of Material Alternatives to Plastics in Consumer Goods



The point in addressing material substitution is not to give PP (and other plastics) a "pass", but it does indicate that a solution should still consider plastics. The remainder of this paper will focus on pathways to a Circular Economy and actions that participants along the value chain can take to improve the sustainability of PP.

[4] "Plastics and Sustainability: A Valuation of Environmental Benefits, Costs and Opportunities for Continuous Improvement," Trucost and American Chemistry Council, July 2016.

4. Recycling of Polypropylene

Post-consumer PP has been recycled since 1981 when KW Plastics (headquartered in Troy, Alabama) began recycling PP lead-acid automobile battery casings. At the time, only PET bottles were recycled (HDPE bottles weren't recycled until 1991). By 2019, U.S. generated PP products and packaging were recycled at the following levels:[5]

- 30 million pounds of PP bottles;
- 442 million pounds of non-bottle rigid PP, including PP used for thermoforms, molded containers, caps, automobile battery casings, crates/trays, and other uses.

In the U.S., only 4 percent of PP is currently recycled, and apart from in-mold PP labels on HDPE bottles, no PP flexible plastic packaging is recycled. This low recycling rate for PP is unfortunate because the demand for recycled PP exceeds the supply. Because other thermoplastics such as HDPE, LDPE, and PET are generated in greater quantities than PP, especially in the residential sector, recycling programs and sorting facilities focus on those other resins first, devoting fewer resources to the collection and sorting of PP for recycling. There are no sorting facilities for mixtures of different resins of flexible packaging film products and as a result only polyethylene films are recycled in the U.S.

Historically, residentially collected PP was frequently baled with other plastic resins, and the mixed bales, commonly referred as #3-7 bales, were primarily exported from the U.S. for further sorting in other countries with low-cost labor. Beginning in 2017, China began taking actions to reduce the amount of lower-quality recyclables of all material types allowed into the country and by 2018 mixed paper and mixed plastics could no longer be shipped to China. Some other Southeast Asian countries also implemented restrictions similar to China. To date, plastics recycling facilities in the U.S. that sort mixed plastics into their component resins have largely struggled to have a stable business model and many have gone out of business.

In response to these market shifts, materials recovery facilities (MRFs) have changed how they sort plastics, in many cases sorting PP as its own grade in place of producing a mixed plastics grade. Robots for sorting recyclables have also been commercialized in the last few years and are increasingly being installed in MRFs to sort PP and other materials at a lower cost than hand sorting or mechanical optical sorting. To further support communities and MRFs in collecting and sorting PP for recycling, The Recycling Partnership established the Polypropylene Recycling Coalition in July of 2020. This initiative supports the expansion of PP recycling from residences through grants for equipment and program expenses, thus encouraging the addition of PP to residential recycling programs. The Recycling Partnership estimates that there may be as much as 17 pounds of PP generated per household each year, or over 2 billion pounds per year in the U.S. In July of 2021 the Sustainable Packaging Coalition released the results of a survey of residential recycling programs regarding the ability to recycle PP in those programs. This study found that 72 percent of the U.S. population has access to recycling programs for PP bottles, 59 percent has access to recycling programs for PP tubs (e.g., dairy containers), and 47 percent has access to recycling programs for PP cups.[6]

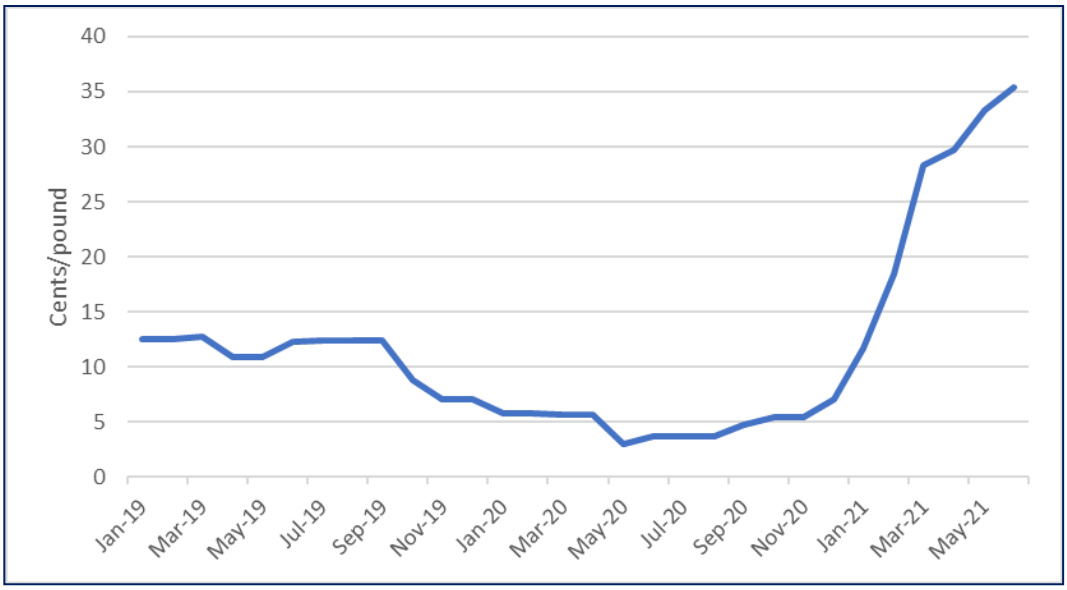
---

[5] "2019 U.S. Post-Consumer Plastic Recycling Data Dashboard," Association of Plastic Recyclers and the Foundation for Plastic Recycling.

[6] "Centralized Study on Availability of Recycling," the Sustainable Packaging Coalition, July 2021.

Domestic market demand for recovered PP has also increased and is reflected in higher prices paid to MRFs for PP containers sorted from mixed residential plastics, as shown in Figure 8.

Figure 8: Value for Baled MRF Polypropylene



Source: "Secondary Materials Pricing," Recycling Markets Ltd., U.S. average prices paid for baled residential PP containers.

As depicted in Figure 8, the value of PP dipped in 2020 in response to the COVID-19 pandemic and its impact on automobile sales and production (a significant market for recycled PP is in automotive applications). Recycled PP is also used in lawn and garden applications, storage cases, septic systems, and plastic paint cans. A small amount of PP is also recycled into resin that has a U.S. Food and Drug Administration Letter of No Objection (FDA LNO) for food contact applications. The capacity to produce this resin is currently very small and is primarily used for crates used for fruits and vegetables and for to-go takeout containers. The reclamation of mixed color and PP resin grades by many current reclaimers means that little PP is recycled closed loop back into high-performance applications – much is overcolored to a black recycled resin. However, this may change.

There is a new company, PureCycle Technologies, that has entered the U.S. recycling space. This company licensed a technology developed by Procter and Gamble that removes colorants and other additives from recycled PP so that it is suitable for a wider variety of color-sensitive applications. This removal capability is important to major brand companies looking to expand use of recycled content in packaging. As this company grows, more recycled PP is expected to flow into cosmetic packaging, food packaging, and other similar applications where an FDA LNO is needed, as well as into houseware applications that are color sensitive.

Recycling capacity for PP is also expanding at KW Plastics, the nation's largest recycler of post-consumer PP:

> "If we can get the equipment, which is tight right now, we have plans to add two or three more [production lines for PP and HDPE], because we feel like we are going to see this demand continue to grow for at least the next two or three years. We want to do

> everything we can to get ahead of that demand...domestic recycled plastic end-markets are very strong and they are reliable."[7]

PureCycle and KW Plastics are not the only recyclers expanding PP capacity. EFS Plastics (Canada) and Merlin Plastics (Canada/US) are recycling PP and enhancing recycling capabilities as well.

For those instances where it is not cost-effective to separate PP from other types of plastics, such as at small MRFs, new recycling technologies and related infrastructure is developing called chemical recycling. Chemical recycling, also called advanced recycling, molecular recycling, or other process-specific terms, entails the breaking down of plastics into basic molecules that allows them to be recycled into other chemicals, plastics, or fuels. Many of these technologies accept mixed plastics, where PP does not have to be separated from other plastic types. A significant number of new chemical recycling plants have been announced and if all of these projects are ultimately developed, the chemical recycling infrastructure may be able to consume as much as 2 billion pounds of plastics not sent to traditional mechanical recycling by 2025.

5. Ensuring the Continued Use of Polypropylene in Packaging

This White Paper's introduction discussed the pressure to improve recycling rates of PP, especially PP packaging. Many large consumer packaged goods companies have committed that 100 percent of plastic packaging they use will be reusable, recyclable, or compostable by 2025. However, as discussed previously, currently only 72 percent of the U.S. population has access to recycling programs for PP bottles, 59 percent has access to recycling programs for PP tubs (e.g., dairy containers), and 47 percent has access to recycling programs for PP cups and thermoforms. It is also concerning that the recycling rates for these packages are low, reported to be 15.9 percent for PP bottles,[8] with recycling rates for other rigid PP packages and bottle caps not reported and likely lower.

The way to improve recycling collection access and recycling rates, maintain its continued use in packaging, and make use of the environmental and performance benefits PP provides is for packaging companies to not deselect it and for municipal recycling programs to not drop it. The CEOs of The Association of Plastic Recyclers, Closed Loop Partners, and The Recycling Partnership released a joint statement of concern regarding the California Statewide Commission on Curbside Recycling and Market Development's omission of PP from the recommended statewide recyclables list, stating "We believe the recommendation not to include PP on the list underestimates the recycling access, capture, and marketability of PP in California and could prove detrimental to PP recycling and waste reduction within the state and nationwide."[9]

Constructive steps to ensure the continued use of PP in packaging include:

---

[7] Remarks by Stephanie Baker, director of market development for KW Plastics, to WasteExpo Together Online 2020, as reported by Resource Recycling, September 22, 2020.

[8] "2019 U.S. Post-Consumer Plastic Recycling Data Dashboard," Association of Plastic Recyclers and the Foundation for Plastic Recycling.

[9] "Industry Statement: Response to California Commission Omission of Polypropylene from CA Statewide Recyclable List Recommendation to CalRecycle," Association of Plastic Recyclers, Closed Loop Partners, and The Recycling Partnership, July 2021.

- **Commitment to development of end markets.** The incorporation and use of PCR PP into packaging must gain commitment from brands and retailers in order to drive demand. Infrastructure and policies to aid supply will be important, but brands must drive end-markets and demand by use of recycled content in their packaging.
- **Commit to expanding collection of PP in municipal recycling programs**. MRF companies are reluctant to invest in sorting equipment for PP without such a commitment. Furthermore, committing to expanding collection of PP allows PP reclaimers to obtain loans or private equity financing under favorable terms. Brand owners can engage with state policymakers to ensure PP is included on statewide recyclables lists.
- **Invest in recycling infrastructure**. MRFs in particular need to expand the use of robotic and optical sorting equipment for PP if they do not already have such equipment. Furthermore, in 2021 the Sustainable Packaging Coalition reported that only 60 percent of U.S. households had curbside recycling collection provided. Many households lack recycling service for any material and the nation's basic recycling infrastructure requires expansion. Following the lead of The Recycling Partnership, further engagement and funding of the PP Recycling Coalition by companies impacted by the PP value chain can further support PP recycling investment.
- **Build flexible plastic packaging (FPP) recycling infrastructure.** Polyethylene FPP, if clean and dry, can be returned to specific retail locations for recycling in most U.S. communities. PP FPP, such as bar and candy wrappers, chip bags, and zip top fruit and vegetable bags lack virtually any collection opportunities.
- **Improve recycling communications to consumers.** Communities not only need to invest in adding PP to existing recycling programs, but also in promoting the recycling of PP packaging in new and existing programs as many households are confused about the recyclability of plastic packaging beyond PET and HDPE bottles. According to the American Chemistry Council, PP caps and closures comprise approximately 30 percent of the PP used in rigid plastic packaging, and those caps and closures are mostly used on non-PP containers. Consumers are still confused about whether to replace caps on containers before recycling or to dispose of them. The plastics recycling industry wants caps replaced on containers before consumers recycle them.
- **Implement governmental policies that support PP recycling.** State policies should encourage and not discourage the inclusion of PP in collection programs. Policies that require recycled content in plastic packaging can stimulate demand for recycled PP, incentivizing PP reclaimers to invest in expanding the U.S. capacity to produce FDA LNO resin, which is currently small. Consideration of chemical recycling of plastics (not to fuels), including

  acceptance of mass balance accounting for meeting recycled content goals,[10] can allow small MRFs (which may not have the capacity to sort out PP into its own single grade) and the communities that supply them to include PP in mixed plastics sent to chemical recycling.

The U.S. recycling industry is working to expand recycling collection access for PP packaging

[10] The "recycled" attribute is valued by consumer packaged goods (CPG) companies and they may be willing to pay more for it than virgin resin. If recycled resin producers are able to account for and credit the recycled content to specific CPG buyers (even though in actuality it may be blended among many products for multiple buyers) then CPGs can financially support chemical recycling and strengthen markets for mixed plastics. This concept of crediting to specific buyers is called mass balance accounting.

through The Recycling Partnership's Polypropylene Recycling Coalition. This Coalition offers grant funding to invest in equipment at MRFs to establish permanent and sustainable MRF acceptance and recycling of PP, as well as grants for education of their residents of the new PP recycling opportunities. The Association of Plastic Recyclers also works to support the growth of PP recycling through model bale specifications that can be used by reclamation markets to clearly communicate with MRFs what should be in those bales, a program to work with grocery chains to collect PP tubs and buckets from bakery, deli, and pharmacy departments, and design for recycling guides for packaging manufacturers to use to ensure that the packaging that they produce is not detrimental to recycling.

Given the many performance attributes of PP, the recycling industry's efforts to increase PP recycling, the pending commercialization of chemical recycling, and the rising demand for recycled content in packaging, PP is positioned for continued use in packaging and expanded recycling. It is incumbent on the entire plastics and packaging value chain, brands, trade associations, and government entities to come together to develop solutions that promote inclusivity of PP, improve access to and recovery of PP after use, enable development of recycling technologies, and incorporate PCR PP into branded products. It is not time to put restrictions or policies in place that limit PP's use and may lead to unintended environmental impacts.