MARGINAL COST OF PCR

Assessing the Costs of Using Post-Consumer Resin in the Manufacture of Plastic Packaging & Products

PREPARED BY:

RRS | recycle.com

COMMISSIONED BY:

Environment Canada

EXECUTIVE SUMMARY

RRS was retained by Environment and Climate Change Canada to determine the marginal cost of incorporating post-consumer recycled resin (PCR) in certain products and packaging. To that end, RRS built a model that quantifies the marginal cost of incorporating post-consumer resin (PCR) in the manufacture of five plastic items, including four packaging formats and garbage bags. Because the assessment was designed to reflect the marginal cost of using PCR in manufacturing, the model includes only the costs incurred during the conversion process – when the PCR is utilized to produce a product or packaging. It does not reflect the costs of reclaiming post-consumer plastics and producing PCR to the specification required by the converter or the cost of acquiring PCR feedstock.

The model documents a marginal cost of incorporating PCR ranging from $.05 to $.24 per kg ($CAD). The main factors influencing whether the cost is at the low or high end of that range is the application, the resin type, and whether the PCR is food contact. The most significant costs related to incorporating PCR typically relate to front end material handling and rejected product (loss rates). Converters also commonly reported increased costs related to testing and quality control, blending, screening, and, in one example, upgrading a legacy extrusion line to a multi-layer line. The research also identified the following considerations related to the cost of incorporating PCR in different contexts:

- **End use application matters**: Costs can vary depending on whether the application is rigid or film, coloured or natural, or molding technology used.
- **Whether inputs are food grade or not impacts process cost factors**: Food grade PCR is often preferred, even for non-food applications, as it is higher quality and more likely to meet stringent specifications.
- **There are cost advantages to producing from 100% PCR:** Using only PCR eliminates the added costs of storage, material handling and blending required for facilities that mix PCR and virgin materials.
- **The size and the legacy of the facility impacts costs:** A large facility with multiple incoming material silos may not face any additional cost to store and handle incoming PCR. A facility that was designed to produce multi-layer materials may be able to easily incorporate PCR in a layer.
- **Use of PCR may increase product weight**: In certain applications (e.g., films) incorporating PCR, particularly at high levels, may require the product to be a thicker gauge, thus using more material and incurring a higher cost per item.

RRS' research revealed several methods that converters use to improve the quality of the products they produce using PCR, and / or reduce production costs.

- **Find the sweet spot**. Identify a level of PCR content at which a high-quality product can be produced without creating significant performance issues, related yield loss, cycle time, and other cost increases.
- **Utilize beneficial additives**. Additives can improve the performance of PCR, either when blended with virgin resin or used in 100% PCR applications.
- **Skip the blending.** Using 100% PCR content or pre-blended resin ("single pellet") avoids the marginal additional costs associated with storing and blending both virgin and PCR.
- **Design for scale**. The ongoing operating costs of handling smaller amounts of PCR is greater than handling quantities through an automated silo-based system, thus investing in silo storage can reduce costs over time.

While the parameters of this analysis were drawn to exclude the impact of supply, it is clear that the shortage of PCR supply impacts the cost and availability of recycled plastic products in the current market context. That cost manifests in additional cost reflected in this study (e.g., the cost of storing and blending small quantities of PCR) and not reflected in this study (e.g., the price premium for high quality PCR).

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

BACKGROUND AND PURPOSE

The Government of Canada established an aspirational goal of incorporating 50% recycled content in plastic products and packaging, where applicable, by 2030. RRS was retained by Environment and Climate Change Canada to fill a key information gap in furtherance of that goal – determining the marginal cost of producing recycled content plastic packaging. To that end, this study was designed to:

- Assess the costs of using post-consumer resin (PCR) in the manufacture of plastic packaging applications, and
- Identify and assess the impact and effectiveness of technologies and practices in use by manufacturers to improve product quality and reduce production costs when using PCR.

To complete the assessment, RRS built a model that quantifies the marginal cost of incorporating post-consumer resin (PCR) in the manufacture of five plastic items, including four packaging formats and garbage bags. Because the assessment was designed to reflect the marginal cost of using PCR in the manufacture of packaging, the model includes only the costs incurred during the conversion process – when the PCR is utilized to produce a product or packaging. It does not reflect the costs of reclaiming post-consumer plastics and producing PCR to the specification required by the packaging converter or the cost of acquiring PCR feedstock. The model output is presented below in Table 2.

In the process of researching the marginal cost of incorporating PCR, the RRS team made note of any technologies and practices in use to improve the quality, or reduce the production costs, of packaging made with PCR. Those are summarized in Section 6.

System Boundaries and Assumptions

This project focused exclusively on the conversion stage in the recycling value chain. Many cost factors of utilizing PCR impact other stages of the value chain, in particular the cost of producing PCR to a quality able to be converted into packaging, is reflected in the reclamation process. However, those costs, which are largely embedded in feedstock costs, are not within the scope of this study. Figure 1 presents the broader recycling value chain.

Figure 1. Recycling Value Chain

This study included the following assumptions to ensure that the costs were isolated to the conversion stage.

- The analysis assumes that PCR and virgin resin prices are the same; the modeling exercises seeks to quantify the additional cost to convert PCR into packaging; not the impact of the price of virgin vs. PCR feedstock
- The model is not constrained by supply, and thus the exercise assumes that supply is not limited
- The model is intended to evaluate mechanically recycled PCR, not advanced, chemically recycled or chemically purified PCR
- The model assumes that PCR quality remains as it is today

In addition to the project assumptions noted above, related to cost, availability and quality of PCR, the RRS team made the following assumptions while building the model:

- The applications modeled are representative of the range of manufacturing conditions
- Marginal costs measured by 1,000,000 product unit, and by weight
- The throughput model is representative of a commercial scale ~35,000 tonnes per year, however the directional impact of larger or smaller scale operations are explained below

PROJECT DETAILS

Definitions

Brand: company that produces and markets finished products to consumers. Commonly purchases packaging from converters

Bottle: a cylindrical plastic container used for holding liquids

Compound Resin: a polymer mixed with additives to achieve desired functionalities of a finished product

Converter: company that specializes in transforming raw materials, such as resin, into finished packaging formats

Extrusion: process of forming continuous shapes by forcing molten plastic material through a die

Extrusion Blow Molding: process of blowing air into an extruded tube of plastic to form it into the shape of a surrounding mold

Film: continuous phase plastic in a form which the thickness is very small in proportion to length and width. Thickness is less than 0.08 mm (0.003 in)

Flake: resin raw material format produced by chopping, shredding, or grinding plastic items. Can be re-melted and molded/extruded to produce pellets or various packaging formats

Food Grade: resin of sufficiently high quality to comply with regulations for food contact use

Injection Blow Molding: two-step process involving the injection molding of a preform followed by the injection of air into the heat-softened plastic to form into the shape of the surrounding mold

Jug: a plastic container that has a formed handle used for holding liquids. Commonly larger than plastic bottles

Mold: hollow form in which molten plastic is poured form a designed shape when the material cools

Monolayer: plastic packaging form consisting of a single layer of one resin type

Multilayer: plastic packaging form consisting of multiple layers of different types of resins or other materials

Non-Food Grade: resins not meeting necessary standards to be used in food-contact applications

Recycler: company that specializes in the sorting, separation, and/or reprocessing of material collected for recycling

Packaging Format: description of packaging based on shape and application (e.g., milk jug, shampoo bottle, etc.)

Resin: plastic of a specific chemical composition

Pellet: resin raw material format produced through extrusion and shaped like a small cylinder or disk. Can be re-melted and molded to produce various packaging formats

Preform: plastic hollow tubed used to form bottles during the blow molding process

Post-Consumer Resin (PCR): recycled resin originating from commercial and residential recycling programs

RRS | 416 LONGSHORE DRIVE, ANN ARBOR, MI 48105 recycle.com

Sheet: continuous phase plastic in a form which the thickness is very small in proportion to the length and width. Thickness is generally greater than 0.25 mm (0.010 in)

Thermoform: package formed from plastic sheet or film by shaping it into or around a mold

METHODOLOGY

RRS' methodology focused primarily on interviews, and secondarily on a literature search. The RRS team interviewed **14** companies to gain insight on the following topics:

- Understand the conversion manufacturing process from feedstock receipt (both PCR and virgin) through end-product(s) production
- Compile information on technologies and practices used to enable the use of PCR
- Identify points within the process where marginal costs would be incurred by using PCR instead of virgin
- Gather data on the added marginal costs of using PCR

The team selected a range of interviewees to represent different plastic packaging formats, and various conditions in which PCR is used in plastic packaging in North America. All of the interviewees were asked the same list of questions to ensure that the information gathered was consistent from one company to the next. Most of those interviewed represented packaging converters, though the RRS team also sought out brand owners with commitments to use PCR in packaging. The team also interviewed plastic reclaimers (the producers of PCR) and companies that both reclaim plastics and produce packaging, thus vertically integrating plastics recycling and packaging conversion. Those interviewed included small and large packaging converters, to provide perspectives on the impact of economies of scale.

RRS also conducted a literature search to supplement the information gained through the interview process.

RESULTS AND DISCUSSION

System Process Flow

Figure 2 presents the generalized process flow for plastics packaging conversion, revealing distinctions in cost factors involving scale and application. The research identified a fundamental distinction in costs associated with receiving, storage and handling depending on scale. Large scale operations utilize silos for storage and receive PCR by rail, while smaller scale operations received PCR in gaylord boxes or super sacks on trucks. Larger operations are more capital intensive but also more automated, while the smaller operations had fewer capital costs but much higher operating costs.

The conversion process itself varied depending on the application with polyolefin-based products incorporating screening and, in some cases, multi-layered lines.

GENERALIZED CONVERSION PROCESS FLOW CHART

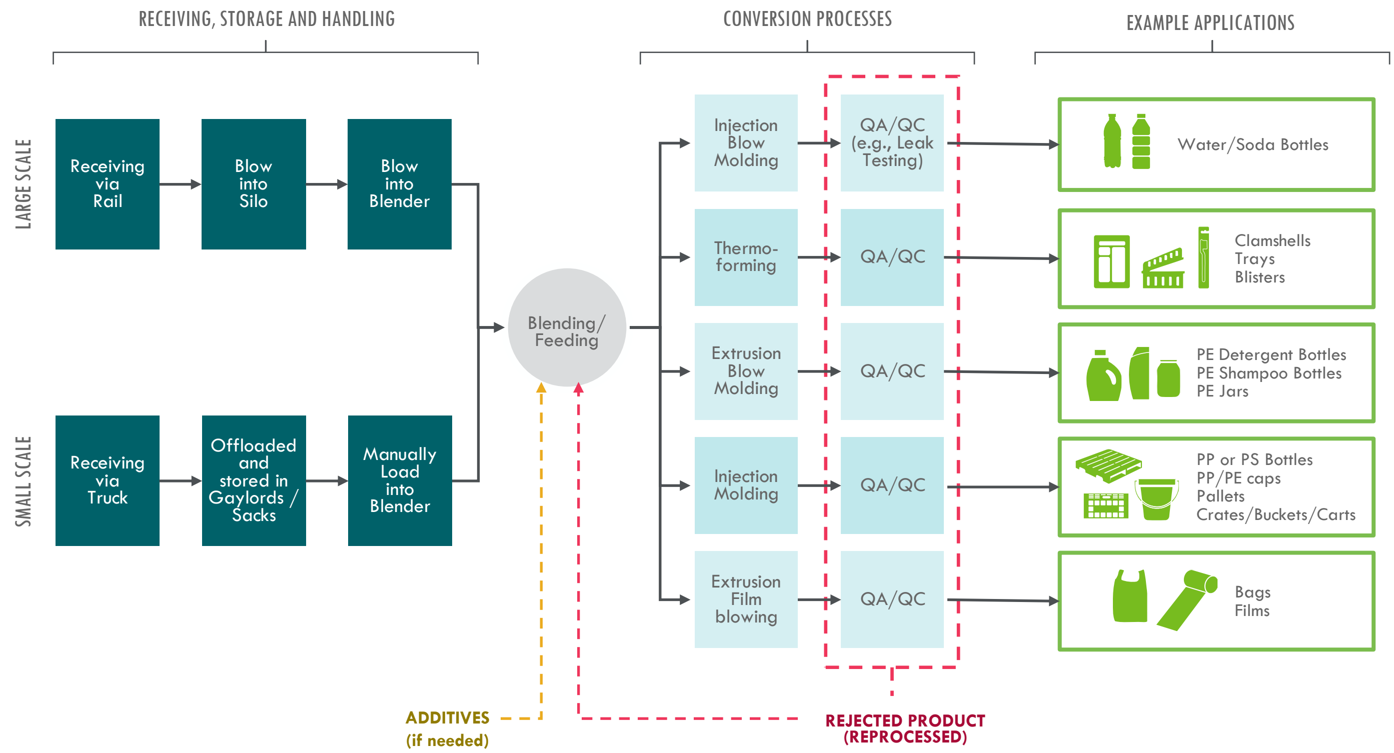

Figure 2. Conversion Process Flow Chart

The interviews identified the points in the process that resulted in increased costs when utilizing PCR instead of virgin, along with the specific associated costs. The cost factors revealed through the research and subsequently modeled by the RRS team are summarized in Table 1.

Table 1. Cost Considerations

CAPITAL COSTS	Storage
	Handling / Loading Equipment
	Pre-Processing Equipment
	Blending Equipment
	Screening System
	Extrusion System
	Testing Equipment
	Production Cost
LABOR COSTS & OTHER EXPENSES	Additives
	Loss Rates
	Added Processing / Cycle Time
	Testing

Model Outputs

Table 2 presents results from the cost model. The model documents a marginal cost of incorporating PCR from $.05 to $.24 per kg ($CAD). The research indicates that main factors influencing whether the cost is at the low or high end of that range is the application, the resin, and whether the PCR is food contact.

Table 2. Model Output (value in Canadian $)

Application	Food Contact	PCR%	Scale	Layers	CapEx per kg	OpEx per kg	Total	Avg weight (g)	Number of units per kg	Cost per unit	Cost per 1 million units
PET Bottle Carbonated	Yes	10-50%	LG	1	$0.08	$0.03	$0.11	27	37	$0.0029	$2,935.12
PET Bottle Water	Yes	100%	LG	1	$0.00	$0.05	$0.05	10	100	$0.0005	$468.73
PET Thermoform	Yes	30%	SM	1	$0.04	$0.11	$0.14	45	22	$0.0064	$6,441.19
Multi-Layer Film	Yes	<60%	SM	5	$0.03	$0.21	$0.24	7	143	$0.0017	$1,697.53
Multi-Layer Film	No	<30%	SM	3	$0.04	$0.15	$0.19	7	143	$0.0013	$1,297.01
Garbage Bag	No	<40%	SM	1	$0.01	$0.10	$0.11	30	33	$0.0034	$3,448.46
HDPE Laundry Bottle	No	25-35%	LG	3	$0.10	$0.08	$0.18	150	7	$0.0273	$27,259.54

The most significant costs related to incorporating PCR in many applications typically relate to front end material handling, quality testing and rejected product that must be reprocessed. Those costs manifest either as capital cost related to the construction of a silo for PCR, incorporation of automated testing (inspection equipment) and equipment for blending PCR and virgin resin, in the case of high-volume resins (e.g., PET), or as a mix of capital and labor costs related to transporting, storing, handling, mixing gaylord boxes or sacks of PCR with virgin, and quality testing, in the case of lower-volume resins. For applications utilizing multiple layers, retrofitting legacy converting systems from mono-layer to multi-layered systems emerged as the key cost consideration. Converters also commonly reported increased costs related to blending, screening, and loss rates. However, those factors were not consistently reported by all converters.

The research also identified the following considerations related to the cost of incorporating PCR in different contexts:

- **End use application matters**: Costs can vary depending on whether the application is rigid or film, coloured or natural, or different molding technologies. Film applications are more technically challenging, due to the thinner gauge material, and therefore experience additional costs in terms of loss rates and quality control. Clear or natural applications can create aesthetic challenges, but coloured applications (film or rigid) may require multi-layer production or other techniques to ensure the outer layer is the appropriate colour. Furthermore, injection molding technologies can be more forgiving than blow molding, as the stretching required during a blow molding application can make it vulnerable to quality issues, and related losses, when using PCR.
- **Whether inputs are food grade or not impacts process cost factors**: Food grade PCR is often preferred, even for non-food applications, as it represents a higher quality, and is more likely to meet more stringent technical specifications than non-food grade materials. Many facilities cannot accept non-food grade materials without triggering significant protocols and related costs to avoid cross-contamination, creating an additional incentive to rely on food grade PCR in all applications.
- **There are cost advantages to producing from 100% PCR relative to mixed PCR and virgin resin**: Using only PCR eliminates the added costs of storage, front-end material handling, and blending required for facilities that mix PCR and virgin materials. Facilities using 100% PCR can also adapt their production lines so that they can run with a lower loss rate. Depending on the packaging format, the converter may be able to reincorporate the packages that represent the "loss" into production. Converters using 100% PCR tend to be in applications that do not require significant stretching, such as non-carbonated PET bottles and thermoforms.
- **The size and the legacy of the facility impacts costs**: A large facility with multiple incoming material silos may not face any additional cost to store and handle incoming PCR, as they can simply reassign existing silos to this material. A facility that was designed to produce multi-layer films or multi-layer bottles may be able to easily incorporate PCR in a central layer, without adding new lines or equipment.
- **Use of PCR may increase product weight**: In certain applications (e.g., films) incorporating PCR, particularly at high levels, may require the product to be a thicker gauge, thus using more material per item. As such, the use of PCR may not lead to an increase in cost on a weight basis, but it will increase the amount of material used and thus the cost per item.

When considering these outcomes alongside existing literature the researchers can point to a survey conducted by the National Zero Waste Council. That study asked respondents to estimate the degree to which manufacturing food grade packaging using PCR would impact cost in comparison to the same package being manufactured using virgin resin. Across all resin types, it was estimated that the inclusion of PCR in the manufacturing of food packaging increased total cost by about 20%. This includes both feedstock and production costs.

The impact of using post-consumer PET, HDPE, and PP was estimated to have a smaller impact on cost in comparison to LDPE films or laminates. Respondents were also asked to gauge the economic viability of a range of recycling materials for use in food grade packaging, including paper, metals, glass and plastic. Less than 40% of respondents considered it to be "economically viable" to use recycled plastics in food grade packaging. Of the various resins, PET and HDPE were considered the most economically viable for recycling into food packaging.

Of note, this research only identified food contact PCR used in PET applications and as middle layers in food contact film applications. There were no examples of rigid food contact HDPE, or PP PCR usage.

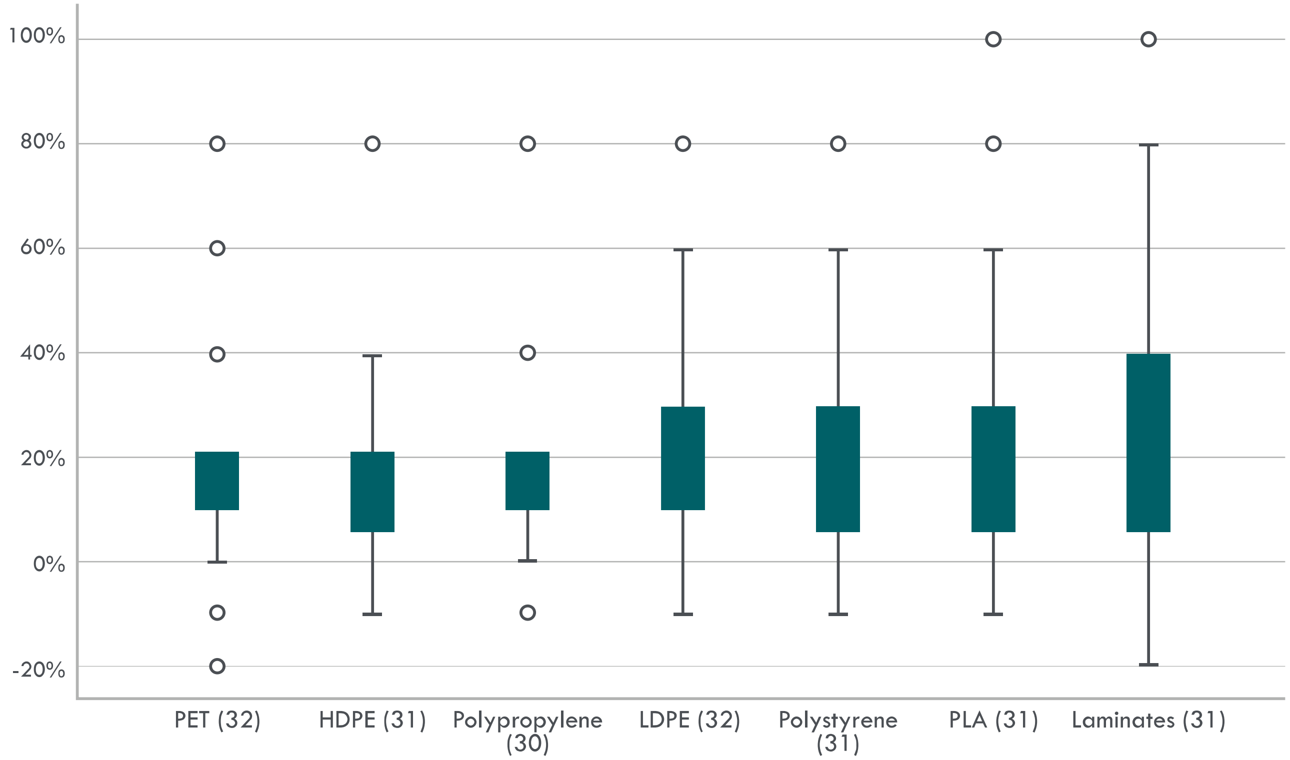

Figure 3. Cost Increase Due to Inclusion of Maximum PCR: Plastic Packaging. Source: National Zero Waste Council, 2020

PCR Content Thresholds

The literature and interviews revealed estimated maximums for PCR that can be used based on resin and specific application. Based on interviews, the most sensitive application for PCR is clear film, where PCR content can affect clarity with as little as 5%, and challenges increasing as the content increases. In general, the thinner a film is, the more sensitive it is to mechanically derived PCR content, which is inherently lower quality than virgin despite exhaustive efforts to improve quality. Interviews indicate that PET and HDPE bottles and thermoforms can incorporate up to 25-30% content before performance or aesthetics are impacted. With rigid PET packaging color becomes an issue when increasing over 30%, though can be overcome through use of additives to reach up to 100% content. Thicker, dark or gray colored film applications can incorporate up to 100% PCR, though the yield loss increases as content goes up beyond 25%. The most common way of incorporating PCR into film is through layering, where PCR is in the middle layers surrounded by virgin. This allows for up to 30% in a 3-layer system and up to 60% in a 5-layer system.

Technologies and Practices to Lower Production Costs

RRS' research revealed several methods that converters use to improve the quality of the products they produce using PCR, and / or reduce production costs.

Find the sweet spot. Several converters noted that they had identified a percentage of PCR content at which they could produce high quality product without creating significant performance issues, related yield loss, cycle time, and other cost increases. Depending on the application, those PCR content rates were typically around 30%. Maintaining production in that "sweet spot" ensures limited additional cost to incorporating PCR, while meeting customer demand for PCR content. This is particularly true in applications that have high performance specifications, such as carbonated soft drink containers, which need to be stretched more than non-carbonated bottles. To get beyond those levels would require an improvement in the quality of the PCR, a redesign of the package to overcome technical challenges, or technology improvements to allow for increased PCR content without related quality and yield issues.

Utilize beneficial additives. Some converters also use additives to improve the performance of PCR, either when blended with virgin resin or used in 100% PCR applications. Additives can overcome the negative impact of incorporating PCR on color and improve the properties of the resin. In one instance, a converter reported that the use of an additive, which was primarily incorporated to improve the color of the bottle being produced, reduced the energy consumption of the bottle's blow molding equipment by 40%, providing a significant process cost savings.

Skip the blending. One converter used 100% PCR content and avoided marginal additional costs associated with storing and blending both virgin and PCR. Some resin suppliers are also providing pre-blended resin, sometimes referred to as a "one-pellet solution". To the extent that the application can use 100% PCR or pre-blended resins this may be an option to reduce costs during the conversion process.

Design for scale. The ongoing operating costs of handling smaller amounts of PCR is greater than handling quantities through an automated silo-based system. The capital cost of building a silo and peripheral parts when amortized over the typical lifespan of 20+ years represents a lower per unit cost and would therefore reflect a production cost savings if the scale makes sense for the operation.

Other Factors that Impact Use of PCR

While the parameters of this analysis were drawn to eliminate the impact of supply, by assuming that there is sufficient supply of PCR at a price equivalent to virgin, it is clear that the shortage of PCR supply impacts the cost of incorporating PCR in the current market context.

The most direct impact of the PCR supply shortage on cost is reflected in the high cost of transportation and handling for PCR when supply isn't available in rail car / silo quantities. Several converters report purchasing PCR in gaylord boxes or sacks that are transported by truck. There is a cost increase in truck vs. rail transport, and significant operational costs to store, manage and handle PCR in boxes or sacks, as compared to silos. Recycled

PET is the only type of PCR that was consistently reported to be available in rail car / silo quantities. As such, the additional cost is typically incurred for all other types of PCR.

The quality of the PCR supply also has impacts on cost. Low quality PCR can have cascading cost impacts, including requiring additional inbound material testing and additional shipping / receiving labor costs and, if materials are rejected, potential downtime and run rate impacts. Quality can vary widely by supplier, depending on the systems and processes used, source of material, as well as quality control, and material testing procedures. Most converters attempt to control these costs by setting tight incoming material specifications and requiring suppliers to demonstrate materials meet them. As such, the cost of achieving the necessary material quality is borne by the plastic reclaimer who produces the PCR. While this cost is reflected in the price of PCR to the converter, it is not reflected in this analysis as the models presented herein assume that PCR and virgin materials are offered at the same price.

Some of the interviewees noted that the cost of PCR was a factor that inhibited increased use. While outside the scope of the study, stakeholders noted that high quality PCR often is at a cost premium over virgin, so even though the cost of conversion was not significantly higher with PCR, the cost of producing packaging with PCR content is. The price premium is most notable in recycled natural HDPE and in food grade recycled PET, both of which experience high demand resulting from corporate commitments to use recycled content and mandatory minimum recycled content laws.

CONCLUSIONS

While there are marginal costs to incorporating PCR in the production of plastic products and packaging, those costs are limited and do not appear to be the central factor in a company's determination of whether or not to utilize PCR. Most companies seek to use PCR where possible, due to increasing customer demand. They incorporate PCR where it is available at a price and quality that meets their business needs. Moreover, converters employ various practices to limit the cost increases related to incorporating PCR.

The interviews conducted as a part of this study revealed that the costs associated with the incorporation of PCR in the conversion process are perceived to be less impactful compared to the costs incurred in the plastic reclamation process to produce PCR at required quality and quantities. That is to say, most of the additional cost in incorporating PCR is embedded in the cost of the PCR to the converter and is not incurred in the process of producing packaging. Since this project assumed that PCR is available at the same price as virgin plastic, that cost is not reflected in this analysis.

Furthermore, building a sufficient supply of PCR would likely reduce the incremental cost of incorporating PCR in the conversion process. The model indicates that rPET products have a lower cost than other PCR resins, due to the availability of rPET in quantities that can be shipped by rail and stored in silos. If other resins were available in sufficient quantities, their transportation, handling and blending costs would be reduced. It is notable that the application with the lowest incremental cost uses 100% PCR, thereby eliminating the need for separate storage and blending. If PCR supply were available in sufficient quantities and at suitable quality to produce more products and packaging at 100% PCR, the incremental cost would also be reduced.

RRS | 416 LONGSHORE DRIVE, ANN ARBOR, MI 48105 recycle.com