Life Cycle Assessment of Corrugated Containers and Reusable Plastic Containers for Produce Transport and Display

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A Corrugated Packaging Alliance (CPA) White Paper

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Corrugated packaging is the most recycled material on Earth – in 2018, more than 96% of U.S. corrugated production was recovered for recycling, a staggering success that comes from decades of industry effort. Compare that with plastic: with an estimated one million plastic bottles (alone) sold globally every minute, **less than 10%** of all plastics are being recovered for recycling at last count (2015), and that number has been projected to shrink below 5% in 2018.

But, to be fair, recycling is only one aspect of any packaging material's environmental impact, and in industry, questions of sustainability are quite a bit more complex. With growing public awareness of sustainability issues, businesses are more focused on their environmental footprint than ever.

Grocery: On the front lines

Today, consumers' values deeply affect their shopping choices, and supermarket retailers are decidedly finding ways to operate as sustainably as possible. When grocers examine their supply chains, looking for ways to optimize logistics, decrease "shrink" (product damage), reduce costs and minimize their environmental impact, they often consider packaging.

The supply chain for fresh produce and perishable grocery products is particularly sensitive to environmental and handling conditions. Temperature control, shipping efficiency and timeliness, and cleanliness are crucial to prevent spoilage. Plus, fresh fruits and vegetables need to be packed in cushioned comfort to avoid bruising.

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The corrugated industry has been proactive and has a long history of working closely with the grocery industry to understand and meet their needs for reliable, responsible, economic packaging. Grower-shippers, too, have relied on box suppliers to innovate, design custom containers for products, and help keep their retail customers happy. In addition, the corrugated industry has regularly evaluated its environmental performance by commissioning third-party, peer-reviewed, ISO-compliant life cycle assessments (LCAs) to objectively assess corrugated packaging's impact on the environment.

In 2018, the Corrugated Packaging Alliance commissioned an LCA with Quantis, a leading sustainability consulting group. The study compares the environmental impact of a corrugated container and a reusable plastic container (RPC) across eight

common produce commodities and shows neither corrugated containers nor RPCs have an advantage in all environmental impact categories.

The assessment indicates that the two container systems have different environmental impacts which create value-based trade-offs. To minimize the footprint of delivering products to market, grower/shippers and packers should evaluate individual commodities, transport distances and other variables rather than rely on a one system fits all perspective.

Further, impact indicators differ in relative importance. When comparing systems using market-weighted averages, the corrugated container system has an advantage for global warming, eutrophication, and non-renewable resources. RPCs have an advantage for acidification, smog, respiratory effects and ozone depletion. When comparing systems using commodity-specific averages, corrugated containers have an advantage for global warming and non-renewable energy use and RPCs have an advantage for acidification, ozone depletion and respiratory effects.

Full results of the latest LCA are available here and are summarized within this document.

2018 LCA Executive Summary

The relative environmental profiles of single-use corrugated shipping containers and reusable plastic shipping containers (RPCs) have been investigated in recent years using a life cycle approach. This research has been aimed at helping industry better understand the relative environmental profiles of corrugated containers and RPCs for produce transport, storage and display in the U.S.

The Corrugated Packaging Alliance (CPA) commissioned Quantis to perform an ISO 14044 compliant comparative Life Cycle Assessment (LCA) of corrugated containers (CCs) and reusable plastic containers (RPCs) used to transport and display fresh produce (e.g., apples) in the U.S. This investigation aimed to identify the relative environmental performance of these two container systems. More specifically, the objectives of the study were to:

1. Establish credible and transparent profiles of the life cycle potential environmental impacts of corrugated containers and RPCs utilizing appropriate and accepted databases and Life Cycle Inventory Assessment (LCIA) characterization factors according to ISO 14040 and 14044:2006;

2. Identify the magnitude and confidence of comparative environmental advantages of either system; and

3. Ensure compliance of results with ISO 14044 (clause 6) and ISO 14040 (clause 7) to support a public comparative claim, including critical review by a panel of interested parties.

This study includes comparative statements regarding the environmental performance of the two products. It evaluates the relative environmental performance of single-use corrugated containers and RPCs in the context of the U.S. produce market through an ISO 14044 compliant LCA.

The corrugated containers and RPCs under evaluation are utilized for transporting produce from produce grower to a retail market. The reusable container studied is a standard footprint RPC that is available in the U.S. as a produce packaging solution. The corrugated containers evaluated for comparison are the most prevalent size used for each commodity and were selected based on data from member companies who combined provide more than 70% of the boxes to the produce sector.

The functional unit for this study is to provide containment during filling, transport and display of 1,000 short tons of grocery market produce in the United States in a manner that maintains the safety of the produce for human consumption and that is consistent with commercial supply chains. The container profiles investigated are specific to eight types of produce: apples, carrots, grapes, lettuce (head), oranges, onions, tomatoes and strawberries. As the intent of this study is to capture a snapshot of average U.S. industry operations, only U.S.-grown produce are considered, and seasonal variation is not discretely evaluated.

This study assesses the life cycle of corrugated containers and RPCs from the extraction and processing of all raw materials through the containers' end-of-life. The models are intended to represent the RPC and corrugated industries and associated processes in the United States at the time the study was conducted. As there is a lack of published studies evaluating the myriad parameters applicable to this

The study investigated container profiles specific to eight types of produce: apples, carrots, grapes, lettuce (head), oranges, onions, tomatoes and strawberries.

assessment (e.g., recycled content, RPC number of uses, etc.), the work herein represents CPA's understanding of each industry based on its own research. Information from pre-existing, recent life cycle studies on corrugated containers and RPCs are used as applicable in conjunction with information offered in confidence by both corrugated and RPC industry members. Available life cycle data for some elements of the systems represent industry operations as early as 2002.

TRACI 2.1 was chosen as the primary impact assessment method for this study, except in the case of the non-renewable energy indicator. TRACI's fossil fuel use indicator was substituted by the non-renewable energy indicator from IMPACT2002+ v2, as it is a direct assessment of energy use and does not require projections regarding the future state of resource availability and consumption. Environmental indicators for land use and land transformation are excluded. These were not able to be adequately quantified due to the lack of inventory data. Also excluded are indicators for ecotoxicity and human health (carcinogens and non-carcinogens) because the toxicity-related data used for the RPC and corrugated container systems are not comparable. A total of seven (7) environmental metrics are evaluated with no normalization of results or weighting of impact categories: acidification, eutrophication, global warming, non-renewable energy, ozone depletion, respiratory effects and smog formation. Two (2) inventory flows are also presented: freshwater consumption and solid waste. GaBi 8 software was employed to perform the calculations. Several additional evaluations were performed to understand the robustness of the study conclusions. These include numerous sensitivity tests around the corrugated container and the RPC systems, calculation of results using a second impact assessment method (ReCiPe 2016), and a data quality assessment. The latter consists of a completeness and consistency check of the data, a contribution analysis, and an uncertainty analysis. An external panel was commissioned to conduct a review in accordance with the ISO 14040 series.

Results

Figures ES-1, ES-2 and ES-3, following below, demonstrate some of the baseline results found in this study. Figure ES-1 depicts the market-weighted average results for each container system. Figure ES-2 shows the commodity-specific results for corrugated containers and RPC systems. Figure ES-3 depicts the potential ranges of impact for each container system carrying apples. Conclusions reached by this study are based on the baseline results for all commodities in combination with results of the sensitivity tests and uncertainty and data quality analyses performed.

Market-Weighted Results

The market-weighted average results in Figure ES-1 show that four of seven (4/7) impact categories are favorable for the RPC system, and three of seven (3/7) impact categories are favorable for the corrugated container system. Specifically, acidification, ozone depletion, respiratory effects and smog formation show lesser environmental impact for RPCs. Eutrophication, global warming and non-renewable energy use demonstrate better environmental performance for corrugated containers.

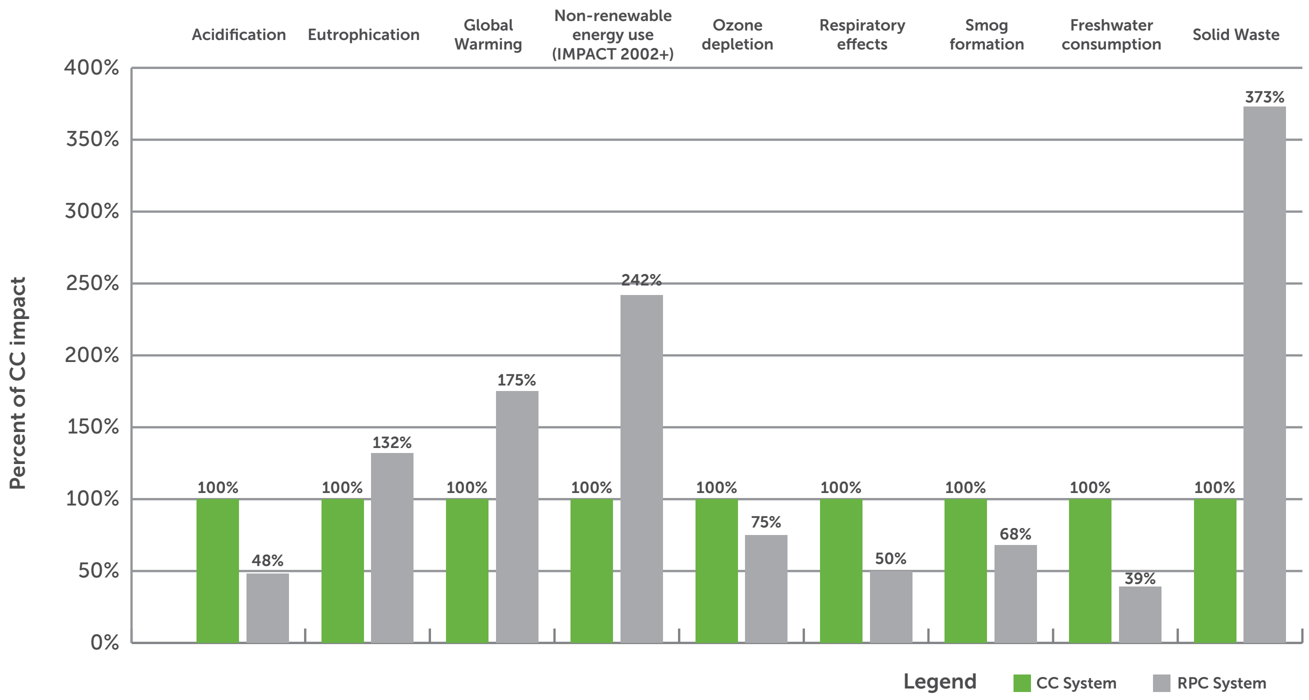

Figure ES-1. Market-weighted average results for the baseline analysis

These observations of the market-weighted average results do not consider uncertainty. While the uncertainty analysis was carried out only for the commodity-specific results, it is reasonable to apply those outcomes here in a broad way. In doing so, the list of indicators that favor RPCs is narrowed to acidification, ozone depletion and respiratory effects, and the list of indicators that show an advantage for corrugated containers reduces to global warming and non-renewable energy use. From a market-weighted average perspective, tradeoffs exist in the environmental profiles of corrugated containers and RPCs.

Commodity-Specific Results

Commodity-specific results show similar trade-offs between the container systems. Digging deeper, across the commodity-specific results shown in Figure ES-2, four of seven (4/7) impact categories are favorable for the RPC system, and two of seven (2/7) impact categories are favorable for the corrugated containers system. For the remaining indicator (eutrophication), the direction of the advantage is not consistent across commodities, as no discernible difference can be made for grapes and onions. Thus, a conclusion for eutrophication regarding the directional results cannot not be made with confidence.

The RPC system has an advantage in acidification, respiratory effects, ozone depletion and smog formation while global warming and non-renewable energy use shows an advantage for corrugated containers. However, after considering the uncertainty assessment of the results, three (3) impact categories show an advantage for RPCs (acidification, respiratory effects, and ozone depletion), and two (2) impact categories show an advantage for corrugated containers (global warming and non-renewable energy use). No difference between the systems can be concluded for smog formation and eutrophication given the level of uncertainty in those results.

Further, the data quality assessment reveals that the corrugated containers inventory data used to calculate eutrophication is characterized by high uncertainty, and due to its important influence on the results, it is not possible to conclude whether one container system is more than or equally impacting eutrophication as the other. This observation reinforces the conclusion made earlier regarding the inability to judge the relative performance of the container systems in terms of eutrophication. Thus, without prioritizing types of impact, it is not possible to say from the present assessment that one of these systems is an overall better environmental performer than the other on the US market, and it does not appear that further refinements in data or methodology would be likely to find a fully consistent directional finding.

Best and Worst Case Results

The best and worst case scenarios support these conclusions. Taking the apple system as an example (Figure ES-3), the RPC system range of results for non-renewable energy use sits completely above the corrugated containers system range of results for the same indicator. This lack of overlap confirms the deduction made from the baseline and uncertainty analyses: the corrugated containers system uses less non-renewable energy than the RPC system across all market conditions. A similar and opposite conclusion can be drawn when comparing the best and worst case

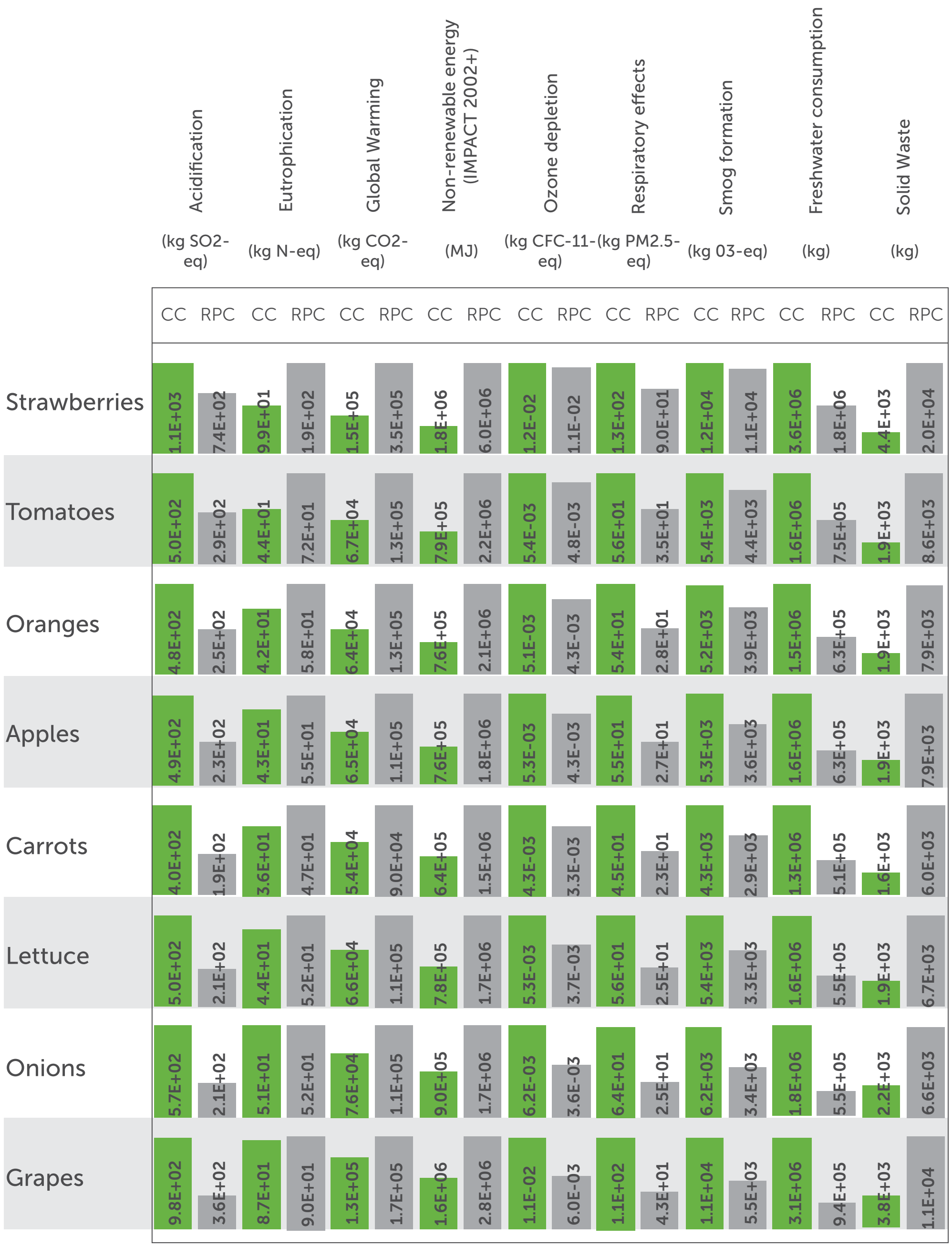

Figure ES-2. Baseline results (impact per functional unit) for the 8 commodities evaluated in this study. Commodities are ordered from greatest to least functional unit mass ratio. Each bar is shown relative to the system of greatest impact for that impact category and commodity.

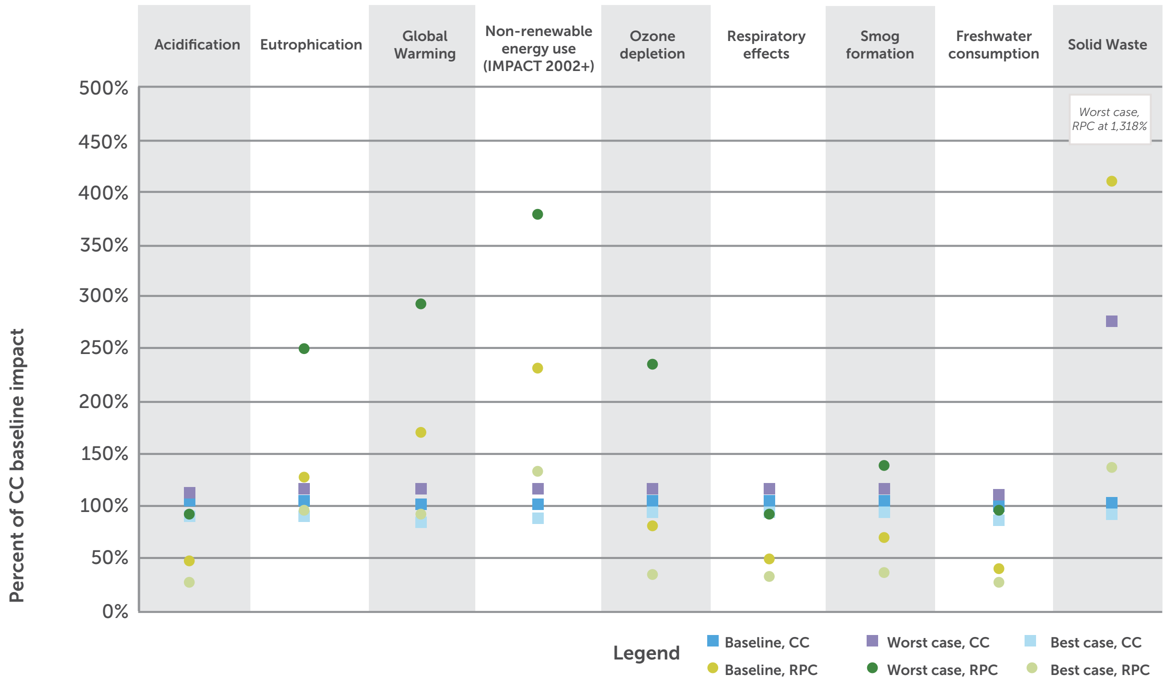

Figure ES-3. Baseline, best and worst case scenarios for RPCs and CCs containing apples. For each indicator, a score higher than 100% indicates greater impact than the CC baseline results.

results for apples in acidification and respiratory effects. The ranges of RPC results are almost entirely below the range of the corrugated containers results, meaning that in most market conditions, RPCs are less impacting for these two indicators. For all other indicators, there is notable overlap between the span of best and worst case results for the two systems. This means that neither container system has a clear advantage for these metrics.

The strawberry and grape systems show similar outcomes. However, the overlap between the best and worst case results occurs in somewhat different indicators. This means that within the range of industry variability captured by the sensitivity analyses, the directional conclusions can change for all but a small number of indicators, specific to each commodity.

Conclusions

While tempting, it is not appropriate to determine the comparative advantage between container types by counting the number of indicators in which a container system shows less impact. Counting the number of categories supporting a container system requires the assumption that each category of impact is equally important. While it is possible to have views or values that define the importance of each category, it is not possible for the authors to defend these values as more correct than the values that might lead another party to a different decision. It is therefore not possible here to draw a definitive conclusion of environmental superiority in cases where there are conflicting indicators that require a trade-off that is primarily value-based. In such cases, including the current one, the only overall conclusion that can be drawn is that trade-offs exist between the systems. Users of this study may apply values systems to arrive at conclusions that may assist in making selections between the container systems under different market conditions.

The inventory flows, freshwater consumption and solid waste, are not considered when comparing the environmental performance of the corrugated containers and RPC systems because they are inventory flows only and not impact indicators. They are included to provide a sense for the amounts of these flows required/generated by the system, which allows for some reflection on how results of this study may differ from those of comparable past and future assessments.

The environmental performance of each system is influenced by variation within their life cycles, and the combination of assumptions made for a single system causes the total impact to vary. The ranges observed for this study's context demonstrate that the assumptions about the RPC life cycle coupled with the assumptions for the corrugated containers life cycle can affect the directional findings of the study in certain indicators. This is true for all indicators.

Corrugated containers' weight and RPC transportation distances are the most influential factors in determining the relative results between the two container systems. However, it appears that even in those conditions within the market variability that would seem to favor one system more so than the other, a clear environmental advantage for either system is not likely to exist for most commodity systems.

The results, on balance, show that variation exists in the comparative findings among the categories of impact assessed, and, for a given commodity, the environmental trade-offs between container systems can be predicted based on the ratio of the masses of containers required to achieve the functional unit for each container system. The difference in container mass needed to ship a specified quantity of produce determines which indicators show an advantage for each container system.

Both systems have opportunities to improve and lessen their impact on the environment. For the corrugated containers system, this includes minimizing container weight and maximizing container recovery. The RPC system can achieve environmental performance improvement through increasing reuse and recycled content along with reducing breakage/loss as well as transport distances.

For most of the environmental indicators considered, the impacts associated with produce production far outweigh most or all of the processes in the life cycle of a container, and differences of even a few percent in produce loss between the two container types would likely dictate the relative environmental performance for those indicators. Data describing product protection of the containers (i.e., perishability differences) are not available but could potentially push the advantage in one direction or the other if a significant difference exists.

While this study considers a steady-state market in which the containers evaluated are not changing in the middle of providing the functional unit, it is important to note that container weights and/or dimensions can change over time. Additionally, custom container designs for specific retailers, though not evaluated here, can result in inventories of containers with useful service life remaining when the designs are no longer needed. When a system stops operating before the containers meet their useful service life, a larger portion of the production and disposal impacts of the containers are allocated to that system. In other words, the impact per container is higher because there are fewer lives over which those impacts are distributed.

An important knowledge gap is around the number of RPCs in float[1]. This study takes a conservative approach, assuming float makes up a very small portion (<1%) of the total mass of crates in the system. The effect of this approach is that environmental impact associated with float is negligible. If float is a much larger portion of total mass, its contribution to impact can be important and therefore should be included in a study such as this one.

Considering the conclusions of this study with those of other LCAs comparing corrugated containers and RPCs, the overall deduction is that environmental trade-offs indeed exist between the RPC and corrugated containers systems, and the market characteristics, which vary by geography, have an important influence on these trade-offs. Given the closeness of results between the two systems in certain impact categories and the sensitivity of the results to certain factors, it is clearly important to model in detail the specific market in question.

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[1] Float refers to the quantity of excess RPCs that exist in the total system. These excess RPCs are required to assure the flexibility.

About the Corrugated Packaging Alliance

The Corrugated Packaging Alliance (CPA) is a corrugated industry initiative, jointly sponsored by the American Forest & Paper Association (AF&PA), AICC – the Independent Packaging Association, the Fibre Box Association (FBA) and TAPPI. Its mission is to foster growth and profitability of corrugated in applications where it can be demonstrated, based on credible and persuasive evidence, that corrugated should be the packaging material of choice; and to provide a coordinated industry focus that effectively acts on industry matters that cannot be accomplished by individual members. CPA members include corrugated manufacturers and converters throughout North America.

For more information about corrugated recycling, visit www.corrugated.org, and follow us on Twitter (@corrugatedpkg) at https://twitter.com/corrugatedpkg.