Sustainability Life Cycle and Economic Impacts of Flexible Packaging in E-commerce

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Prepared for The Flexible Packaging Association
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About the Flexible Packaging Association

The Flexible Packaging Association is the voice of the U.S. manufacturers of flexible packaging and their suppliers. The association's mission is connecting, advancing, and leading the flexible packaging industry. Flexible packaging represents over $31 billion in annual sales in the U.S. and is the second largest and one of the fastest growing segments of the packaging industry. Flexible packaging is produced from paper, plastic, film, aluminum foil, or any combination of those materials, and includes bags, pouches, labels, liners, wraps, rollstock, and other flexible products.

About PTIS

PTIS, LLC is a leading business and technology management company focused on Creating Value Through Packaging© and helping clients throughout the packaging value chain develop long term packaging strategies and programs. PTIS, recognized for foresight, thought leadership, and the success of their 20 year *Future of Packaging* program, helps companies achieve and incorporate these elements into their innovation programs, e-commerce, holistic productivity, sustainability, holistic design, and consumer/ retail insights related to packaging. To learn more about PTIS, visit their website www.ptisglobal.com

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List of Acronyms

APR	Association of Plastic Recyclers
BON	Biaxially Oriented Nylon
BPI	Biodegradable Products Institute
BTU	British Thermal Unit
EPA	U.S. Environmental Protection Agency
FPA	Flexible Packaging Association
GHG	Greenhouse Gas Emissions
HDPE	High Density Polyethylene (labeled as #2 plastic)
IPCC	Intergovernmental Panel on Climate Change
ISO	International Organization for Standardization
LCA	Life Cycle Assessment
LCI	Life Cycle Inventory
LCIA	Life Cycle Impact Assessment
LDPE	Low Density Polyethylene (labeled as #4 plastic)
LLDPE	Linear Low-Density Polyethylene
MJ	Megajoule
MRFF	Materials Recovery for the Future
MSW	Municipal Solid Waste
NAPCOR	National Association for PET Container Resources
PCR	Post-Consumer Recycled
PE	Polyethylene
PET	Polyethylene Terephthalate (labeled as #1 plastic)
PP	Polypropylene (labeled as #5 plastic)
SMM	Sustainable Materials Management
SPC	Sustainable Packaging Coalition
WRAP (UK)	Waste Resources Action Programme

Chapter 1

Executive Summary

Introduction

E-commerce is a growing economic segment, experiencing a 14.9% growth rate in 2019[1] in the U.S., and is expected to maintain annual growth rates of approximately 13% through 2023[2]. As more products are shipped via e-commerce, brands continue to look for ways to optimize the shipping, reduce costs, and reduce environmental impact, while offering consumers a positive experience. In an effort to achieve these goals, more brands and e-commerce providers are using flexible packaging as either the primary package due to its ability to withstand robust handling and limit leaks, or as the e-commerce delivery pack itself as a way to reduce the amount of packaging material and space utilized.

This report looks at five different case studies and products to quantify the environmental impact of different flexible and non-flexible e-commerce packaging options, as well as the economic shipping impacts, based on dimensional weight charges vs. billable weight. To quantify the environmental impacts, a streamlined Life Cycle Assessment (LCA) tool (EcoImpact-COMPASS®) was used, along with calculations on overall material used, recycled, and disposed.

The case studies include a wide range of products including shoes, cereal, peanut butter, laundry detergent, and flat mailers across an array of packaging options used in e-commerce packaging. All of the products were purchased online in September and October 2019.

For the assessment all primary, secondary, and tertiary packaging, including dunnage from the packages were used.

Report Objective

The Flexible Packaging Association (FPA) commissioned this report with the goal to:

- Provide a holistic view on the sustainability benefits that flexible packaging offers in e-commerce
- Quantify the environmental and economic shipping impacts comparing flexible packaging to other formats across a range of products

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[1] Young, Jessica. "US Ecommerce Sales Grow 14.9% in 2019." February 20, 2020. https://www.digitalcommerce360.com/article/us-ecommerce-sales/

[2] Lipsman, Andrew. "US Ecommerce 2019." *EMarketer,* 27 June 2019, https://www.emarketer.com/content/us-ecommerce-2019

Quantifying Environmental Impacts - About Life Cycle Assessment (LCA)

Because of the many challenges in quantifying sustainability impacts, a number of companies are using life cycle assessments (LCA) to help understand and quantify the environmental impacts in the design phase, before a package is brought to market. An LCA is a method for characterizing impacts associated with the sourcing, manufacturing, distributing, using, and disposing of a product or product system.

The goal of LCA tools is to understand the environmental impacts of packaging selection in the design phase, so packaging designers and brands can make more informed selections based on company and brand sustainability goals and package performance variables and attributes.

Life Cycle Assessment Case Study Results

For the report, five different LCA case studies were developed using the EcoImpact-COMPASS® LCA software, which allows for quick life cycle comparisons between different package formats. This is also known as a streamlined LCA since the data is based on industry averages rather than a specific company's process. Streamlined LCAs are much more cost effective and time efficient than full blown LCAs. All packaging materials used to get the product to the consumer (primary, secondary, tertiary) were evaluated for this report. Additionally, the product-to-package ratio as well as the amount of packaging that is landfilled for 1000 kg of each product was determined. The amount of packaging landfilled was based on the recycling rates for each material, while assuming none of the flexible packages were recycled.

The results from many of the case studies show that flexible packaging has more preferable environmental attributes for carbon impact, fossil fuel usage, water usage, as well as material disposed, when compared to other package formats. This is due to the efficient use of resources enabled by flexible packaging.

Much of the flexible packaging used in e-commerce applications, including bubble dunnage or poly mailers are made of LDPE, which can be recycled with grocery bags as part of the grocery store drop-off program. These materials can qualify for the How2Recycle® store drop-off designation if they go through the certification process. Dunnage is a filler that is used to prevent a product from shifting during shipping, resulting in product damage. Dunnage may be either paper or plastic based, and includes crumpled paper, corrugated inserts, air pillows, and bubble wrap.

An additional benefit of flexible packaging can include the robust nature of the material, which can help reduce leaks or package breaks, thus significantly improving consumer enjoyment of a product (and brand). This can be especially important in an e-commerce environment where the product is handled at least three times as often as is done within a traditional retail channel.

When making any environmental claims, it is important to follow the U.S. Federal Trade Commission *Green Guides* to be sure companies are not "greenwashing" or overstating any claims.

In all of the tables, the percentages shown are using the flexible package as the baseline in the case study. Percentages in red mean those (positive) values are less preferable than the flexible package, while percentages shown in blue mean those (negative) values are preferable to the flexible package.

The example below (Table 1-A) shows the case study for cereal. For additional information on the individual studies see Chapter 3 which includes the detailed analysis for each study.

Table 1-A. Cereal Packaging Comparison Summary

Format	Fossil Fuel Consumption (MJ deprived) *(from Fig 3-4)*	GHG Emissions (kg-CO2 equiv) *(from Fig 3-5)*	Water Use (l) *(from Fig 3-6)*	Product-to-Package ratio and percent wt. *(from Table 3-E)*	Pkg Landfilled (g)/1,000 kg cereal *(from Table 3-E)*
Stand-up Pouch w/ Press to Close Zipper, Case	1.22	.07557	12.50	7.4:1 88.0%:12.0%	12,619
Bag-in-box, Case in Overbox	3.94 (+223%)	.4117 (+445%)	100.98 (+708%)	1.65:1 62.2%:37.8%	91,034 (+621%)
Bag-in-box, Case (no Overbox)	2.70 (+121%)	.2951 (+291%)	65.10 (+421%)	3.0:1 75.1%:24.9%	50,532 (+300%)

Note: Trayak constantly updates the EcoImpact-COMPASS® LCA software with new inputs from data sources. Therefore, results for specific life cycle metrics may change over time.

Shipping Economic Impact (Dimensional Weight)

For the shipping impact of the different options, 4 case studies were reviewed to look at the overall shipping container size and impact of published shipping costs. Dimensional weight is a term that combines two disparate measures of distance (length x width x height) and a measure of mass (weight) and relates them into a specific calculation. Carriers then use the greater of dimensional weight or actual product weight to determine the billable rate they will charge for shipping.

Cost for dimensional weight in this report are directional as most major retailers, e-commerce providers, and brand owners will negotiate preferred rates for their products.

The results summary:

- In 3 of the 4 case studies, the flexible primary format delivered the smallest dimensional weight, which translated to lowest shipping costs when it was the billable weight
- Flexible formats demonstrate great potential to take advantage of Flat Rate Shipping costs, which offer dimensional weight tiers that are cost effective for products under 50 lbs. actual weight
- The cereal case study showed an example where a primary package made from flexible packaging yielded a much smaller cube and thus a reduction in shipping cost
- The use of flexible packaging as the tertiary shipping package for e-commerce applications (for categories like shoes and clothes) can drive additional package reduction and savings in shipping costs as highlighted in the shoe case study
- Dunnage can play a role in product protection, but also increase package dimensions
- Some products arrived with an additional e-commerce overbox that appears could be eliminated if the product went through an e-commerce certification program such as Amazon's Frustration Free shipping program, showing there is still ample opportunity to continue to optimize e-commerce packaging

Note: The study did not look at damage rates for products in a particular format for e-commerce. This can vary based on a number of attributes and handling conditions. All products evaluated for this study arrived in good shape.

Acronyms – Chapter 1

CE	Circular Economy
EPA	U.S. Environmental Protection Agency
FPA	Flexible Packaging Association
LCA	Life Cycle Assessment
LDPE	Low Density Polyethylene

Chapter 2

Life Cycle Assessment and Flexible Packaging

Introduction

As companies have become more conscious about sustainability, many have set specific goals to reduce their environmental impact. Corporate sustainability goals often include specific metrics tied to packaging. These may include weight reduction in total amount of packaging used, recyclable packaging use, reduction in factory waste sent to landfill, and carbon footprint among others.

Making a selection of the “optimal” package requires a balance of a number of key attributes which are conveyed in Figure 2-1. These include product protection, packaging cost and material options, brand equity that is conveyed through the package design, the consumer experience enabled through features such as easy opening and reclose, sustainability attributes linked to the brand/company goals, and finally any service such as weblinks or 1-800 numbers for other product information.

Figure 2-1. PTIS Product Formula

Consumers view products as an integrated experience and transfer experiences with the package to the product. As such, sustainability attributes are almost never considered on their own, but as part of the entire product experience for consumers.

About Life Cycle Assessment (LCA)

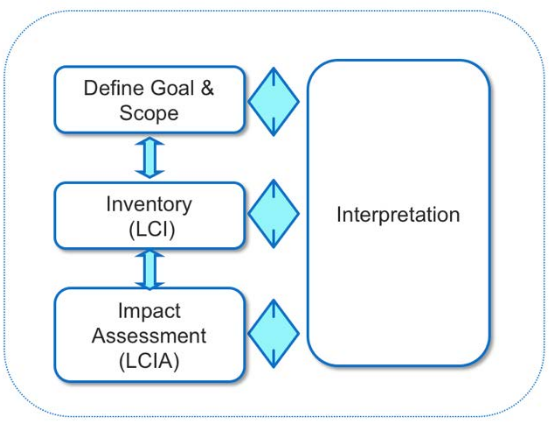
Because of the many challenges in quantifying sustainability impacts, a number of companies are using life cycle assessment (LCA) tools to help understand and quantify the environmental impacts in the design phase, before a package is brought to market. An LCA is a method for characterizing impacts associated with the sourcing, manufacturing, distributing, using, and disposing of a product or product system. The tool is used by product and package developers to calculate environmental impacts such as fossil fuel consumption, greenhouse gas emissions, and water consumption. Understanding these LCA indicators gives package developers an idea of the environmental footprint of products and packages. This allows developers to benchmark current designs and compare new design options.

A full LCA, however, can be a very time consuming and expensive process looking at impacts of material extraction, processing, transportation, and end of life for every product. More companies are using "streamlined" LCA tools, which use industry provided data, validated by independent third parties, rather than data specific to an individual company's exact process. This allows for much faster and less costly assessments. It also allows for packaging developers to do more "what if" scenarios quickly to understand potential environmental impacts at the design stage and hone in on the preferred options more quickly.

The development and use of an LCA requires the definition of the boundaries, as well as obtaining the background information necessary to obtain the environmental impact metrics.

The first step is to define the goal and scope of the system that will be evaluated (Figure 2-2). In the case of this study, the system is the process of extracting materials, converting, distribution, and end of life for a package.

Figure 2-2. LCA Overview



The inventory analysis utilizes data of energy or water used within each stage (extraction, conversion, etc.) of the system. The impact assessment uses that input data to drill down to "what does it mean," such as what are the emissions based on the fossil fuel used in production of that system.

Terminology

Life Cycle Inventory (LCI) - component of an LCA that tabulates or prepares a numerical accounting of the emissions or energy and raw materials consumption of a system.

Life Cycle Impact Assessment (LCIA) - the "what does it mean" step. In LCIA, the inventory is analyzed for environmental impact. For example, manufacturing a product may consume a known volume of fossil fuel (this data is part of the inventory); in the LCIA phase, the greenhouse gas impact from combustion of that fuel is calculated.

Life Cycle Assessment (LCA) - A holistic assessment of the environmental emissions and resource and energy consumption of a system of processes or activities and the potential environmental impacts of those emissions or consumption. It is holistic because it includes activities from cradle (extraction of resources from the earth or biota) to grave (ultimate disposal of the expended resources back into the earth).

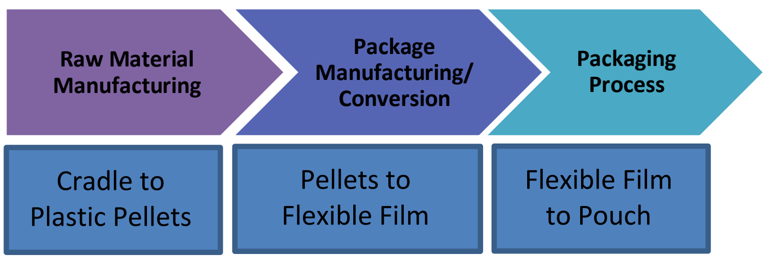
System – The set of process or activities necessary to perform a service or produce a product.

Finally, the LCA tool allows for interpretation and comparison of different materials, package formats, and packaging components based on a common functional unit, such as weight of product, or number of product uses.

Life Cycle Boundaries

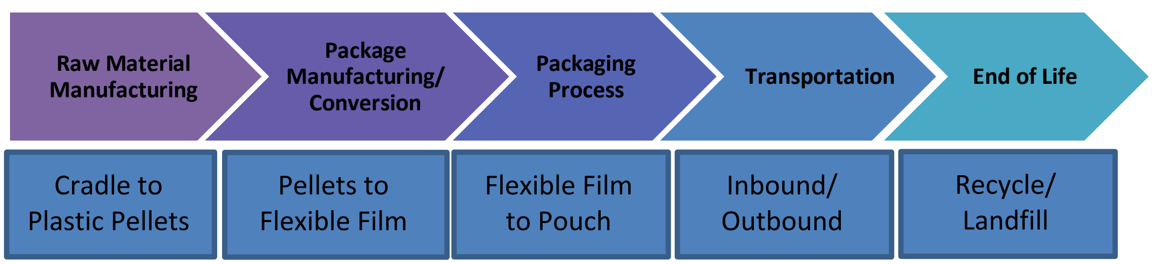
Within the use of an LCA, one of the critical components to consider is what the boundary of the system will be. An example in packaging, is a system boundary of "Cradle to Factory Gate" or "Cradle to Grave." Figure 2-3 shows an example of a "Cradle to Factory Gate" where the boundary goes from raw material manufacture up to the forming of a package, which could be laminating multiple layers of film to form a flexible pouch.

Figure 2-3. Cradle to Factory Gate Boundary and Flexible Package System Example



In Figure 2-4, a Cradle to Grave approach expands the boundary to include the transportation and end of life impacts.

Figure 2-4. Cradle to Grave Boundary and Flexible Package System Example



For the life cycle assessment used in this study, a Cradle to Grave boundary was used for primary, secondary, and tertiary packaging.

The software tool utilized for the LCA examples provided in this report was EcoImpact-COMPASS®. This tool was developed specifically to provide an LCA for the packaging industry.

About EcoImpact-COMPASS®

EcoImpact is a holistic package and product sustainable platform to calculate various sustainability indicators. The platform houses the Comparative Packaging Assessment

(COMPASS®) developed by the Sustainable Packaging Coalition (SPC), which is part of GreenBlue, an environmental nonprofit dedicated to the sustainable use of materials in society and Trayak, a software and sustainability company which now maintains and updates the software. COMPASS® is a module that enables companies to model various packaging systems and calculate the environmental impact using a screening LCA method. EcoImpact was developed as a guidance tool that can inform material selection for packaging and/or product design. Essentially, it is a design-phase tool that provides comparative environmental profiles for packaging/product designs based on life cycle assessment metrics and additional attributes.

The information provided through an LCA can help a company make data-driven decisions in evaluating alternative packaging options. The packaging systems are modeled using industry average data for common packaging materials, processes, and end of life scenarios. This provides a consistent approach to gauge the relative performance of one package design to another based on the packaging functional unit.

COMPASS® also allows users to:

- Model primary, secondary, and tertiary packaging components + entire systems
- Analyze detailed environmental impacts (consumption and emission metrics)
- Identify hotspots or areas for improvement
- Benchmark the environmental profile of a company's existing packaging
- Compare a range of different design alternatives
- Incorporate environmental feedback into designs

More companies are incorporating the use of an LCA tool as part of the development process to drive decision making and alignment with overall corporate sustainability goals. Some tools such as EcoImpact-COMPASS® can be used to help measure the carbon impact or total packaging weight used annually, when linked with procurement and specification systems. This can help companies understand their total impact of packaging and compare metrics from year to year.

The scope of the study used in this report focused on fossil fuel consumption, greenhouse gas emissions (carbon footprint), and water consumption utilizing an LCA tool, in this case EcoImpact-COMPASS®. Additional information about the tool and background on life cycle assessments are below. (Note: Any references related to LCA discussion throughout this report is through the use of EcoImpact-COMPASS®, which is a streamlined LCA. Any references to LCA throughout this report are inferred to be a "streamlined" LCA)

Why EcoImpact-COMPASS®

EcoImpact-COMPASS® was used for the life cycle assessment package comparison in this report as it is a widely accepted tool within the packaging community. The tool has been continuously revamped as new manufacturing and converting information is available. The EcoImpact-COMPASS® tool also uses data from ecoinvent, U.S. Life Cycle Inventory Database (part of the National Renewable Energy Laboratory), and other LCA databases which are widely used. EcoImpact-COMPASS® allows for a Cradle to Grave boundary as it can also incorporate in transportation and end of life (recycling or landfill) impacts.

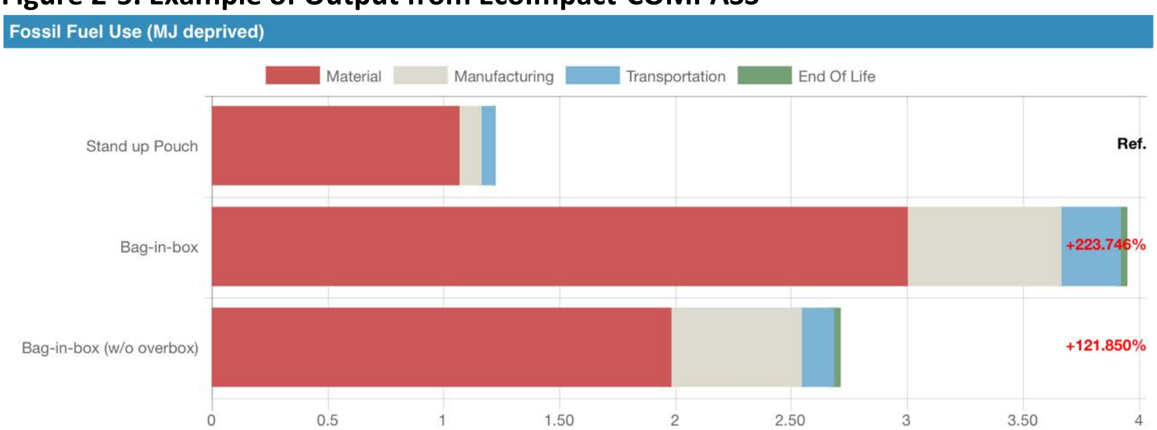
EcoImpact-COMPASS® output includes metrics around a number of environmental impact categories, including:

- Fossil Fuel Use (MJ-deprived)
- Greenhouse Gas Emissions (Kg CO_2-equivalent)
- Water Use (Liters)

To generate comparable data, the EcoImpact-COMPASS® tool will calculate a common weight, volume, or number of uses (or loads of laundry) of a product between the different package formats, and develop a report based on all package formats using the same amount of product. This allows package formats that may not be exact in size to be compared, based on overall product weight or volume. For comparisons used in the study, products with as similar as possible weights or volumes were used to minimize the environmental impacts caused by size differences.

The output from the tool allows for an easy comparison across the environmental impacts, incorporating data from material formation, package manufacturing, transportation, and end of life. (See Figure 2-5 below)

Figure 2-5. Example of Output from EcoImpact-COMPASS®



The example in Figure 2-5 is for Fossil Fuel Use. The x-axis in this case is the amount of megajoules (MJ) deprived (Total quantity of fossil fuel consumed throughout the life cycle, reported in megajoules). Since it requires different quantities of these fossil fuels to generate one unit, this measure uses MJ-eq deprived to aggregate. The x-axis scale changes between case studies based on the "normalized" value that the tool uses to compare the different package options. The normalized value is the equivalent number of weight or uses for a product to allow for a comparison. For examples, a beverage with one container holding 6 ounces of product and another holding 8 ounces, may be normalized to 24 ounces.

LCA Application and Case Studies

The following section will provide an overview of how the product categories were selected, along with the approach, data, and output gathered.

<u>Approach:</u>

PTIS and FPA selected product/packages from five unique product categories, each with high sales volume and/or high sales growth, and represents a range of options for products delivered via e-commerce. The approach helped develop the data requirements, establish data collection methods and analysis approaches, and facilitate understanding of the life cycle trends and drivers.

The FPA inquired about comparing different packages using environmental metrics, including:

Fossil fuel consumption
Greenhouse gas emissions
Water consumption
Product/package ratio
Material (by weight) to landfill

EcoImpact-COMPASS® requires the following information (Table 2-A) for inputs into the tool:

Table 2-A. EcoImpact-COMPASS® Required Inputs and Assumptions

Input	Example	Assumptions
Type of material	PET, HDPE, PP	
Converting process	Blow molding, injection molding, laminating, extrusion	Based on best estimation of process used
Weight	By package material and component (for multi-layer flexible packaging, weight need by each layer)	Based on weighing each package and individual layers to best capability
Recycled content	Corrugated	No recycled content was assumed for any primary packages unless specifically called out on the package, other than corrugated where a value

		of 48% based on industry average is incorporated into EcoImpact-COMPASS®
Transportation - outbound	Distance for finished good by truck by package	100 miles

To generate the necessary inputs for the LCA, PTIS ordered materials from e-commerce providers, and weighed all of the primary, secondary, and shipping packaging components, including any dunnage. (Note: A primary package is the package/material that makes immediate contact with the product inside. Secondary packaging may be a carton which the primary product is contained. Some secondary packaging can also be used for shipment via e-commerce. In other instances, an additional overbox or tertiary packaging may be used). For description purposes, a shipping case is a traditional (typically brown) corrugated case. An "overbox" is an additional corrugated case that holds another corrugated case and is used for e-commerce purposes, perhaps as extra protection or because the interior corrugated shipping case was not designed to withstand the rigors of e-commerce handling. Consumers may also refer to this as a "box in a box."

All of the multi-material flexible packages were weighed, but as the materials are adhered to each other, it is not possible to separate them. An outside packaging expert was consulted to provide typical packaging structures used for each of the multi-material flexible structures, and weights based on material densities were calculated for inputs into the EcoImpact-COMPASS® tool.

The EcoImpact-COMPASS® LCA tool was used to calculate the fossil fuel consumption, greenhouse gas emissions, and water consumption rates.

The focus of this LCA was on a comparison of primary packages as shown in Table 2-B. The EcoImpact-COMPASS® tool was used to evaluate a wide range of product categories with a number of packaging configurations for the following product categories:

Table 2-B. Overview of Case Study Package Formats

Case Study	Formats Assessed	General Product Information
Peanut Butter	• Pouch with Fitment (6 pack) into Case • Pouch with Fitment (6 pack) into Case, into an Overbox • PET Jars (3 pack) into Case	• High volume product • Standard jar and newer pouch formats
Cereal	• Stand-up Pouch (6 pack) in Case • Bag-in-box (6 pack) in Case • Bag-inbox (6pack) in Case, into an Overbox	• Common food item, high volume

Shoes	● Shoe Box in Outer Flexible Poly Mailer ● Shoe Box into Outer Case	● Common product for e-commerce
Laundry Detergent	● Pouch with Fitment (3 pack - liquid) into Case ● HDPE Bottle (liquid) into Case ● Pods in Rigid Container into Case ● Pods in Flexible Pouch (4 pack) into Case into an Overbox ● Pods in Flexible Pouch (4 pack) in Case ● Bag-in-box with Fitment	● Heavy, dense product ● Liquid format for some options ● Wide range of product/packaging available
Mailer	● Poly Mailer ● Bubble Mailer ● Paper Cushion Mailer ● Paperboard Document Mailer ● Paper/Bubble Mailer	● More common for smaller items or magazines/ books ● More examples as companies look to reduce space used in shipping products

All of the products selected for the case studies were in high volume or growing sectors, where a variety of package formats are available for comparison.

General LCA Assumptions/Exclusions

Outbound transportation was modeled for 100 miles of shipping.

Items not included in the LCA were:

- Minor packaging components – generally less than 5% by weight – which include adhesives, inks, and coatings impact.
    - These components make up a very small percentage of most packages and are not available in many streamlined LCAs or part of the analysis within the EcoImpact-COMPASS® tool.
    - Full LCAs have usually shown these components to have a minor impact in fossil fuel, greenhouse gas, and water consumption.
- Pallet loads – again, with a focus on e-commerce and without calculating size and weight of incoming tertiary packaging, the pallet load pattern was not calculated or included.
- Note: Scenarios which are different than what was purchased but could be a next step to reduce packaging are called out.

About the Environmental Indicators/Metrics

The following will discuss the background of the environmental indicators and metrics selected for this report to provide broader context as to why these metrics are important considerations for package format and material selection. (See Table 2-C for an example of how these metrics are reported)

For all percentage comparisons in EcoImpact-COMPASS®, the tool uses percent change. The formula is: ((Other pkg value – flexible pkg value)/ flexible pkg value) *100 = percent change. This formula for percent change was also used for any "packaging landfilled" comparisons in the tables.

Fossil Fuel Use

Fossil fuel use focuses on the energy consumption through the use of fossil fuels (i.e., coal, crude oil, and natural gas) throughout the package life cycle, from raw material extraction, through conversion, and ultimately end-of-life impacts. As mentioned earlier, it is a measure of the total quantity of fossil fuel consumed (deprived) throughout the life cycle reported in megajoule equivalents deprived. Since it requires different quantities of these fossil fuels to generate one unit MJ, this measure uses MJ-equivalents deprived to aggregate them. It is also a measure of how efficiently energy or fossil fuels are used in the manufacture of materials. In this metric, lower fossil fuel consumption values are preferred.

One point to keep in mind is that the plastics industry in the U.S. has undergone a transformation in the past decade with the surge in natural gas production from shale. The plastic industry in the U.S. has switched over to the use of natural gas as the main feedstock for plastics production from oil-based sources. This has resulted in over three-quarters of U.S. plastic production (as of 2015) using natural gas as the main feedstock, unlike production in Asia and Europe, which largely continue to rely on oil-based feedstocks. EcoImpact-COMPASS® uses the latest information from the U.S. energy sector which takes this transition into account when calculating the fossil fuel consumption.

Greenhouse Gas Emissions (GHG)

Greenhouse gas emissions (GHG), or carbon footprint, is one of the more widely used environmental indicators in life cycle assessment work. In response to legislation in many countries and regions that place a cost on carbon output, many companies have set goals to reduce their overall carbon emissions. Packaging can have a role here, not only in the carbon impact of the manufacturing of the different materials, but also through the transportation impacts of the different materials based on the weight of the materials, and number of trucks needed to transport both incoming materials, as well as outgoing materials to retailers and consumers. Additionally, greenhouse gas emissions are an important factor in climate change. The U.S. EPA says "Carbon dioxide (CO_2) is the primary greenhouse gas emitted through human activities. In 2015, CO_2 accounted for approximately 82.2% of all U.S. greenhouse gas emissions from human activities." The EPA goes on to say, "Human activities are altering the carbon cycle–both by adding more CO_2 to the atmosphere and by influencing the ability of natural sinks, like forests, to remove CO_2 from the atmosphere."

The EcoImpact-COMPASS® software measures the total quantity of greenhouse gases (GHG) emitted throughout the lifecycle reported in CO_2 equivalents. This calculation follows the latest Green House Gas Protocol (GHGP) and is updated with latest substance flows and factors from Intergovernmental Panel on Climate Change (IPCC) 2013. Again, lower emissions values are preferred, as they show more efficient use of resources and the resulting emissions.

Water Use

Water use is a topic that has grown in awareness as concerns about water quality and drought impacts increase. Concerns are generally in relation to production of different beverage or food products, which can have a high water consumption and not packaging. While packaging materials will often have a much smaller water consumption than the products themselves, there are some packaging materials, such as paper-based materials, which can be more water intensive than others.

Within the EcoImpact-COMPASS® tool, water use is a measure of quantity of the available water remaining in the water shed after human, ecosystem and production use throughout the life cycle, reported in liters. It takes into account overall usage and a scarcity factor based on country where a package is produced. Lower water use values are preferred, as they show more efficient use of resources.

Product-to-Package Ratio (including by percentage)

The Product-to-Package Ratio takes the declared product weight divided by the total package weight to develop a ratio showing material efficiency.

Product-to-Package ratio = (declared product weight/ primary package weight)

A higher product number (the first number) indicates more efficient use of materials as less packaging by weight is being used to protect the product. The higher product to package number is preferred.

The Product-to-Package ratio (by percentage) is calculated by dividing the declared product weight, by the total weight of declared product weight and primary packaging weight combined * 100, resulting in a percentage of what proportion sold to the consumer is attributed to the product (by weight) and the percentage attributed to the package (by weight).

Product-to-Package ratio (by percentage) for a product = declared product weight/ (declared product weight + primary package weight) * 100

Again, this is a measure of the efficiency of overall material usage. As before, a higher first number for the product, and lower second number for the package is preferred as it shows the most efficient use of packaging resources necessary to contain and protect the product.

Packaging Landfilled
The packaging landfilled is a measure of how much packaging material typically ends up in a landfill, after current recycling values for each packaging component are taken into account. The recycling values for each material were determined based on published reports from the *U.S. EPA Advancing Sustainable Materials Management Fact Sheet,* the *2017 APR/Napcor Post Consumer PET Container Recycling Activity in 2017*, and *A Study of Packaging Efficiency as It Relates to Waste Prevention* (January 2016) reports. For all of the materials, it was assumed that all materials collected for recycling were actually recycled. Additionally, it was assumed that none of the multi-material flexible packaging used in the case studies was recycled.

The values in the case study charts were based on a comparison of the amount of packaging material ultimately disposed for 1,000 kg of product, with lower values being preferred, as this means less material is going for landfill disposal. An example of these values are shown below in Table 2-C.

Table 2-C. Cereal Packaging Comparison Summary

Format	Fossil Fuel Consumption (MJ-deprived) *(from Fig 3-4)*	GHG Emissions (kg-CO2 equiv) *(from Fig 3-5)*	Water Use (liters) *(from Fig 3-6)*	Product-to-Package ratio and percent wt. *(from Table 3-E)*	Pkg Landfilled (g)/1,000 kg cereal *(from Table 3-E)*
Stand-up Pouch w/ Press to Close Zipper, Case	1.22	.07557	12.50	7.4:1 88.0%:12.0%	12,619
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Bag-in-box, Case (no Overbox)	2.70 (+121%)	.2951 (+291%)	65.10 (+421%)	3.0:1 75.1%:24.9%	50,532 (+300%)

Summary
To enable comparisons between products with different weights, the EcoImpact-COMPASS® tool calculated a common weight or volume of product between the different package formats, and generated a report based on all package formats using the same amount of product. Therefore, the fossil fuel consumption, greenhouse gas emissions, and water consumption values should not be compared between the different studies as they all utilize a different functional unit (or common weight) value

to enable comparisons within each of the product categories but can be used for comparison within each case study.

Additionally, in all of the tables, the percentages shown are using the flexible package as the baseline in the case study. Percentages in red mean those (positive) values are less preferable than the flexible package, while percentages shown in blue mean those (negative) values are preferable to the flexible package.

For detail of the individual studies, visit the detailed analysis for each in the following section titled Life Cycle Assessment Case Studies.

Acronyms – Chapter 2

EPA	U.S. Environmental Protection Agency
GHG	Greenhouse Gas Emissions
GHGP	Greenhouse Gas Protocol
LCA	Life Cycle Assessment
LCI	Life Cycle Inventory
LCIA	Life Cycle Impact Assessment
MJ	Megajoule
SPC	Sustainable Packaging Coalition

References and Sources:

A Study of Packaging Efficiency as It Relates to Waste Prevention. Use-Less-Stuff, Jan. 2016, use-less-stuff.com/wp-content/uploads/2017/10//2016-Packaging-Efficiency-Study-1.19.16.pdf.

Advancing Sustainable Materials Management: 2015 Tables and Figures - Assessing Trends in Material Generation, Recycling, Composting, Combustion with Energy Recovery and Landfilling in the United States. U.S. EPA, July 2018, https://www.epa.gov/sites/production/files/2018-07/documents/smm_2015_tables_and_figures_07252018_fnl_508_0.pdf.

Advancing Sustainable Materials Management: Fact Sheet 2017. U.S. EPA, Nov. 2019 https://www.epa.gov/sites/production/files/2019-11/documents/2017_facts_and_figures_fact_sheet_final.pdf.

Environmental Claims: Summary of the Green Guides. U.S. FTC, https://www.ftc.gov/system/files/documents/public_events/975753/ftc_-_environmental_claims_summary_of_the_green_guides.pdf.

"Life cycle assessment (LCA) is a scientific method for measuring the environmental footprint of materials, products and services over their entire lifetime." Athena Sustainable Materials Institute, www.athenasmi.org/resources/about-lca/whats-the-difference/.

"Overview of Greenhouse Gases." EPA, Environmental Protection Agency, 14 Apr. 2017, www.epa.gov/ghgemissions/overview-greenhouse-gases.

Report on Postconsumer PET Container Recycling Activity in 2017. Napcor.com, November 15, 2018., https://napcor.com/wp-content/uploads/2018/11/NAPCOR_2017RateReport_FINAL.pdf

Chapter 3

Life Cycle Assessment and Case Studies

Note: For the life cycle assessments used in this study, a cradle to grave boundary was used. Additionally, the assessments were based off actual packs delivered via e-commerce. The assessments include primary packaging, secondary packaging, and any outer e-commerce shipping packaging.

These case studies describe representative systems which include plausible assumptions for other packages and therefore may be generalized when making comparisons to other package formats. Also note that multi-laminate, or composite structures, included in the case studies are representative package structures and may not be the specific structure used for a particular package. Care was used to ensure inputs were as accurate as possible by utilizing actual package weights, along with material density calculations to determine weight inputs for each material.

Peanut Butter E-commerce Packaging Comparison

Peanut Butter is an example of a food product that is shipped via e-commerce, does not require refrigeration and is available in multiple sizes and formats. For this Life Cycle Assessment (LCA) study, three separate e-commerce packaging scenarios were evaluated. Two of the scenarios involve peanut butter in a pouch with fitment. In one of the e-commerce deliveries the pouch arrived in small corrugated box as the shipping unit. In the other, that corrugated box was then placed into an additional corrugated overbox for delivery. Both pouch with fitment scenarios were included as they were ordered from different retailers and arrived in different e-commerce packaging. The final scenario included peanut butter in a PET jar, which arrived in a corrugated e-commerce case. Primary package weights shown are on a per pack basis. There are multiple primary packs going into the e-commerce corrugated shipping container. Details for the different options are shown in Table 3-A on the following page.

Table 3-A. Peanut Butter E-commerce Packaging Evaluation Comparison

Package Type/Product Weight	Structure (package weight)	Photo
Stand-up Pouch with Fitment, 6 pack into corrugated case		
Stand-up Pouch w/ Fitment 176g- (6 oz.) – 6 ct.	Pouch - PET/Foil/LLDPE – 5.3g Fitment – PP – 5.9g	
Primary Pkg Total Wt.	*Total = 67.2g*	
Corrugated Box – (1,056g/36oz.)	Corrugated – 84.5g	
	TOTAL = 151.7g	
Stand-up Pouch with Fitment, 6 pack into corrugated case, into corrugated e-commerce overbox		
Stand-up Pouch w/ Fitment 176g- (6 oz.) – 6 ct.	Pouch - PET/Foil/LLDPE – 5.3g Fitment – PP – 5.9g	
Primary Pkg Total Wt.	*Total = 67.2g*	
Corrugated Box – (1,056g/36 oz.)	Corrugated – 84.5g	
Corrugated Overbox with Dunnage	HDPE Bubble – 3.9g Corrugated – 191.6g	
	TOTAL = 347.2g	
PET Jar, 3 pack, into corrugated case		
PET Jar – 454g – (16 oz.)	PET Jar – 25.7g PP Lid – 8.3g Lidstock – Paper/Foil/LDPE – 1.3 g Paper label – 1.5g	
Primary Pkg Total Wt.	*Total = 110.4g*	
Corrugated Box – 3 pack (1,362g/48 oz.)	Corrugated – 108.7g	
	TOTAL = 219.1g	

Packages as close as possible in size/volume were selected to make the lifecycle comparison. Not in all cases were packs of identical size/volume available for purchase.

Below are photos of the different e-commerce formats that were ordered, shown as arrived:

Figure 1. Above is a view of the 3 e-commerce packaging systems evaluated.

Figure 2. Pouch with fitment. 6 pack in corrugated case.

Figure 3. Peanut butter with fitment and overbox. Arrived 6 pack of pouches, in a corrugated box. That corrugated box was packed in another outer corrugated box with flexible air pillow dunnage.

Figure 4. Example of inflated polyethylene dunnage with How2Recycle® Store Drop-off designation, indicating the air pillows can be recycled with plastic grocery bags.

Figure 5. Peanut butter in PET jar. Arrived as a 3 pack in a corrugated box.

Figure 6. Size comparison of PET jar shipping container (in front) vs. stand-up pouch with fitment shipping container, including overbox (in rear).

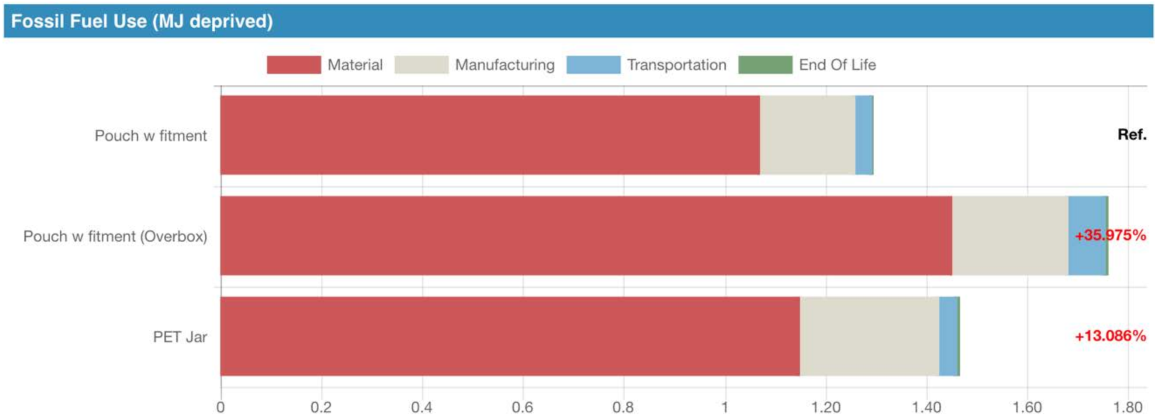
Figure 7. Comparison of stand-up pouch with fitment - overbox size on left, and standard size on right.

Figure 8. Size comparison of PET jar package (left) and stand-up pouch with fitment (right) (no overbox).

<u>Fossil Fuel Consumption, Greenhouse Gas Emissions, and Water Consumption Comparison</u>

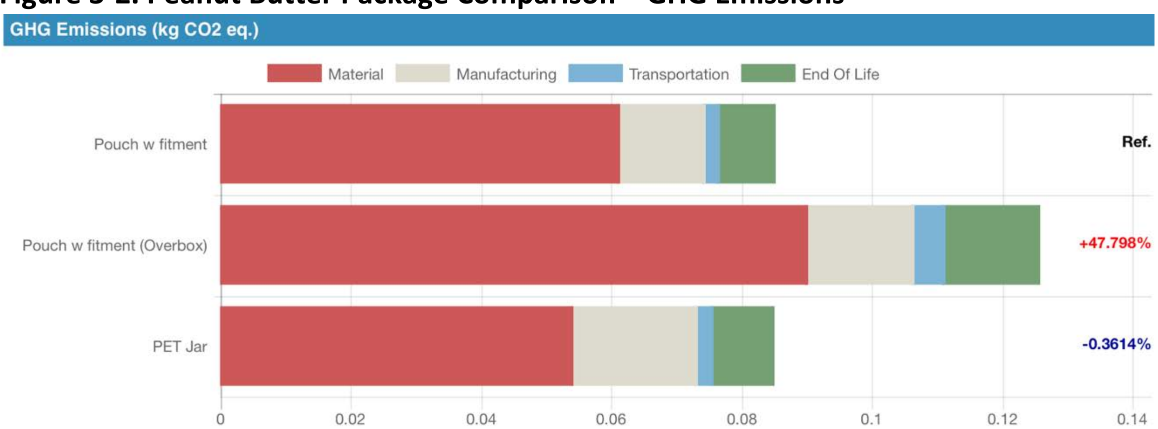
The following charts highlight the results of the fossil fuel usage, greenhouse gas (GHG) emissions, and water use for each of the three e-commerce package systems evaluated. These are some of the primary indicators that package developers consider when appraising the environmental impacts of a particular package. All of the scenarios reviewed are compared to the stand-up pouch with fitment e-commerce pack as the standard. The EcoImpact-COMPASS® software "normalizes" the data based on the functional unit such as weight or number of uses to allow comparison between package formats which may not be the exact same size. For all of the following charts, the stand-up pouch with fitment is considered the reference item to which all other packs are compared.

Figure 3-1. Peanut Butter Comparison – Fossil Fuel Consumption



The Fossil Fuel Consumption chart shows that the pouch with fitment has the lower fossil fuel use, followed by the PET jar. The second scenario of the pouch with fitment and overbox results in nearly 36% more additional fossil fuel used. This is due to the additional corrugated used in shipment resulting in over double the total amount of packaging used (347.2g) vs. just the pouch with fitment (151.7g). The PET jar pack comes out as preferable to the pouch with fitment in an overbox as the pack has no dunnage and is very tightly packed, but still has more fossil fuel use (13%) than that the pouch, when the overbox is removed.

Figure 3-2. Peanut Butter Package Comparison – GHG Emissions



The GHG emissions results are quite similar to the fossil fuel results in that the pouch with fitment and overbox has much larger GHG emissions (+47.8%) than the other two scenarios, largely driven by the additional overbox. The additional corrugated case results in the pouch with fitment using over double the amount weight of overall packaging than the scenario without the overbox.

Both the PET jar and pouch with fitment (overbox eliminated) are extremely efficient e-commerce packs, with little ‘dead space’ or air being shipped and have very similar results in overall GHG emissions, despite one pack using a rigid PET jar and the other a flexible pouch.

Figure 3-3. Peanut Butter Package Comparison – Water Use

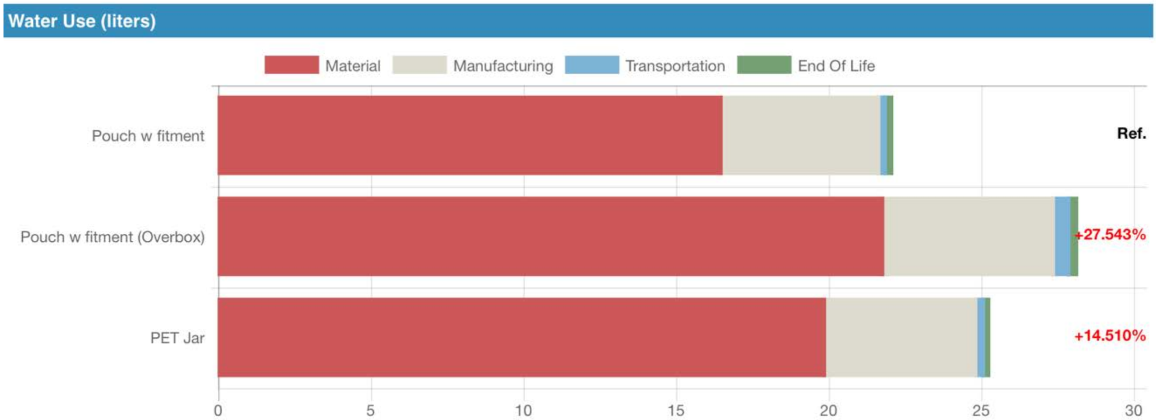


Figure 3-3 shows a comparison of water use during the life cycle of the different package formats. Again, the base scenario of the pouch with fitment and PET jar (+14%) are quite similar, while the pouch with the additional overbox, results in approximately 27% higher overall water use. Corrugated and paper production tend to be much more water intensive than the production of plastic pouches, thus driving the higher water use value due to increased corrugated use (191.6g) from the overbox.

End of Use Results

Table 3-B shows considers the amount of packaging material that ends up landfill when current recycling rates are considered.

Table 3-B. Peanut Butter E-commerce Packaging Format - Recycled and Landfilled Material Comparison

Format	Component	Total Pkg Wt. (g)	Product % Wt.	Package % Wt.	Pkg wt./ 1,000 kg peanut butter	Pkg Recycled/ 1,000 kg peanut butter	Pkg Landfilled (g)/1,000 kg peanut butter
Stand-up Pouch w/ Fitment, Case	Stand-up Pouch, Case	151.7	87.4%	12.6%	115,851	73,942	41,910
Stand-up Pouch w/ Fitment, Case in Overbox	Stand-up Pouch, Case, E-commerce Overbox	347.2	75.2%	24.8%	301,195	241,748	59,446
PET Jar, Case	PET jars, Case	219.1	86.1%	13.9%	144,694	91,091	54,113

To determine the package recycled and packaging discard rate, the following assumptions were made:

- *Corrugated container 48% recycled content (based on U.S. average)*
- *Corrugated recycling rate 92.3% (EPA)*
- *PET Jars 29.2% (Napcor 2018)*
- *HDPE Bubble wrap 4% (Closed Loop Partners)*
- *Flexible packaging with fitment was assumed to have 0% recycling rate*
- *All material collected for recycling was assumed to be actually recycled*
- *Packaging landfilled is amount of packaging not recycled, goes to municipal solid waste*

End of Use Summary

The U.S. EPA Waste Hierarchy cites source reduction and reuse as the most preferred method for waste management. The previous examples show that limiting the amount of packaging used in the design phase can have significant environmental impacts all the way up through e-commerce delivery packaging. This is highlighted by the example in the stand-up pouch with fitment (no overbox). In this scenario, while the flexible stand-up pouch is not recyclable, it limits the amount of material used in the design phase and would have the lowest amount of packaging sent to landfill of the three scenarios. The example also highlights how some brands and are still working to optimize their packaging for e-commerce, as one order of the stand-up pouch arrived with an additional overbox but is believed to qualify for Amazon Ship In Own Case (SIOC), based on the case size, should it go through testing and certification.

The PET jar pack is well optimized for e-commerce, as the package is dense, with little space. Many of the main materials for this pack, including the PET jar and corrugated outer box are considered recyclable. However, for comparison, just the weight of the PP lid and lidstock (without the PET jar itself) is nearly the same weight as the entire flexible pouch with fitment (9.6g vs. 11.2g). The PET jar, however, is given a recycling credit of 29.2% (based on PET bottles), so the weight of the additional PET jars not recycled drives the higher value of material sent to landfill. Additionally, a challenge for both the PET jars and pouches are that they are likely have product contamination from the peanut butter, and the PET jar would likely need to be thoroughly washed (potentially including in a dishwasher) to be clean enough for recycling and not viewed as a contaminant.

Summary/Implications

E-commerce provides a unique application in that products are handled on average about three times as frequently to get from producer to consumer when compared to the traditional retail channel. Therefore, it is incumbent on making sure that the package can survive the additional handling, which can even include sitting outside upon delivery. This is critical to consider when designing any package for e-commerce.

When considering the amount of material discarded in landfill (based on current recycling rates for the different formats), the stand-up pouch with fitment results in the least amount of material not recovered by a wide margin (41,910g vs. 54,113g for the PET jar). Even though the pouch with fitment is not currently recyclable due to its multi-material construction, it weighs much less than the other options, including the PET jar and is a good example of source reduction.

The pouch with fitment also has the lowest or nearly lowest energy usage, greenhouse gases (GHG) emissions, and water use when compared to the other packs. In all of the peanut butter scenarios reviewed, the primary packs were made from materials that can limit damage and leakage, an important consideration in e-commerce packaging. The primary flexible stand-up pouch with fitment pack would likely have very little if any damage in an e-commerce environment, while there would be some opportunity for denting but likely little in terms of product leakage from the PET jar. This e-commerce package case study highlights that a flexible package with fitment can provide appropriate product protection while minimizing the amount of overall e-commerce packaging used. That said, any pack needs to be considered for how it aligns with consumer usage, sustainability attributes, brand equity, and can meet or exceed consumer expectations in an e-commerce environment.

Table 3-C summarizes much of the critical data and package comparison discussed for this peanut butter packaging case study.

Table 3-C. Peanut Butter E-commerce Comparison Summary

Format	Fossil Fuel Consumption (MJ deprived) *(from Fig 3-1)*	GHG Emissions (kg-CO2 equiv) *(from Fig 3-2)*	Water Use (liters) *(from Fig 3-3)*	Product-to-Package ratio and percent wt. *(from Table 3-B)*	Pkg Landfilled (g)/1,000 kg peanut butter *(from Table 3-B)*
Stand-up Pouch w/ Fitment, Case	1.29	.08491	22.01	7:1 87.4%:12.6%	41,910
Stand-up Pouch w/ Fitment, Case in Overbox	1.76 (+36.0%)	.1255 (+47.8%)	28.08 (+27.5%)	3.0:1 75.2%:24.8%	59,446 (+41.8%)
PET Jar, Case	1.46 (+13.1%)	.08461 (-0.36%)	25.21 (+14.5%)	6.2:1 86.1%:13.9%	54,113 (+29.1%)

Notes:

- *A functional unit of 6.2 oz. of product was used for Fossil Fuel, GHG, and Water Use calculations.*
- *All percentages cited are for other formats compared to the stand-up pouch with fitment and case (no overbox).*
- *A higher number for product-to-package ratio (first number) cited means a higher percentage of weight is attributed to product, and less to packaging, resulting in more efficient use of packaging resources.*

- *For all percentage comparisons in EcoImpact-COMPASS®, the tool uses percent change. The formula is: ((Other pkg value – flexible pkg value)/ flexible pkg value) *100 = percent change.*
- *Package landfilled values are based on the of amount of packaging sent to municipal solid waste after recycling, based on 1,000 kg of peanut butter.*

Sources:

- Recycling rates used in calculations based on EPA Advancing Sustainable Materials Management Fact Sheet, July 2018 (Accessed October 29, 2019)
- Additional recycling rate sources:
  - Other recycling rates determined from "*A Study of Packaging Efficiency as It Relates to Waste Prevention," January 2016.* Use Less Stuff Report - http://use-less-stuff.com/wp-content/uploads/2017/10//2016-Packaging-Efficiency-Study-1.19.16.pdf
  - 2017 APR/Napcor Postconsumer PET Container Recycling activity - https://napcor.com/wp-content/uploads/2018/11/NAPCOR_2017RateReport_FINAL.pdf
  - Paperboard/ corrugated recycling - https://www.epa.gov/sites/production/files/2016-11/documents/2014_smm_tablesfigures_508.pdf
- E-commerce 3x number of touches - http://www.bemis.com/Bemis/media/Library/pdf/restricted/amcor-ebook-ecommerce-na.pdf

Cereal Packaging E-commerce Comparison

This scenario looked at two different primary package formats for cereal. One is cereal in a stand-up pouch, with the second option in the traditional bag-in-box. Both options came packed as a 6 pack in a corrugated box. The bag-in-box option, however, also came with an additional overbox. Because of this, an additional scenario was run for the bag-in-box cereal, but without the additional overbox, in the event that the shipping case could undergo certification for the Amazon Ship In Own Case (SIOC) program, which eliminates the need for overboxing, by certifying that the initial case can withstand the e-commerce distribution cycle as it is.

For this Life Cycle Assessment study, the following popular package formats were evaluated:

Table 3-D. Cereal Packaging Evaluation Comparison

Package Type/Product Weight	**Structure (package weight)**	**Photo**
Stand-up Pouch with Press to Close, 6 pack into corrugated e-commerce case		
Stand-up Pouch w/ Press to Close Zipper - 12 oz. (340g)	Stand-up Pouch – HDPE/HDPE lamination- 7.0g Press to Close Zipper- LDPE -1.8g	
Primary Pkg Total Wt.	*Total = 52.8g*	
Corrugated Case – 6 pack (72 oz./2,041g)	Corrugated – 224.8g	
	TOTAL = 277.6g	
Bag-in-box, 6 pack into corrugated case, into corrugated e-commerce overbox with paper dunnage		
Flexible Bag Liner	HDPE 5.1 g	
Carton – 10 oz. (283.5g)	Paperboard (recycled) – 55.1g	
Primary Pkg Total Wt.	*Total = 361.2g*	
Corrugated Case – 6 Pack (60 oz./1,701g)	Corrugated – 202.4g	
Corrugated Overbox w/ Paper Dunnage	SUS Paper Dunnage – 51.1 g Corrugated – 416.9g	
	TOTAL = 1,031.6g	

Bag-in-box, 6 pack into corrugated case		
Flexible Bag Liner	HDPE 5.1g	
Carton – 10 oz. (283.5g)	Paperboard (recycled) – 55.1g	
Primary pkg total wt.	*Total = 361.2g*	
Corrugated Case – 6 Pack (60 oz./1,701g)	Corrugated – 202.4g	
	TOTAL = 563.6g	

Packages as close as possible in size/volume were selected to make the life cycle comparison. Not in all cases were packs of identical size/volume available for purchase.

Below are photos of the different e-commerce formats that were ordered for evaluation:

Figure 1. Stand-up pouch in 6 pack box for e-commerce.

Figure 2. Stand-up pouch with pouches nested for space efficiency inside case.

Figure 3. Cereal pouch has How2Recycle® designation for store drop-off for recycling with plastic grocery store bags.

Figure 4. Bag-in-box cereal as arrived for e-commerce.

Figure 5. Bag-in-box with overbox removed.

Figure 6. Comparison of Bag-in-box with overbox and cereal in a pouch e-commerce case size comparison.

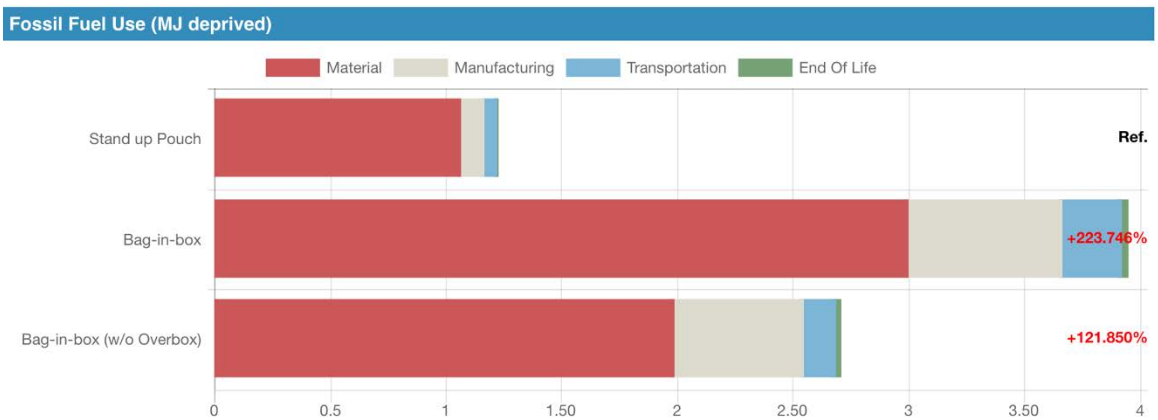
The stand-up pouch that was evaluated was comprised of an all-polyethylene structure which is recyclable with plastic grocery bags as part of Store Drop-off programs. This pouch had the How2Recycle® logo designation to alert consumers to take the bag to a participating grocery store for recycling at grocery bag drop-off bins.

Note: The third scenario with the bag-in-box in a corrugated case was a scenario that was evaluated but did not arrive in this format upon order. The bag-in-box (scenario 2) arrived through e-commerce distribution with an additional overbox and folded paper dunnage. The example without the overbox was evaluated to determine the impacts if the case was an appropriate size and design which would enable certification for SIOC for Amazon shipping, thus eliminating the overbox. The corrugated case containing the cereal cartons is large enough to qualify for SIOC designation but may need to go through certification.

Fossil Fuel Consumption, Greenhouse Gas Emissions, and Water Consumption Comparison

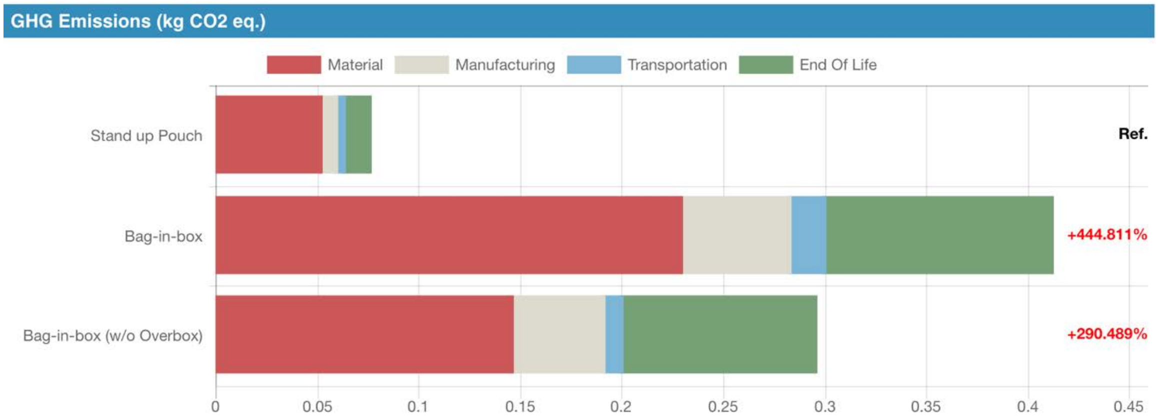
The following charts highlight results of the fossil fuel usage, greenhouse gas (GHG) emissions, and water use for each of the package formats evaluated. These are some of the primary common indicators that package developers consider when appraising the environmental impacts of a particular package. The EcoImpact-COMPASS® software "normalizes" the data based on the functional unit such as weight or number of uses to allow comparison between package formats which may not be the exact same size. For all of the charts below, the stand-up pouch with press to close is considered the reference item to which all other packs are compared.

Figure 3-4. Cereal Package Comparison – Fossil Fuel Consumption



The Fossil Fuel Consumption chart above (Figure 3-4) shows that the stand-up pouch and e-commerce case use considerably less fossil fuel than the bag-in-box options. The bag-in-box carton as shipped (1,031.6g), uses nearly four times the amount of packaging as the stand-up pouch system (277.6g), largely by virtue of the use of two separate corrugated cases. Even when the overbox is eliminated as in the final scenario, however, the bag-in-box option (536.6g) still uses more than twice the amount of packaging (277.6g) than the stand-up pouch e-commerce option, and over double the amount of fossil fuel used.

Figure 3-5. Cereal Package Comparison – GHG Emissions



Similar to fossil fuel usage, GHG emissions are often closely aligned with the amount of packaging used. Again, both bag-in-box cereal options result in considerably high overall GHG emissions than the stand-up pouch scenario. Even the bag-in-box option with the overbox eliminated results in 290% more GHG, which is driven largely by the amount of packaging used (277.6g for the stand-up pouch with case vs. 563.6g for the bag-in-box, without overbox). The nesting of the pouches within the case also ensures a very tight pack, with minimal amount of corrugated needed for the shipping case.

Figure 3-6. Cereal Package Comparison – Water Use

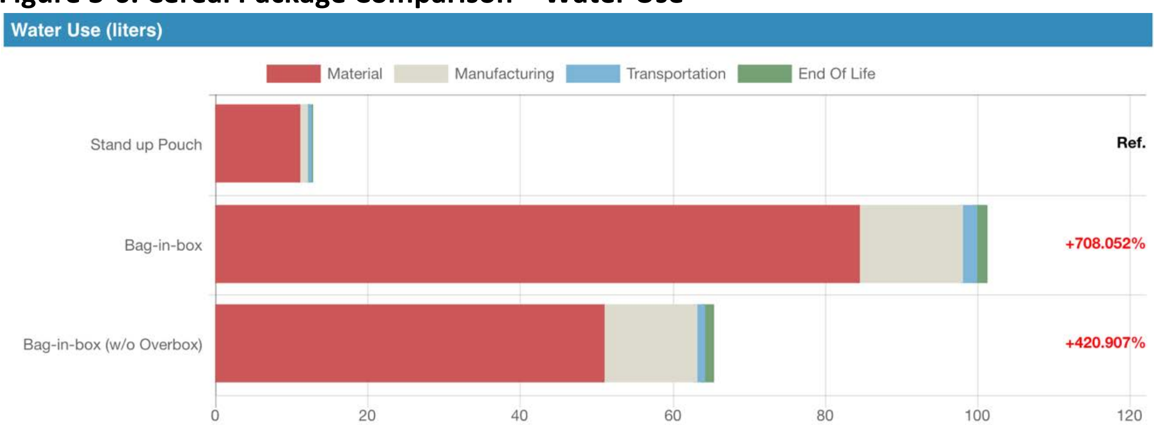


Figure 3-6 shows a comparison of water consumption during the life cycle of the three package formats. Production of any paper-based substrate, including cartons and corrugated, typically results in much higher water use than plastic production. The bag-in-box option as shipped with the overbox used 670g of paper (including paper dunnage and carton) vs. 225g of corrugated for the stand-up pouch, resulting in water use of +708% over the stand-up pouch scenario. Even the bag-in-box option with the overbox eliminated used slightly less corrugated than the stand-up pouch (202g vs. 225g) but had a much higher overall water impact (+420%) due to accounting of the water use in the production of cartons. The stand-up pouch format, which is formed by laminating multiple thin layers of film together, uses much less water in its manufacturing and conversion process.

End of Use Results

The results above show that the stand-up pouch has a much lower usage of fossil fuel as well as carbon and water impact when compared to the bag-in-box options. Package developers also consider the amount of material that is recycled or sent to landfill, to ensure that the package aligns with the circular economy or sustainable materials management goals. Table 3-E shows the results when current recycling rates are considered, as well the product-to-package ratio, which is a measure of the resource efficiency of the materials used. For this measure, a high product and a low package number are desired.

Table 3-E. Cereal Packaging - Recycled and Landfilled Comparison

Format	Component	Pkg Wt. (g)	Product % Wt.	Package % Wt.	Pkg wt. (g)/ 1,000 kg cereal	Pkg Recycled (g)/1,000 kg cereal	Pkg Landfilled (g)/1,000 kg cereal
Stand-up Pouch w/ Press to Close Zipper, Case	Stand-up Pouch, Case	277.6g	88.0%	12.0%	114,446	101,827	12,619
Bag-in-box, Case in Overbox	Bag-in-box, Case, Overbox	1,031.6g	62.2%	37.8%	444,503	354,247	90,256
Bag-in-box, Case (no Overbox)	Bag-in-box, Case	563.6g	75.1%	24.9%	169,371	119,616	49,755

To determine the package recycled and packaging discard rate, the following assumptions were made:

- *Corrugated container 48% recycled content (based on U.S. average)*
- *Corrugated recycling rate 92.3% (U.S. EPA)*
- *HDPE Bag 4% (Closed Loop Partners) – How2Recycle® Store Drop-Off*
- *Cereal liner in bag-in-box assumed same 4% recycling rate as many are included in the How2Recycle® Store Drop-Off*
- *Carton and paper filler recycling rate of 25.6% (U.S. EPA)*
- *All material collected for recycling was assumed to be actually recycled*
- *Packaging landfilled is amount of packaging not recycled, goes to municipal solid waste*

End of Use Summary

One of the interesting components of the cereal scenarios, are that all of the packaging components used for both the stand-up pouch and bag-in-box scenarios can be recycled with existing infrastructure. All of the corrugated boxes and paperboard cartons can be recycled in most curbside programs, while both the cereal liner (in most cases) and the stand-up pouch (used in this case) are made of all-polyethylene structures that can be part of the How2Recycle® store drop off programs.

For the summary of the amount of packaging recycled, the report used publicly available recycling rates for each of the materials. Taking these into account, the stand-up pouch would average 12,619g of packaging going to landfill over 1,000kg of cereal sold, while the current bag-in-box option would result in over seven times that amount when sold in the current configuration, and about four times the amount of material discarded, even if the overbox was eliminated.

The previous examples highlight that while many multi-material flexible packages are not yet recovered and recycled today, some structures that are made of an all polyethylene structure do have a path for recycling, and can result in a substantial reduction in the amount of material sent to landfill vs. other the bag-in-box cereal option.

Summary/Implications

The results show that the stand-up pouch in cereal with pouches nested in the shipping case results in a large reduction in environmental impacts across a number of key attributes vs. the bag-in-box system, including fossil fuel used, greenhouse gas emissions, water use, and material discarded when compared to the bag-in-box carton system in an e-commerce application. The results are driven by the stand-up pouch using anywhere from one-quarter to one-half of the materials as the other options, while still offering excellent product protection and consumer convenience features, such as a press-to-close zipper system.

As with all package decisions, there are other package attributes such as product protection, brand message, ease of use, and other consumer features that must be considered, including the sustainability benefits of each package format used in an e-commerce application, and the total package design using a holistic approach. As mentioned earlier, another key consideration is that both the stand-up pouch evaluated in this scenario, and the cereal box liner could be recycled in a store drop-off system, so all packaging components used can be recycled in existing infrastructure. When considered holistically, the stand-up pouch compares positively across a variety of positive environmental attributes for cereal, and other products, in e-commerce applications.

Table 3-F on the following page summarizes much of the critical data and package comparison discussed for this cereal packaging case study.

Table 3-F. Cereal Packaging Comparison Summary

Format	Fossil Fuel Consumption (MJ deprived) *(from Fig 3-4)*	GHG Emissions (kg-CO2 equiv) *(from Fig 3-5)*	Water Use (liters) *(from Fig 3-6)*	Product-to-Package ratio and percent wt. *(from Table 3-E)*	Pkg Landfilled (g)/1,000 kg cereal *(from Table 3-E)*
Stand-up Pouch w/ Press to Close Zipper, Case	1.22	.07557	12.50	7.4:1 88.0%:12.0%	12,619
Bag-in-box, Case in Overbox	3.94 (+224%)	.4117 (+445%)	100.98 (+708%)	1.65:1 62.2%:37.8%	91,034 (+621%)
Bag-in-box, Case (no Overbox)	2.70 (+122%)	.2951 (+290%)	65.10 (+421%)	3.0:1 75.1%:24.9%	50,532 (+300%)

Notes:

- *A functional unit of 12 oz. of product was used for Fossil Fuel, GHG, and Water Use calculations.*
- *All percentages cited are for other formats compared to the stand-up flexible pouch.*
- *A higher number for product-to-package ratio (first number) cited means a higher percentage of weight is attributed to product, and less to packaging, resulting in more efficient use of packaging resources.*
- *For all percentage comparisons in EcoImpact-COMPASS®, the tool uses percent change. The formula is: ((Other pkg value – flexible pkg value)/ flexible pkg value) *100 = percent change.*
- *Package landfilled values are based on the of amount of packaging sent to municipal solid waste after recycling, based on 1,000 kg of cereal.*

Sources:

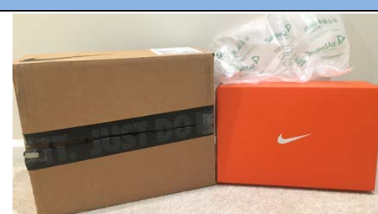
- Recycling rates used in calculations based on EPA Advancing Sustainable Materials Management Fact Sheet, July 2018 (Accessed October 29, 2019)
- Additional recycling rate sources:
- Flexible film recycling rate: Closed Loop Foundation- Film Recycling Investment Report (2017)- https://www.closedlooppartners.com/wp-content/uploads/2017/09/FilmRecyclingInvestmentReport_Final.pdf
  - 2017 APR/Napcor Postconsumer PET Container Recycling activity - https://napcor.com/wp-content/uploads/2018/11/NAPCOR_2017RateReport_FINAL.pdf
  - Paperboard recycling - https://www.epa.gov/sites/production/files/2016-11/documents/2014_smm_tablesfigures_508.pdf

Shoe E-commerce Packaging Comparison

Clothing and footwear are an area where there has been significant growth in e-commerce. For this scenario, shoes were purchased from two separate e-commerce retailers. Both shipped the shoes in a traditional corrugated shoe box, with one retailer placing that shoe box into a corrugated overbox for e-commerce shipping, while the other retailer used a flexible pouch with a feature to enable returns.

For this Life Cycle Assessment study, the following package formats were evaluated:

Table 3-G. Shoe E-commerce Packaging Evaluation Comparison

Package Type/Product Weight	Structure (package weight)	Photo
Shoe Box with Flexible E-commerce Shipping Mailer		
Internal Shoe Box	Corrugated – 184.8g	
Flexible Pouch	HDPE – 43.7g	
	TOTAL = 228.5g	
Shoe Box with E-commerce Overbox		
Internal Shoe Box	Corrugated – 184.8g	
Overbox with Dunnage	Dunnage – HDPE – 3.8g Corrugated – 348g	
	TOTAL = 536.6g	

Packages as close as possible in size/volume were selected to make the lifecycle comparison. Not in all cases were packs of identical size/volume available for purchase.

For this comparison, the same “shoe box” and pair of shoes were used to ensure that comparisons were as equal as possible, without differences between the “shoe box” or weight of different pair of shoes as a factor.

Following are photos of the different e-commerce formats that were ordered for evaluation.

Figure 7. Shoe box with outer flexible pouch mailer.

Figure 8. Shoe box with outer overbox and bubble dunnage.

Figure 9. Comparison between both e-commerce outer packs.

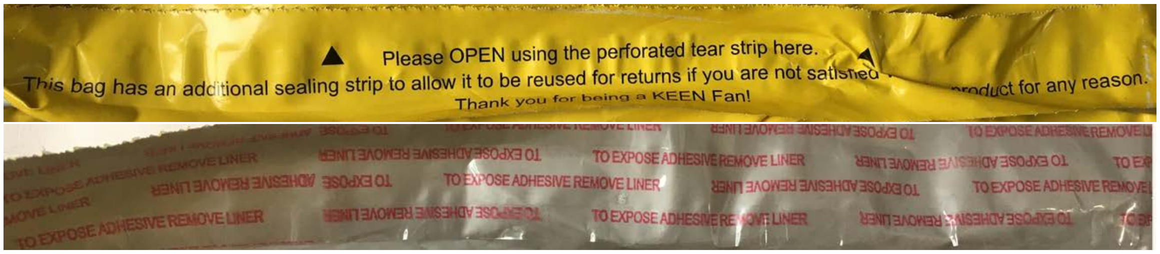


Figure 10. Flexible mailer includes an adhesive strip to enable easy returns.

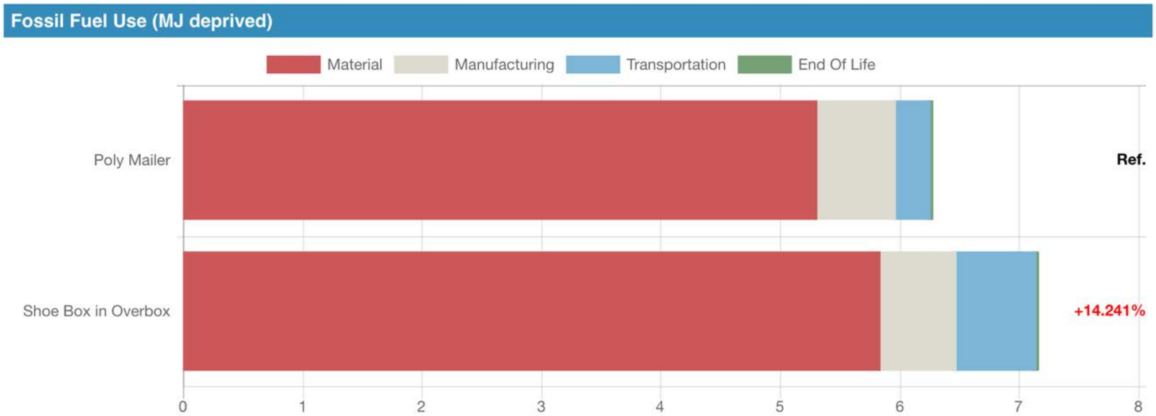
Figure 11. Flexible mailer is made from LDPE, which is recyclable in store drop-off locations with plastic grocery bags (if labels are removed). Note: for the LCA, the flexible mailer was not given credit for recycled content since the example uses Post-Industrial vs. Post-Consumer recycled content.

Figure 12. The inflated bubble dunnage is made from HDPE and can be recycled with grocery bags as part of the Store Drop-off program.

Fossil Fuel Consumption, Greenhouse Gas Emissions, and Water Use Comparison

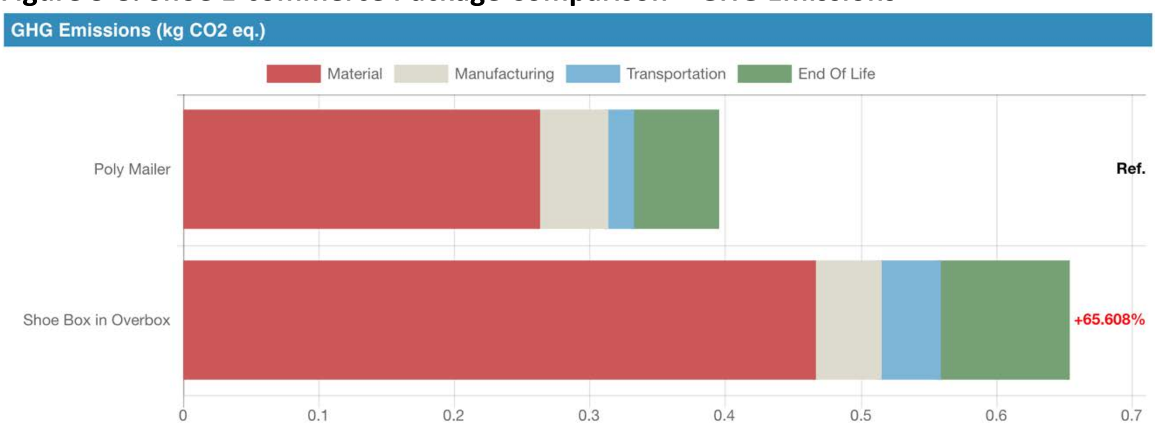
The following charts highlight results of the fossil fuel usage, greenhouse gas (GHG) emissions, and water use for each of the package formats evaluated. These are some of the common indicators that package developers consider when appraising the environmental impacts of a particular package. The EcoImpact-COMPASS® software "normalizes" the data based on the functional unit such as weight or number of uses to allow comparison between package formats which may not be the exact same size. For all of the charts below, the flexible poly mailer is considered the reference item to which all other packs are compared.

Figure 3-7. Shoe E-commerce Package Comparison – Fossil Fuel Consumption



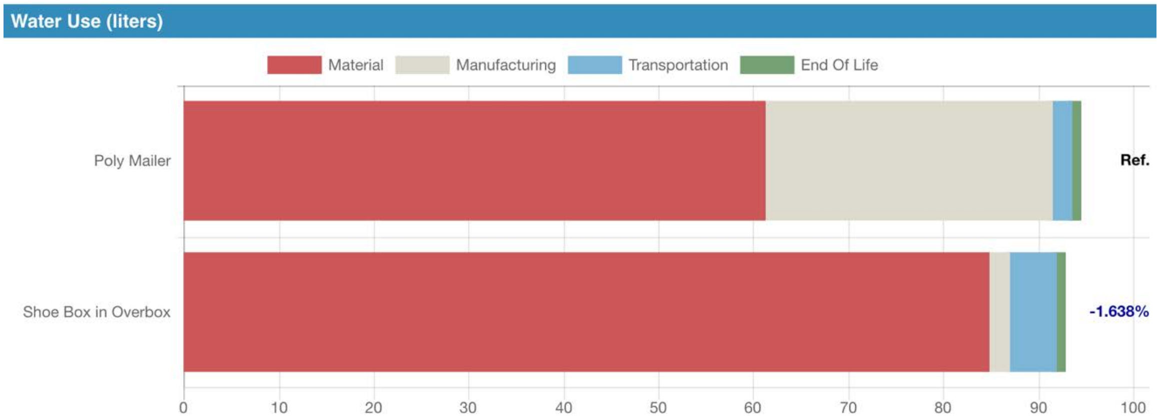
The Fossil Fuel Consumption chart shows the shoe box with an overbox results in approximately 14% more fossil fuel use than the flexible mailer. This is largely driven by the flexible mailer using less than half (228.5g vs. 536.6g) the amount of packaging material for an e-commerce delivery.

Figure 3-8. Shoe E-commerce Package Comparison – GHG Emissions



The shoe box with the overbox results in greenhouse gas (GHG) emissions about 66% greater than that of the shoe box and flexible mailer. The material impact alone (red part of the graph) for the overbox scenario is greater than that the material, manufacturing, transportation, and end of life GHG impacts combined for the flexible mailer. Again, this is largely driven by the overbox example (536.6g) using more than double the amount of material as the shoe box/flexible mailer (228.5g) combination.

Figure 3-9. Shoe E-commerce Package Comparison – Water Use



Water use for the shoe box with the overbox and the poly mailer are nearly identical, with the production of LDPE being more water intensive on a per gram basis than corrugated, even though far less material is used.

End of Use Results

The previous charts show that the flexible poly mailer has lower environmental impacts including fossil fuel usage, GHG emissions, and water usage in this e-commerce scenario than the shoe box with overbox. In this section, the impacts of a material recycled or discarded are considered to ensure that the package aligns with the circular economy or sustainable materials management goals. Table 3-H (on the following page) shows the results when current recycling rates are considered, as well the product-to-package ratio, which is a measure of the resource efficiency of the materials used. For this measure, a high product and a low package number are desired. For this study, the same pair of shoes were weighed and used as the product.

Table 3-H. Shoe E-commerce Packaging - Recycled and Landfilled Comparison

Format	Component	Pkg Wt. (g)	Product % Wt.	Package % Wt.	Pkg wt. (g)/ 1000 kg shoes	Pkg Recycled (g)/1,000 kg shoes	Pkg Landfilled (g)/1,000 kg shoes
Flexible E-comm Pouch	Flexible Mailer Pouch	228.5	75.4%	24.6%	326,429	246,169	80,259
Outer Overbox	Corrugated Box	536.6	56.6%	43.4%	766,571	702,752	63,819

To determine the package recycled and packaging discard rate, the following assumptions were made:

- *Corrugated container 48% recycled content (based on U.S. average)*
- *Corrugated recycling rate 92.3% (U.S. EPA)*
- *HDPE Flexible Mailer Pouch and HDPE Bubble Filler - 4% recycling rate (Closed Loop Partners) – How2Recycle® Store Drop-Off*
- *All material collected for recycling was assumed to be actually recycled*

- *Package landfilled is amount of packaging not recycled, goes to municipal solid waste*

End of Use Summary

The U.S. EPA Waste Hierarchy considers source reduction and reuse as the top method for overall waste reduction, followed by recyclability. The comparison of percent of product vs. percent of packaging by weight is an example of measure of package efficiency. In this case the flexible mailer results in approximately 75% of the total weight when delivered attributed to the shoes, while the shoe box with an overbox is much lower with only 56% being attributed to the shoes. This can vary widely by shoe type, size, materials, of course.

In both scenarios all of the packaging material can be recycled using existing infrastructure. Both the corrugated shoe box and the overbox can be recycled in the curbside system, as corrugated is one of most recycled materials around with over 92% of corrugated being recycled in the U.S. The HDPE bubble wrap dunnage (used with the overbox) as well as the HDPE flexible poly mailer, can both be recycled as part of the store drop-off recycling with plastic grocery bags, if it goes through the How2Recycle® certification process.

The example above shows that while the flexible mailer can be recycled at store drop-off, with current recycling levels of approximately 4%, the corrugated overbox scenario results in less material being discarded to landfill because of the high rate of curbside availability and consumer convenience in recycling corrugated.

The example above highlights some of the tradeoffs that must be considered when looking at the environmental impacts of any packaging material in an e-commerce application. In the case study review, the flexible mailer results in lower overall materials used and much better product-to-package ratio than the corrugated overbox, but it still has more material sent to the landfill due to the current low recycling rates of the flexible mailer. Recycling rates for the flexible mailer would need to be approximately 30% to have less materials discarded to landfills than the overbox.

Summary/Implications

In both scenarios for delivery of shoes via e-commerce, all of the packaging materials used are considered recyclable. The results of the shoe e-commerce case study show that the flexible mailer results in a lower environmental impact across fossil fuel use, greenhouse gas emissions, and water use than the shoes arriving in an overbox. However, the flexible pouch results in more material discarded in landfill due to the low recycling rates today for the flexible mailer and additional steps consumers need to take, by going cutting out any labels and taking the mailer to a store drop-off location.

As in almost all package selection criteria, a wide range of package and product usage occasions need to be considered holistically. Both package formats allow for product protection during delivery, though the flexible mailer may hold up better in a wet or humid environment, while also allowing for easy opening and easy returns, an important consideration for consumer convenience. Overall, the combination of environmental impacts, brand alignment, consumer benefits, and economic impacts, including dimensional weight and shipping impacts are important considerations in any e-commerce package.

Table 3-I below summarizes much of the critical data and package comparison discussed for this e-commerce packaging case study.

Table 3-I. Shoe E-commerce Packaging Comparison Summary

Format	Fossil Fuel Consumption (MJ deprived) *(from Fig 3-7)*	GHG Emissions (kg-CO2 equiv) *(from Fig 3-8)*	Water Use (liters) *(from Fig 3-9)*	Product-to-Package ratio and percent wt. *(from Table 3-H)*	Pkg Landfilled (g)/1,000 kg shoes *(from Table 3-H)*
Flexible E-commerce Pouch	6.26	0.3943	94.23	3.1:1 75.4%:24.6%	80,259
Outer Overbox	7.15 (+14.2%)	.6529 (+65.6%)	92.68 (-1.6%)	1.3:1 56.6%:43.4%	63,819 (-20.5%)

Notes:

- *A normalized product weight (common value divisible by all package formats) of 1 pair of shoes was used for Fossil Fuel, GHG, and Water Consumption calculations. Same shoes (700g) and shoe box (184.8g) were used in shoe box assessment. Only the outer e-commerce package was changed.*
- *All percentages cited are for other formats compared to the flexible e-commerce pouch.*
- *A higher number for product-to-package ratio (first number) cited means a higher percentage of weight is attributed to product, and less to packaging, resulting in more efficient use of packaging resources.*
- *For all percentage comparisons in EcoImpact-COMPASS®, the tool uses percent change. The formula is: ((Other pkg value – flexible pkg value)/ flexible pkg value) *100 = percent change.*
- *Package landfilled values are based on the of amount of packaging sent to municipal solid waste after recycling, based on 1000 kg of the shoes used as the basis for both comparisons.*

Sources:

- Recycling rates used in calculations based on EPA Advancing Sustainable Materials Management Fact Sheet, July 2018 (Accessed October 29, 2019)
- Flexible film recycling rate: Closed Loop Foundation- Film Recycling Investment Report (2017)- https://www.closedlooppartners.com/wp-content/uploads/2017/09/FilmRecyclingInvestmentReport_Final.pdf

Laundry Detergent E-commerce Packaging Pods

Laundry detergent is a product that is available across a wide range of product formats, including both concentrated liquids and pods as well as package formats. For this evaluation, five popular formats were evaluated. An additional evaluation was conducted for laundry pods in a flexible pouch, which arrived in an overbox, but likely can be shipped without the overbox.

The unit of measure for the comparison was based on loads of laundry claimed on each package, vs. fluid ounces due to the different concentration levels available.

Table 3-J. Laundry Detergent E-commerce Packaging Evaluation Comparison

Package Type/Product Weight	**Structure (package weight)**	**Photo**
Liquid Detergent in Stand-up Pouch with Fitment, 3 pack (50 fl. oz.) into corrugated case (84 loads)		
Stand-up Pouch w/ Fitment (50 fl. oz./28 Loads)	Pouch - 48 ga PET/Ink/Adh/60 ga BON/Adh/4 mil Coex LLDPE/HDPE/LLDPE - 24.4g Fitment - PP – 5.9g	
Primary pkg total wt.	*Total = 90.9g*	
Corrugated Case – 3 Pack	Corrugated Divider – 50.7g Corrugated Case -242g	
	TOTAL = 383.6g	
Liquid Detergent in HDPE Bottle, into corrugated case (64 loads)		
Bottle	HDPE Bottle – 110.8g PP Insert – 13.3g PP Cap – 19.9g	
Corrugated Case w/ Dunnage	LDPE Bag Overwrap – 12.2g HDPE Bubble Dunnage - 15.1g Corrugated Case -263.1g	
	TOTAL = 434.4g	

Laundry Pods in Rigid PET Container, into corrugated case (81 loads)		
Container	PET Container – 147.9g PP Lid – 18.8g	
Corrugated Case w/ Dunnage	HDPE Bubble Dunnage – 15.6g Corrugated Case – 229.6g	
	TOTAL = 411.9g	
Laundry Pods in Flexible Pouch, 4 pack (27 loads) in corrugated case in corrugated overbox (108 loads)		
Pouch	Flexible Pouch - 48 ga. PET/Ink/Adh/60 ga BON/Adh/3.5 mil LLDPE – 16.9g Zipper – LDPE – 1.6g Slider – PP – 0.8g	
Primary pkg total wt.	*Total = 77.2g*	
Corrugated Case – 4 pack	Corrugated Case – 210.1g	
Corrugated Overbox	Corrugated Case – 266.8g	
	TOTAL = 554.1g	
Laundry Pods in Flexible Pouch, 4 pack (27 loads) in corrugated case (108 loads) – **No overbox**		
Pouch	Flexible Pouch - 48 ga. PET/Ink/Adh/60 ga BON/Adh/3.5 mil LLDPE – 16.9g Zipper – LDPE – 1.6g Slider – PP – 0.8g	
Primary pkg total wt.	*Total = 77.2g*	
Corrugated Case – 4 pack	Corrugated Case – 210.1g	
	TOTAL = 287.3g	

Liquid detergent Bag-in-Box, 105 fl. oz. (96 loads)		
Bag-in-box System w/ Dispensing Fitment and Measuring Cup	Inner bag – LLDPE/ Nylon – 28g Fitment – PP – 23.9g Measuring Cup – 10g Corrugated Box – 272.6g	
Flexible overwrap	HDPE – 17.8g	
	TOTAL = 352.3g	

Packages as close as possible in size/volume were selected to make the lifecycle comparison. Not in all cases were packs of identical size/volume available for purchase or the same number of loads of laundry.

Below are photos of the different e-commerce formats that were ordered for evaluation:

Figure 13. A view of all of the packs evaluated for laundry detergent e-commerce packaging.

Figure 14. Above photos show liquid detergent in pouch with a fitment. Case included a corrugated divider.

Figure 15. Liquid detergent in HDPE bottle came with LDPE bag over the bottle to prevent any leaking, along with bubble dunnage.

Figure 16. Above photos show plastic bag around bottle for e-commerce shipping to control leaks, along with bubble dunnage.

Figure 17. Photos above show rigid PET container for detergent pods, with bubble dunnage to fill shipping case and reduce product movement during transportation.

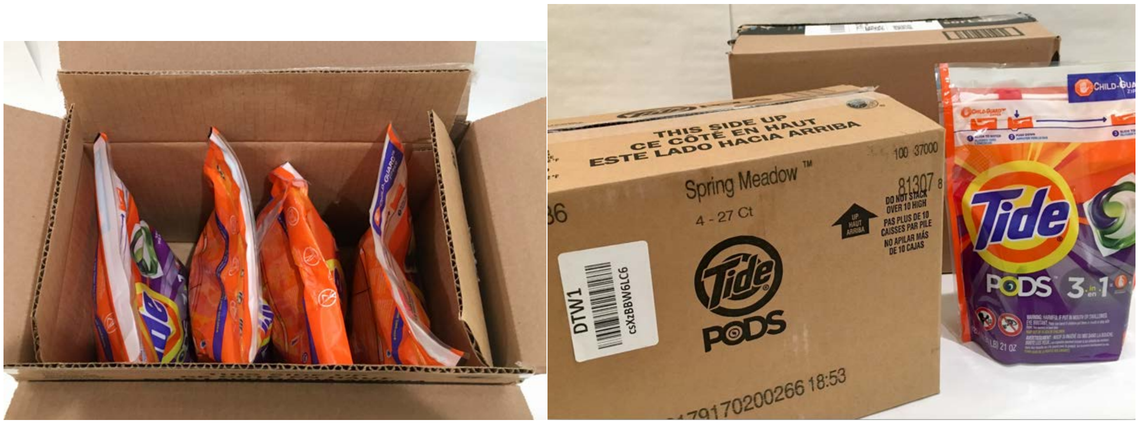


Figure 18. Above photos show detergent pods in a flexible pouch with zipper closure. Four flexible pouches are packed into a shipping case, which arrived with an additional overbox just slightly larger than the interior shipping case.

Figure 19. The above photo shows a scenario where the flexible pouch arrives in shipping case, but with overbox eliminated.

Figure 20. The bag-in- box option above arrived with a flexible overwrap to help ensure that perforations in case did not open during transportation or handling. The corrugated shipping box then includes a flexible pouch inside which contains the liquid detergent.

Figure 21. The corrugated case contains the How2Recycle® designation, instructing consumers to recycle the corrugated box, and dispose of the multi-layer flexible bag inside.

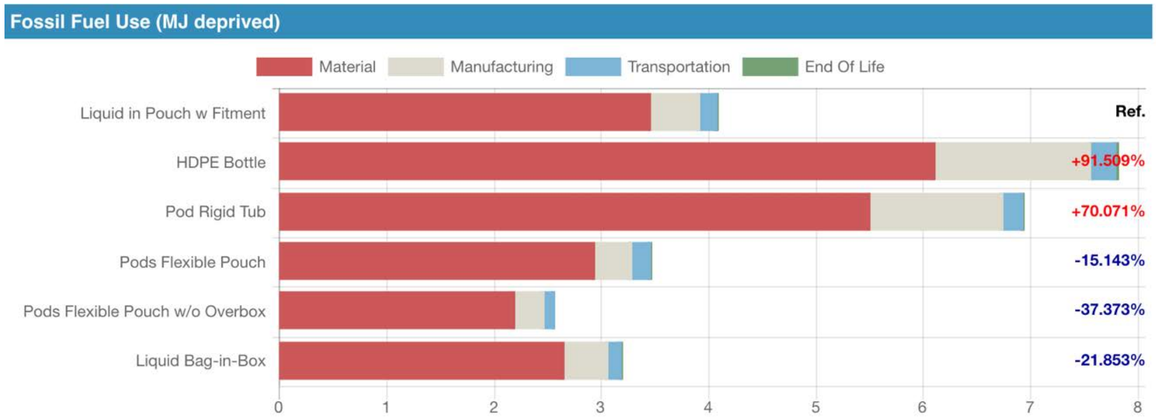
Figure 22. All of the bubble dunnage contained the How2Recycle® Store Drop-off designation, indicating it is recyclable where plastic grocery store bags are collected and recycled.

Fossil Fuel Consumption, Greenhouse Gas Emissions, and Water Consumption Comparison

The following charts highlight results of the fossil fuel usage, greenhouse gas (GHG) emissions, and water consumption for each of the package formats evaluated. These are some of the common indicators that package developers consider when appraising the environmental impacts of a particular package. The EcoImpact-COMPASS® software "normalizes" the data based on the functional unit such as number of laundry loads to allow comparison between package formats which may not be the exact same size.

In all of the comparisons, the stand-up pouch with fitment with liquid detergent was used as the standard. All of the values in the far right on the graphs are in comparison to the stand-up pouch with fitment. The values are for the complete packaging system that arrived upon ordering via e-commerce. This may include the primary package itself, along with any dunnage, shipping cases, or additional components such as a measuring cup.

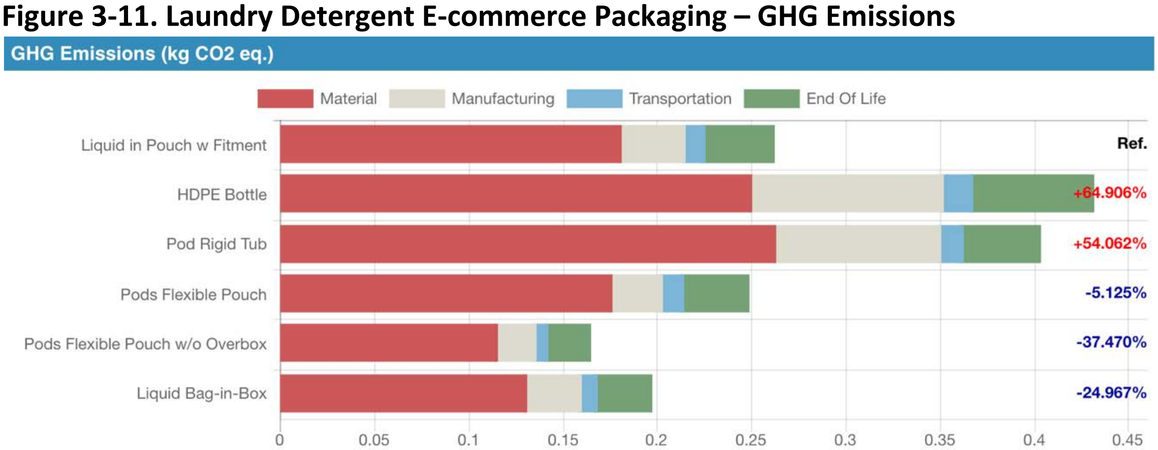
Figure 3-10. Laundry Detergent E-commerce Packaging – Fossil Fuel Use



The fossil fuel use shows that in general, the packages with a primary package that utilizes a flexible structure vs. a rigid structure have lower fossil fuel usage. The two package formats which had the highest fossil fuel used were the HDPE Bottle (+91.5%) and pods in a rigid PET container (+70.1%). Both of the rigid formats were two of the heavier packaging systems, but not the heaviest. That went to the pods in a flexible pouch, which arrived with an overbox. Corrugated, while relatively heavy, does not result in as much fossil fuel usage per gram of material as do most plastics.

The two formats that had the lowest overall fossil fuel used were the scenario with the pods in a flexible pouch and the corrugated overbox eliminated (-37.4%) and the liquid detergent in a bag-in-box format (-21.9%). Both of these formats are the lightest overall e-commerce packaging systems and are very efficient in their use of materials and loads of laundry.

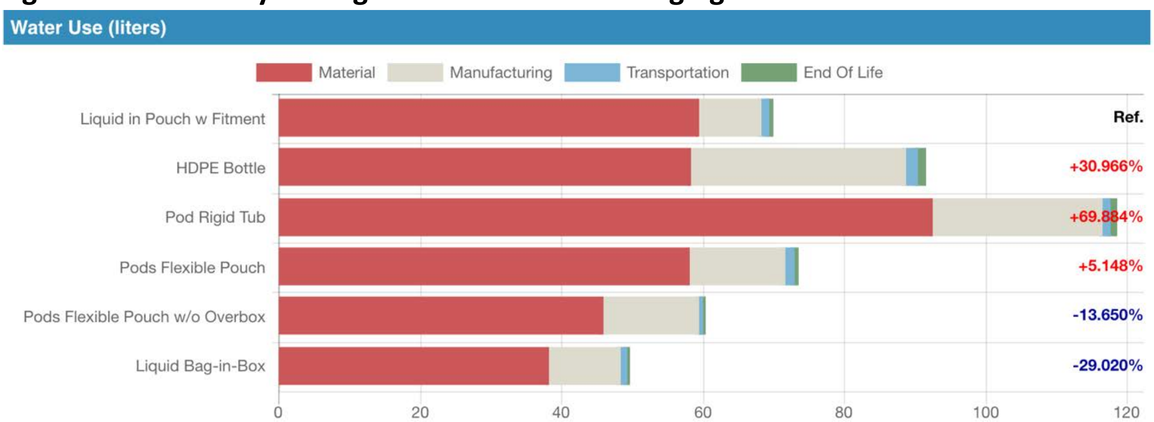
Figure 3-11. Laundry Detergent E-commerce Packaging – GHG Emissions



The overall Greenhouse Gas (GHG) emissions are fairly similar to the fossil fuel results, with the lighter packs, which generally consist of more use of flexible structures, resulting in lower emissions. The lowest GHG emissions come from the pods in a flexible pouch with the corrugated overbox eliminated (-37.5%) and the liquid detergent in a bag-in-box format (-25.0%), when compared to the reference of the flexible pouch with fitment (liquid detergent).

The highest GHG emissions came from the system using the rigid HDPE bottle (+64.9%) and pods in a rigid PET container (+54.1%). Both of these systems used approximately double the amount of plastic material for their primary package as the flexible pouch (144g for the HDPE Bottle, 166.7g for the rigid PET container, and 73.2g for the 3 pack of flexible pouches with fitment, and also contained a lower overall number of laundry loads). Additionally, the manufacturing (gray bar on the graph) is generally higher for rigid plastic processes such as blow molding or injection molding for parts than the extrusion and laminating processes used in the production of multi-layer flexible packaging films.

Figure 3-12. Laundry Detergent E-commerce Packaging – Water Use



Results for water use follow a similar pattern to the fossil fuel usage and GHG emissions charts. The packaging systems including the HDPE bottle and rigid PET container have the highest amount of water use. This is likely driven by additional water needed to cool molds during injection molding or blow molding processes for the rigid containers. All of the different scenarios used a fairly significant amount of corrugated (at least 210g), which also drives water usage. This is a reason the pods in a flexible pouch are also higher (+5.1%) vs. the standard pouch with fitment, as the additional overbox, which weighed 266.8g, results in higher water usage. The impact of the overbox can be seen in the scenario of pods in a flexible pouch with the overbox eliminated results in an approximately 20% swing (from +5.148% to -13.65%) for water usage vs. the standard (flexible pouch with fitment), just by eliminating the overbox.

<u>End of Use Results</u>

In this section, we will explore the impacts of material recycled or sent to municipal solid waste to ensure that the package aligns with the circular economy or sustainable materials management (SMM) goals. According to the UK based Waste Resources Action Programme (WRAP), *"A circular economy is an alternative to a traditional linear economy (make, use, dispose) in which we keep resources in use for as long as possible, extract the maximum value from them whilst in use, then recover and regenerate products and materials at the end of each service life."*

The U.S. EPA defines SMM as "*use and reuse of materials in the most productive and sustainable way across the entire lifecycles by minimizing the amount of materials involved and minimizing associated environmental impacts.*"

Both are important metrics to consider in a holistic view on sustainability. While a circular economy approach focuses on keeping materials in use, such as through recycling, a SMM approach focused on the most efficient use of resources with the lower overall environmental impact. Both approaches can complement each other but can at times be difficult to achieve both models.

Table 3-K (below) shows the results when current recycling rates are considered, as well the product-to-package ratio, which is a measure of the resource efficiency of the materials used. For this measure, a high product and a low package number are desired. For this summary, the packaging landfilled was based on 1,000 loads of laundry vs. weight of laundry detergent since different levels of concentrate or product forms (pods vs. liquid detergent) can impact the amount of packaging used. It was determined that basing the comparison on loads was more appropriate than product weight, which was used in the other case study comparisons.

Table 3-K. Laundry Detergent E-commerce Packaging - Recycled and Landfilled Comparison

Format	Component	Pkg Wt. (g)	Product % Wt.	Package % Wt.	Pkg wt. (g)/ 1,000 loads	Pkg Recycled (g)/ 1,000 loads	Pkg Landfilled (g)/1,000 loads
Liquid Detergent in Stand-up Pouch w/ Fitment	Flexible Pouch with Fitment	383.6	92.2%	7.8%	4,567	3,216	1,350
Liquid Detergent in HDPE Bottle	HDPE Bottle	434.4	87.2%	12.8%	6,788	4,407	2,380
Laundry Pods in PET Container	Pods – Rigid PET Container	411.9	81.9%	18.1%	5,085	3,166	1,919
Laundry Pods in Flexible Pouch	Pods – Flexible Pouch	554.1	81.8%	18.2%	5,131	4,076	1,055
Laundry Pods in Flexible Pouch (no overbox)	Pods – Flexible Pouch	287.3	89.6%	10.4%	2,660	1,796	865
Bag-in-box	Bag-in-box	352.3	89.8%	10.2%	3,670	2,621	1,049

To determine the package recycled and packaging discard rate, the following assumptions were made:

- *Corrugated container 48% recycled content (based on U.S. average)*
- *Corrugated recycling rate 92.3% (U.S. EPA)*
- *PET container recycling rate of 29.2% (2017 APR PET Container Recycling Activity Report)*
- *Multi-material flexible packaging was assumed to have 0% recycling rate*
- *HDPE Bubble dunnage recycling rate of 4% (per Closed Loop Partners Film Recycling Investment Report)*
- *All material collected for recycling was assumed to be actually recycled*
- *Package landfilled is amount of packaging not recycled, goes to municipal solid waste*

End of Use Summary

As mentioned previously, a SMM system looks to maximize the use of resources in packaging. Additionally, the U.S. EPA Waste Hierarchy lists source reduction and reuse at the very top of the hierarchy as a method to reduce overall waste.

The end of use summary shows some interesting findings. All of the formats used corrugated cases as the e-commerce shipping container which has a high recycling rate of 92.3%. The two scenarios with rigid containers, the HDPE bottle and PET rigid container, are generally recyclable in most curbside programs, yet yielded an amount of packaging discarded, often double (2,380g and 1,920g respectively) that of the amount discarded where a multi-layer flexible pouch is the primary packaging system (1,350g for flexible pouch with fitment, 1,055g for pods in flexible pouch and 1,049g for bag-in-box system) when considering current recycling rates.

A final note is that while flexible bubble dunnage was used only in the rigid packaging systems (HDPE bottle and PET container), these materials are generally recyclable in grocery store drop-off programs (but not curbside).

The examples highlight that while many multi-layer flexible materials are not yet recovered, they still result in a substantial reduction in the amount of material sent to landfill vs. other package formats and can help limit the amount of material needed in e-commerce shipping because of the robustness and lack of denting/damage/leaking often seen in rigid packaging.

Summary/Implications

The results of the laundry detergent e-commerce case study show that while there are a number of different formats that use multi-layer flexible packaging as the primary package to contain either liquid detergent or pods, they are well suited to use in an e-commerce environment. Whether a flexible pouch with fitment or bag-in-box for liquid detergent, or a stand-up pouch containing pods, the flexible based options often had a number of sustainability benefits when compared to primary package using a rigid format. These benefits included reduced fossil fuel usage, carbon impact, water usage, and municipal solid waste over the rigid container options in this e-commerce scenario, even when taking the current recycling rate of the rigid container into consideration.

Additionally, flexible packaging can have an additional benefit in e-commerce applications. The toughness of multi-layer flexible structures and the ability to flex upon drops and additional handling make them ideal for products categories where leaks or a crack/puncture could be detrimental to consumer use, such as laundry detergent.

When selecting a particular package format, a number of product and package attributes need to be considered. These may include retail/shipping environment, shelf impact, consumer usage, product branding, reclose features, and sustainability benefits. Sustainability attributes are never considered on their own, but always as part of broader, more holistic packaging solution.

Table 3-L summarizes much of the critical data and package comparison discussed for this laundry detergent pod packaging case study.

Table 3-L. Laundry Detergent E-commerce Packaging Comparison Summary

Format	Fossil Fuel Consumption (MJ deprived) *(from Fig 3-10)*	GHG Emissions (kg-CO2 equiv) *(from Fig 3-11)*	Water Use (liters) *(from Fig 3-12)*	Product-to-Package ratio and percent wt. *(from Table 3-K)*	Pkg Landfilled (g)/1,000 kg Magazine *(from Table 3-K)*
Liquid Detergent in Stand-up Pouch w/ Fitment	4.07	.2613	69.61	11.9:1 92.2%:7.8%	1,350
Liquid Detergent in HDPE Bottle	7.80 (+91.5%)	.4309 (+64.9%)	91.16 (+31.0%)	6.8:1 87.2%:12.8%	2,380 (+76.3%)
Laundry Pods in PET Container	6.93 (+70.1%)	.4026 (+54.1%)	118.25 (+69.9%)	4.5:1 81.9%:18.1%	1,919 (+42.1%)
Laundry Pods in Flexible Pouch	3.46 (-15.1%)	.2479 (-5.1%)	73.19 (+5.1%)	4.5:1 81.8%:18.2%	1,055 (-21.9%)
Laundry Pods in Flexible Pouch (no overbox)	2.55 (-37.4%)	.1634 (-37.5%)	60.11 (-13.7%)	8.7:1 89.6%:10.4%	865 (-35.9%)
Bag-in-box	3.18 (-21.9%)	.1961 (-25.0%)	49.41 (-29.0%)	8.8:1 89.8%:10.2%	1,049 (-22.3%)

Notes:

- *A normalized functional unit of loads of laundry was used for Fossil Fuel, GHG, and Water Consumption calculations.*
- *All percentages cited are for other formats compared to the liquid detergent in stand-up flexible pouch with fitment.*
- *A higher number for product-to-package ratio (first number) cited means a higher percentage of weight is attributed to product, and less to packaging, resulting in more efficient use of packaging resources, however, this metric may be a bit less relevant in laundry uses due to different product concentrations.*
- *For all percentage comparisons in EcoImpact-COMPASS®, the tool uses percent change. The formula is: ((Other pkg value – flexible pkg value)/ flexible pkg value) *100 = percent change.*
- *Package landfilled values are based on the amount of packaging sent to municipal solid waste after recycling, based on 1,000 loads of laundry.*

Sources:

- Recycling rates used in calculations based on EPA Advancing Sustainable Materials Management Fact Sheet, July 2018 (Accessed October 29, 2019)
- Additional recycling rate sources:
  - Flexible film recycling rate: Closed Loop Foundation- Film Recycling Investment Report (2017)- https://www.closedlooppartners.com/wp-content/uploads/2017/09/FilmRecyclingInvestmentReport_Final.pdf
  - 2017 APR/Napcor Postconsumer PET Container Recycling activity - https://napcor.com/wp-content/uploads/2018/11/NAPCOR_2017RateReport_FINAL.pdf

Mailer E-commerce Packaging Comparison

While much of e-commerce is shipped in corrugated cases, there are a number of other formats that are being used, particularly for smaller items. For this scenario, a number of alternatives for mailing items such as magazines, books, clothing, etc. were explored. The mailers include both polymer and paper-based options, as well as one option that uses a combination of paper and plastic.

All of the mailers were similar in size (ranging from 10.5” to 12” wide and 14.25” to 16” in length). To normalize the data, all samples were extrapolated to be the same size (12” x 15.5” – 186 square inches) for the assessment in the EcoImpact-COMPASS® software.

For this Life Cycle Assessment study, the following package formats were evaluated:

Table 3-M. Mailer E-commerce Packaging Evaluation Comparison

Package Type/Product Weight	Structure (package weight)	Photo
Poly E-commerce Mailer		
Poly Mailer	HDPE – 17.33g	
	TOTAL = 17.33g	
Bubble E-commerce Mailer		
Bubble Mailer	HDPE – 29.68g	
	TOTAL = 29.68g	
Paper Cushion E-commerce Mailer		
Paper Cushion Mailer	SUS Paper – 78.45g Shredded Recycled Paper – 52.30g	
	TOTAL = 130.75g	

Paperboard Document E-commerce Mailer		
Paperboard Document Mailer	SUS Paperboard – 139.07g	
	TOTAL = 139.07g	

Kraft Paper/Bubble E-commerce Mailer		
Kraft Paper/Bubble Mailer	Kraft Paper – 28.08g HDPE – 12.52g	
	TOTAL = 40.6g	

Packages as close as possible in size/volume were selected to make the lifecycle comparison. Not in all cases were packs of identical size/volume available for purchase.

For this comparison, the same size was used (186 sq. inches) to ensure that comparisons were as equal as possible. For the product: package ratio and other product metrics, a magazine weighing 100g was used as the product, though any of these mailers could be used with other documents, small electronics, or other small items.

Following are photos of the different e-commerce formats that were ordered for evaluation:

Figure 23. Photo showing all of the mailers together. All were very close in overall size and normalized for same area in EcoImpact-COMPASS software. From left to right: poly mailer, bubble mailer, paper cushion mailer, paperboard document mailer, and kraft paper/bubble mailer.

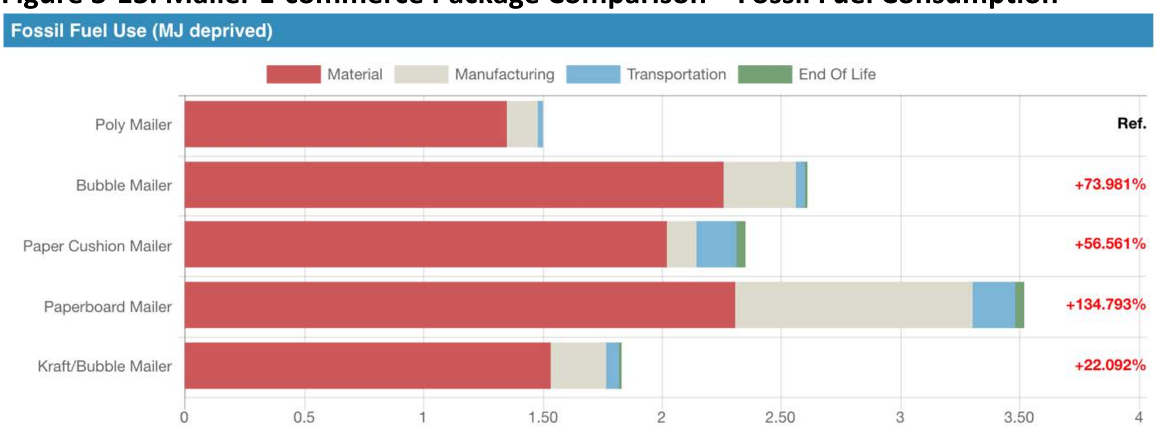
Figure 24. Flexible mailers tend to be made from LDPE, which is recyclable in store drop-off locations with plastic grocery bags (if labels are removed). The samples acquired for this test did not have any specific recycling or use of recycled content called out, though both are possible with poly and/or all bubble mailers and shown as examples above.

Fossil Fuel Consumption, Greenhouse Gas Emissions, and Water Use Comparison

The following charts highlight results of the fossil fuel usage, greenhouse gas (GHG) emissions, and water use for each of the package formats evaluated. These are some of the common indicators that package developers consider when appraising the environmental impacts of a particular package. The EcoImpact-COMPASS® software "normalizes" the data based on the functional unit such as weight or number of uses to allow comparison between package formats which may not be the exact same size.

For all of the following comparison charts, the poly mailer was considered the "standard" to which other samples were being compared.

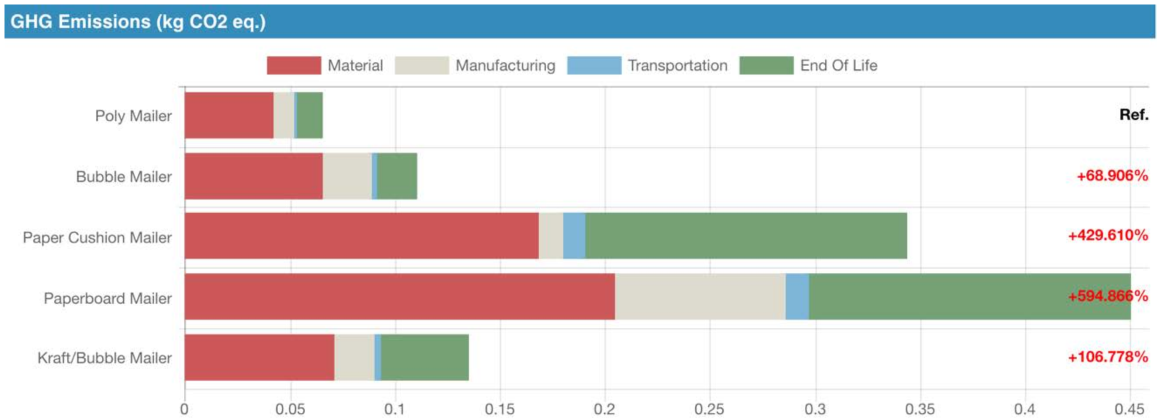
Figure 3-13. Mailer E-commerce Package Comparison – Fossil Fuel Consumption



The chart above shows that the poly mailer has the lowest overall fossil fuel consumption when compared to the other four variables. This is due to the poly mailer having the lowest weight. The second lowest fossil fuel use came from the kraft paper/bubble mailer, which was quite light compared to the other paper-based mailers, while also offering additional cushioning protection.

The highest fossil fuel use came from the paperboard document mailer, which weighed approximately eight times (139.07g vs. 17.33g) that of the poly mailer. Even with the paperboard mailer using a paper-based substrate vs. the poly mailer, the production of paper still requires additional energy, which reflects the higher fossil fuel usage number (+135%).

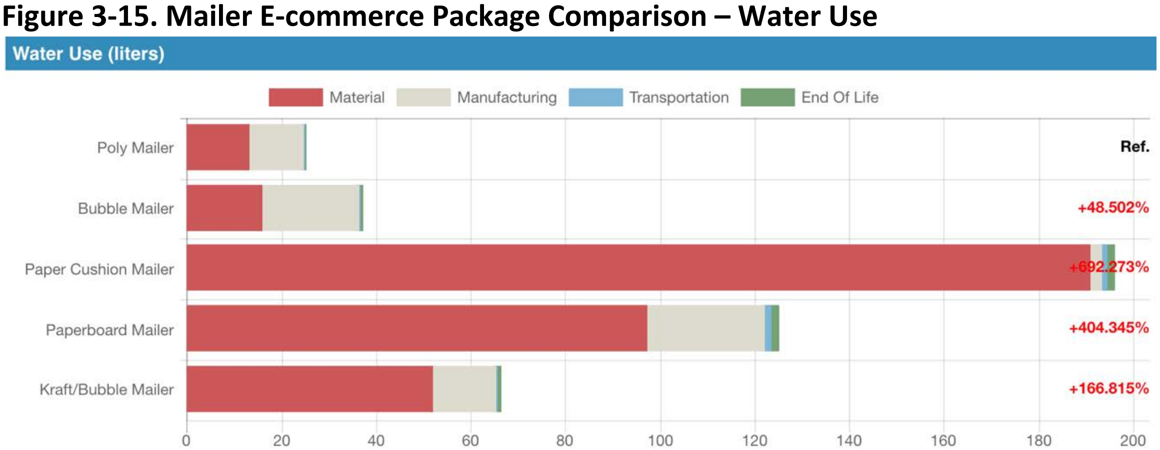
Figure 3-14. Mailer E-commerce Package Comparison – GHG Emissions



For GHG emissions, the poly mailer came in the lowest by a wide margin, followed by the bubble mailer (+68.9%), and then the kraft paper/bubble mailer. It should be noted that these are the three lightest options (17.33g, 29.68g, 40.6g), in their respective order.

The two paper-based options – the paper cushion mailer (130.75g) and paperboard document mailer (139.07g) are by the far the heaviest samples, and also have the highest GHG emissions (+429% and +595%). The end of life impacts (green bar) are highest for the paper-based items despite the fact that they have a higher recycling rate than the poly based options, as they still result in much more material being discarded at the end of life.

Figure 3-15. Mailer E-commerce Package Comparison – Water Use



Most plastic production, particularly flexible items, have low water usage in the material production and manufacturing stages. This is reflected in the lower water usage for the poly mailer and bubble mailer in particular.

The paper cushion mailer (+692%) and paperboard document mailer (+404%) on the other hand, both contain a large amount of paper, which is generally a water intensive production process.

End of Use Results

The poly mailer has the lowest environmental impacts when considering fossil fuel usage, GHG emissions, and water usage in this e-commerce scenario when compared to the other formats, followed by the bubble mailer.

The impacts of material recycled or discarded are considered to ensure that the package aligns with the circular economy or sustainable materials management goals. Table 3-N shows the results when current recycling rates are considered, as well the product-to-package ratio, which is a measure of the resource efficiency of the materials used. For this measure, a high product and a low package number are desired.

Table 3-N. Mailer E-commerce Packaging - Recycled and Landfilled Comparison

Format	Component	Pkg Wt. (g)	Product % Wt.	Package % Wt.	Pkg wt. (g)/ 1,000 kg mag	Pkg Recycled (g)/1,000 kg mag	Pkg Landfilled (g)/1,000 kg mag
Poly Mailer	Flexible Mailer	17.33	85.2%	14.8%	173,333	6,933	166,400
Bubble Mailer	Flexible Mailer	29.68	77.1%	22.9%	296,848	11,874	284,975
Paper Cushion	Paper-based Mailer	130.75	43.3%	56.7%	1,307,536	334,729	972,807
Paper-board	Paperboard Mailer	139.07	41.8%	58.2%	1,390,720	356,024	1,034,696
Kraft/ Bubble	Kraft Paper/ Bubble Mailer	40.6	71.1%	28.9%	405,952	0	405,952

To determine the package recycled and packaging discard rate, the following assumptions were made:

- *A magazine weighing 100g was considered as the product for the product: package ratio. Packaging weight, amount recycled, and amount landfilled based off the amount of packaging need for delivery of 1,000kg of the magazine*
- *Paperboard recycling – 25.6% Cartons U.S. EPA – https://www.epa.gov/sites/production/files/2018-07/documents/2015_smm_msw_factsheet_07242018_fnl_508_002.pdf*
- *HDPE Flexible Mailer Pouch and LDPE Bubble Filler - 4% recycling rate (Closed Loop Partners) – How2Recycle® Store Drop-Off*
- *All material collected for recycling was assumed to be actually recycled*

- *Package landfilled is amount of packaging not recycled, goes to municipal solid waste*

End of Use Summary

The U.S. EPA Waste Hierarchy considers source reduction and reuse as the top method for overall waste reduction, followed by recyclability. The results show that the poly mailer and bubble mailer both use the least amount of packaging by a wide margin when compared to the other mailers. In fact, the total amount of packaging used for the poly mailer option is about one half the amount of material recycled for the paper-based options, based on U.S. carton/ paperboard recycling rates (25.6%). The kraft paper/bubble mailer comes out in the middle, as would be expected as it is lighter than the paperboard options but is not considered recyclable as it includes a combination of both paper and bubble wrap, making separation extremely difficult. Still it provides good cushioning protection in a relatively lightweight package.

The paper-based mailers, while having a higher recycling rate than the poly-based mailers, used much more material and resulted in approximately five times as much material going to landfill, based on current U.S. recycling rates.

Summary/Implications

In summary, the poly flexible mailer, as well as the bubble mailer made from HDPE, came in with the lowest environmental impacts across a range of metrics, including fossil fuel use, greenhouse gas emissions, water use, material used, and the amount of material discarded. This was due to the much lower amount of material that the plastic based options used when compared to the paper-based mailers. Both of the paper-based mailers are recyclable, and both included a high percentage of recycled content (95% PCR paper for the paperboard mailer and 100% PCR for the filler portion of the paper cushion mailer), but still resulted in more material discarded as well as other environmental impacts. It should be noted as well that both the poly mailer and bubble mailer could be labeled for recycling through the store drop-off programs if they went through the How2Recycle® certification process and included communication that the label should be removed from the pack before recycling. A number of mailers have gone through this step, though the samples acquired and used in this comparison had not gone through the certification process.

As in almost all package selection criteria, a wide range of package and product usage occasions need to be considered holistically. For example, the bubble mailer or paper cushion mailer should be considered if a product needs better protection during shipment, but items like clothing may not need the additional cushioning. One additional advantage of the both the poly mailer, as well as the bubble mailer, is that they may be more weather resistant in a wet or humid environment than paper-based options. Some flexible mailers also allow for easy opening and include a return feature (using an additional tape strip for easy reclose), an important consideration for consumer convenience. Overall, the combination of environmental impacts, brand alignment, consumer benefits, and economic impacts, including shipping impacts are important considerations in any e-commerce package, but the use of a poly mailer or bubble mailer may fit many of these critical criteria.

Table 3-O summarizes much of the critical data and package comparison discussed for this e-commerce packaging case study.

Table 3-O. Mailer E-commerce Packaging Comparison Summary

Format	Fossil Fuel Consumption (MJ deprived) *(from Fig 3-13)*	GHG Emissions (kg-CO2 equiv) *(from Fig 3-14)*	Water Use (liters) *(from Fig 3-15)*	Product-to-Package ratio and percent wt. *(from Table 3-N)*	Pkg Landfilled (g)/1,000 kg Magazine *(from Table 3-N)*
Poly Mailer	1.49	.06467	24.70	5.8:1 85.2%:14.8%	166,400
Bubble Mailer	2.60 (+74.0%)	.1092 (+68.9%)	36.68 (+48.5%)	3.4:1 77.1%:22.9%	284,975 (+71%)
Paper Cushion	2.34 (+56.6%)	.3425 (+430%)	195.68 (+692%)	0.8:1 43.3%:56.7%	972,807 (+485%)
Paper-board	3.51 (+135%)	.4494 (+595%)	124.56 (+404%)	0.7:1 41.8%:58.2%	1,034,696 (+522%)
Kraft/ Bubble	1.82 (+22.1%)	.1337 (+107%)	65.90 (+167%)	2.5:1 71.1%:28.9%	405,952 (+144%)

Notes:

- *A normalized product functional unit of 1 magazine with a weight of 100g was used for Fossil Fuel, GHG, and Water Consumption calculations.*
- *All percentages cited are for other formats compared to the flexible e-commerce pouch.*
- *A higher number for product-to-package ratio (first number) cited means a higher percentage of weight is attributed to product, and less to packaging, resulting in more efficient use of packaging resources.*
- *For all percentage comparisons in EcoImpact-COMPASS®, the tool uses percent change. The formula is: ((Other pkg value – flexible pkg value)/ flexible pkg value) *100 = percent change.*
- *Package landfilled values are based on the of amount of packaging sent to municipal solid waste after recycling, based on 1000 kg of the magazine used as the basis for both comparisons.*

Sources:

- Recycling rates used in calculations based on EPA Advancing Sustainable Materials Management Fact Sheet, July 2018 (Accessed October 29, 2019) - https://www.epa.gov/sites/production/files/2018-07/documents/smm_2015_tables_and_figures_07252018_fnl_508_0.pdf
- Flexible film recycling rate: Closed Loop Foundation- Film Recycling Investment Report (2017)- https://www.closedlooppartners.com/wp-content/uploads/2017/09/FilmRecyclingInvestmentReport_Final.pdf

Acronyms – Chapter 3

APR	Association of Plastic Recyclers
BON	Biaxially Oriented Nylon
DTC	Direct to Consumer
EPA	U.S. Environmental Protection Agency
EVOH	Ethylene Vinyl Alcohol
GHG	Greenhouse Gas Emissions
HDPE	High Density Polyethylene (labeled as #2 plastic)
LCA	Life Cycle Assessment
LDPE	Low Density Polyethylene (labeled as #4 plastic)
LLDPE	Linear Low Density Polyethylene
NAPCOR	National Association for PET Container Resources
PET	Polyethylene Terephthalate (labeled as #1 plastic)
PP	Polypropylene (labeled as #5 plastic)
SMM	Sustainable Materials Management

Chapter 4: Dimensional Weight and Economics

The term "Dimensional Weight" is part of the new digital economy lexicon; combining two disparate measures of distance (length x width x height) and a measure of mass (weight) and relating them into a specific calculation. Specifically, dimensional weight is defined as package dimensions (L x W x H) divided by a carrier provided divisor (139) which equals an assigned dimensional weight. Once calculated, the amount charged for shipping, the "billable weight," is the greater of actual or the dimensional weight. This billable weight process anchors the new economics for e-commerce shipping.

Packages are billed and charged by the greater of the following weights:

1.) Dimensional Weight = L x W x H / Carrier Divisor or
2.) Actual Weight (based on actual product weight)

The traditional retail shipping model was built and optimized for large scale pallet loads for delivery to retailers in large quantities. This retail model relied upon filling fixed cost truckloads, optimizing for weight or cubed pallets, and single point distribution destinations that handled the final store shelf sets. Brand owners and retailers became very good at efforts in efficiency gains.

E-commerce miniaturizes shipping to an individual unit and integrates into the consumer decision making process, as seen in promotions with "free shipping". The consumer now considers shipping costs in the path to purchase. Brands must also rethink delivery of direct-to-consumer (DTC) and via parcel carriers that consider dimensional weight impacts. It is critical for brands to develop a deep understanding of dimensional weight drivers and the resulting economics to be successful in e-commerce.

Note: For purposes of comparison and shipping cost analysis, carrier published rates were utilized for this report. Brand owners and e-ecommerce retailers are known to negotiate lower rates with scale so the prices in the report reflect published rates and are intended for comparative purposes and not as absolute cost to ship.

In addition, flat rate shipping was calculated, which is an emerging shipping rate now available from carriers (and pioneered by USPS). Flat Rate Shipping is designed for shipments of actual weight 50 lbs. and under and assigns rates directly from the dimensional cube (L x W x H) of a package. This in effect rewards optimal dimensional cube and provides further evidence of the link between shipping costs and package design.

<u>Dimensional Weight Details</u>

The dimensional weight calculation is straightforward, but nuanced and important to be fully understood. The following assumptions are critical for product and package design and being opportunistic with rounding/input rules. Some of the key rules to understand include:

- Dimensional weight (DW) always rounds up (i.e. a dimensional weight that calculates to 8.2 lbs., will be rounded up to 9 lbs. for costing purposes)
- Dimensional cube = (L x W x H) follows traditional rounding principals (i.e. 11.4" rounds to 11" and 8.7" rounds to 9")
- The transportation carriers determine the divisor and have modified over years (see example below)
  - In 2017 DW = 1000/166 = 6.02 = 7.0
  - Current (2020) DW = 1000/139 = 7.19 = 8.0

These assumptions should lead brands to consider targeting a weight closest to a whole number, for example a dimensional weight of 7.2 lbs. rounds to 8 and leaves dimensional space of .8 lbs. equivalence on the table. The divisor change between 2017 and 2019 effectively increased shipping costs by 10%-20% for identical sized packages simply by increasing the dimensional weight divisor and rounding up. This underlies Amazon's push to acquire and internalize shipping operations in an effort to contain delivery costs.

Other Dimensional Weight Factors

Beyond the finer points of the dimensional weight calculation, other factors will influence a dimensional weight calculation. Product density, package weight, package geometry, dunnage, and fulfillment operations all contribute to a final dimensional weight. In a majority of products shipped via e-commerce, the dimensional weight is greater than actual weight. The resulting billable weight (or the charged rate) differential indicates an opportunity to optimize and directly reduce costs.

For example, a potato chip bag picked off a retail shelf would have an actual weight of 1 lb., but have a dimensional weight = (11" x 9" x 8")/139 = 5.39 = 6.0 lbs. So, the billable weight will be the greater of these two; the dimensional weight of 6.0 lbs. This highlights the need for a product/package configuration that can optimize shipping costs and ultimately drive a brand's profit.

E-commerce Packaging Case Studies

The objective of these e-commerce case studies was to determine the influence and quantify the impact of flexible packaging formats on dimensional weight and subsequently on shipping costs.

Four products (based on the LCA case studies) were reviewed for this report.

- Shoes - Ultra lightweight product category
- Cereal - Lightweight product category
- Detergent - Medium to heavy weight product category
- Peanut Butter - Medium weight product category

Note: The mailers for e-commerce were not included in this report as they are flat in dimension and would generally have minimal impact for dimensional weight. See the appendix for the details of the case studies.

Summary of case studies:

The case studies collectively demonstrate the advantages of the flexible format selection for e-commerce across multiple categories:

- In 3 of the 4 case studies, the flexible primary format delivered the smallest dimensional weight, which translated to lowest shipping costs when it was the billable weight
- Flexible formats demonstrate great potential to take advantage of Flat Rate Shipping costs, which offer dimensional weight tiers that are cost effective for products under 50 lbs. actual weight
- The cereal case study showed an example where a primary package made from flexible packaging yielded a much smaller cube and thus shipping cost reduction, including when shipped in a corrugated overbox for e-commerce
- The use of flexible packaging as the tertiary shipping package for e-commerce applications (for appropriate categories like shoes and clothes) can drive additional package reduction and savings in shipping costs as highlighted in the shoe case study
- Dunnage can play a role in product protection, but also increase package dimensions
- Some products arrived with an additional e-commerce overbox that could be eliminated if the product went through an e-commerce certification program such as Amazon’s Frustration Free shipping program.

Appendix

Life Cycle Assessment and Case Study Data Input

Peanut Butter:

EcoImpact-COMPASS® LCA Tool inputs:

Format	Prod. Wt.(g)	Component	Material	Pkg Wt.(g)	Process	Pkg Type
Stand-up Pouch w/ Fitment	176	Multi-layer Pouch	PET/Foil/ LLDPE	5.3	Film Extrusion/ Laminating/ Aluminum Sheet Rolling/ Film Extrusion/ Laminating	Composite
		Fitment	PP	5.9	Injection Molding	Composite
		Corrugated Case	Corrugated	84.5	Production of Corrugated Containers	Corrugated Boxes
Stand-up Pouch w/ Fitment & Overbox	176	Multi-layer Pouch	PET/Foil/ LLDPE	5.3	Film Extrusion/ Laminating/ Aluminum Sheet Rolling/ Film Extrusion/ Laminating	Composite
		Fitment	PP	5.9	Injection Molding	Composite
		Corrugated Case	Corrugated	84.5	Production of Corrugated Containers	Corrugated Boxes
		Overbox	Corrugated	191.6	Production of Corrugated Containers	Corrugated Boxes
		Dunnage	HDPE	3.9	Film Extrusion	Bags, Sacks & Wraps
PET Jar	454	Jar	PET	25.7	Blow Molding	Other Plastic Containers
		Lidstock	Paper/ Foil/ LDPE	1.3	Laminating/ Paper Cutting/ Aluminum Sheeting Rolling	Composite
		Lid	PP	8.3	Injection Molding	Other Plastic Pkg
		Label	Paper Label	1.5	Paper Cutting	Non-recyclable
		Case	Corrugated	108.7	Production of Corrugated Containers	Corrugated Boxes

Cereal:

EcoImpact-COMPASS® LCA Tool inputs:

Format	Prod. Wt.(g)	Component	Material	Pkg Wt.(g)	Process	Pkg Type
Stand-up Pouch w/ Press to Close Zipper	340	Stand-up Pouch	HDPE/HDPE	7.0	Co-extrusion	Other Plastic Pkg
		Press to close	LDPE	1.8	Extrusion (Plastic Tube)	Other Plastic Pkg
		Outer box	Corrugated	224.8	Production of Corrugated Containers	Corrugated Boxes
Bag-in-box (w/ overbox)	283.5	Flexible Bag Liner	HDPE	5.1	Co-extrusion	Other Plastic Pkg
		Carton	Paperboard (recycled)	55.1	Production of Cartons	Folding Cartons
		Corrugated Case	Corrugated	202.4	Production of Corrugated Containers	Corrugated Boxes
		Dunnage	Unbleached Kraft Paper	51.1	Paper Cutting	Other Paper Pkg
		Corrugated Overbox	Corrugated	416.9	Production of Corrugated Containers	Corrugated Boxes
Bag-in-Box	283.5	Flexible Bag liner	HDPE	5.1	Co-extrusion	Other Plastic Pkg
		Carton	Paperboard (recycled)	55.1	Production of Cartons	Folding Cartons
		Corrugated Case	Corrugated	202.4	Production of Corrugated Containers	Corrugated Boxes

Laundry Detergent:

EcoImpact-COMPASS® LCA Tool inputs:

Format	Prod. Wt.(g)	Component	Material	Pkg Wt.(g)	Process	Pkg Type
Liquid Detergent in Stand-up Pouch w/ Fitment	84 Loads (50 fl. oz)	Stand-up pouch	48 ga PET/Ink/Adh/ 60 ga BON/Adh/4 mil Coex LLDPE/HDPE/ LLDPE	24.4	Film Extrusion/ Laminating/ Co-extrusion	Composite
		Fitment	PP	5.9	Injection Molding	Composite
		Outer box	Corrugated	242	Production of Corrugated Containers	Corrugated Boxes
		Divider	Corrugated	50.7	Production of Corrugated Containers	Corrugated Boxes
Liquid Detergent in HDPE Bottle	64 Loads	Bottle	HDPE	110.8 (25% PCR)	Blow Molding	Other Plastic Containers
		Spout	PP (insert)	13.3	Injection Molding	Other Plastic Containers
		Measuring Cup	PP	19.9	Injection Molding	Other Plastic Containers
		Bag Overwrap	LDPE	12.2	Film Extrusion	Bags, Sacks & Wraps
		Bubble Dunnage	HDPE	15.1	Film Extrusion	Bags, Sacks & Wraps
		Corrugated Overbox	Corrugated	263.1	Production of Corrugated Containers	Corrugated Boxes
Laundry Pods in Rigid PET Container	81 Loads	Rigid Tub	PET	147.9	Blow Molding	Other Plastic Containers
		Lid	PP	18.8	Injection Molding	Other Plastic Pkg
		Bubble Dunnage	HDPE	15.6	Film Extrusion	Bags, Sacks & Wraps

		Corrugated Case	Corrugated	229.6	Production of Corrugated Containers	Corrugated Boxes
Laundry Pods in Flexible Pouch (Overbox)	108 Loads	Flexible Pouch	48 ga. PET/Ink/Adh/ 60 ga BON/Adh/3.5 mil LLDPE	16.9	Film Extrusion/ Laminating/ Co-Extrusion	Composite
		Zipper	LDPE	1.6	Film Extrusion	Composite
		Slider	PP	.8	Injection Molding	Composite
		Inner Case	Corrugated	210.1	Production of Corrugated containers	Corrugated Boxes
		Overbox	Corrugated	266.8	Production of Corrugated Containers	Corrugated Boxes
Laundry Pods in Flexible Pouch	108 Loads	Flexible Pouch	48 ga. PET/Ink/Adh/ 60 ga BON/Adh/3.5 mil LLDPE	16.9	Film Extrusion/ Laminating/ Co-extrusion	Composite
		Zipper	LDPE	1.6	Film Extrusion	Composite
		Slider	PP	.8	Injection Molding	Composite
		Case	Corrugated	210.1	Production of Corrugated Containers	Corrugated Boxes
Liquid Detergent Bag-in-box	96 Loads	Inner Bag	LLDPE/ Nylon/ LDPE/ HDPE	28	Film Extrusion/ Laminating	Composite
		Measuring Cup	PP	10	Injection Molding	Other Plastic Pkg
		Fitment/ Spout	PP	23.9	Injection Molding	Composite
		Overbox	Corrugated	272.6	Production of Corrugated Containers	Corrugated Boxes
		Overwrap	HDPE	17.8	Film Extrusion	Composite

Shoes:

EcoImpact-COMPASS® LCA Tool inputs:

Format	Prod. Wt.(g)	Component	Material	Pkg Wt.(g)	Process	Pkg Type
Shoe Box w/ flexible E-commerce Shipping Mailer		Shoe Box	Corrugated	184.8	Production of Corrugated Containers	Corrugated Boxes
		E-comm Pouch	LDPE	43.7	Film Extrusion/ Laminating	Other Plastic Pkg
Shoe box w/ E-commerce Overbox		Shoe Box	Corrugated	184.8	Production of Corrugated Containers	Corrugated Boxes
		Dunnage	HDPE	3.8	Film Extrusion	Other Plastic Pkg
		Overbox	Corrugated	348	Production of Corrugated Containers	Corrugated Boxes

Mailers

EcoImpact-COMPASS® LCA Tool inputs:

Format	Prod. Wt.(g)	Component	Material	Pkg Wt.(g)	Process	Pkg Type
Poly Mailer	100	Poly Mailer	LDPE	17.33	Film Extrusion	Bags, Sacks & Wraps
Bubble Mailer	100	Bubble Mailer	HDPE	29.68	Film Extrusion/ Laminating	Bags, Sacks & Wraps
Paper Cushion	100	Paper	SUS Paper – 78.45g Shredded Recycled Paper (100% PCR) – 52.30g	130.75	Production of Paper bags/	Bags & Sacks
Paper-board	100	Paperboard	SUS Board (95% PCR)	139.07	Production Carton	Other Paperboard Packaging
Kraft/ Bubble	100	Kraft Paper/ Bubble Wrap	Kraft Paper – 28.08g HDPE – 12.52g	40.6	Laminating/ Paper Cutting Film Extrusion/ Laminating	Composite

APPENDIX – Dimensional Weight

Case Studies in Dimensional Weight

Overview Summary

The case studies collectively demonstrate the advantages of flexible packaging for e-commerce across several categories. Across three categories, the flexible primary format delivered the smallest dimensional weight, which translated to the lowest shipping costs when it was the billable weight. Furthermore, flexible formats demonstrate great potential to take advantage of Flat Rate Shipping costs, which offer dimensional weight tiers that are cost effective for products under 50 lbs. actual weight. Flexible formats can leverage the lower dimensional weight tiers for Flat Rate Shipping, which other formats are challenged to achieve. This positions flexible formats with the capability to capture the lowest shipping costs by comparison.

For example, in both the cereal and peanut butter categories, flexible formats ranked in the top for lowest dimensional cube. This also led to them yielding the lowest shipping costs for their respective category as well. In the case of cereal, the favorable flexible primary package also enabled more product in a smaller cube, which could be a direct opportunity to drive more sales with a fixed shipping cost.

In the detergent category, flexible formats ranked in the top three for lowest dimensional cube (see case study for bag-in-box, pouch with fitment, and pod pouch with no overbox). This also translated to a bag-in-box delivering the lowest shipping cost due largely to optimized flexible and shipping case dimensions. The rest of the formats were billed largely by their actual weight due to the product attributes and density. However, in the pouch with fitment and pods in pouch examples, if the secondary packaging was optimized for flexible selections then there are potential savings in shipping costs. This example highlighted the necessity in secondary packaging design to compliment a flexible primary package selection.

Current Carrier Rates can be calculated at UPS website link below. For the report the team used Ground shipping costs from Michigan to Texas for distance.

https://wwwapps.ups.com/ctc/request?loc=en_US

Peanut Butter Dimensional Weight and Economic Comparison

Item Description	L (in.)	W (in.)	H (in.)	Cubic inches	Dim Weight (lbs.)	Actual Weight (lbs.)	Flat Rate (Carriers)	UPS (STD)
Stand-up Pouch w/ Fitment (No Overbox) (36 oz.)	8	4	7	224	2	3	$10.95	$11.95
Stand-up Pouch w/ Fitment, and Overbox (36 oz.)	12	9	6	648	5	4	$14.95	$13.15
PET Jars, 3 pack case (48 oz.)	10	5	3	150	2	4	$10.95	$13.15

Insight: In the medium density product category, flexible packaging shows opportunity and promise for dimensional weight reduction. The rigid PET jar was packed into a small box, which netted a positive dimensional and billable weight (in line with the flexible pouch but providing more actual product). One shipment of the flexible pouch with fitment was delivered with an excessive overbox, which drove the dimensional weight and shipping costs higher. In a second shipment, this overbox was removed, and demonstrated a lower dimensional weight and shipping cost. This highlights the importance of holistic design of secondary packaging to take advantage of the lack of shipping damage a flexible primary package may have, and results in a reduced dimensional (and therefore billable) weight.

Cereal Dimensional Weight and Economic Comparison

Item Description	L (in.)	W (in.)	H (in.)	Cubic inches	Dim Weight (lbs.)	Actual Weight (lbs.)	Flat Rate (Carriers)	UPS (STD)
Stand-up Pouch, Case (60 oz.)	15	10	4	600	5	6	$14.95	$14.70
Bag-in-box, Case and Overbox (72 oz.)	17	11	13	2,431	18	7	$23.95	$22.34
Bag-in-box, Case (72 oz.)	13	11	7	1,001	7	6	$19.95	$16.12

Insight: In a lightweight category such as cereal, a stand-up pouch primary package selection reduced the dimensional weight of the case and resulted in the smallest shipping container, by a wide margin, and the best shipping cost. This was due to a combination of the overall space savings generated by the stand-up pouch packing format and efficient secondary packaging.

The bag-in-box arrived packed in an excessive overbox, which drove the dimensional weight and shipping costs higher ($23.95/$22.34). Note that this case had over four times the volume as the stand-up pouch case! If the overbox was removed, then the dimensional weight is more competitive and aligned more closely with the pouch ($19.95/$16.12). However, the dimensional weight still nets out higher than the flexible pouch due to the inherent headspace in a bag-in-box pack.

Shoes Dimensional Weight and Economic Comparison

Item Description	L (in.)	W (in.)	H (in.)	Cubic inches	Dim Weight (lbs.)	Actual Weight (lbs.)	Flat Rate (Carriers)	UPS (STD)
Shoe Box with Flexible E-commerce Mailer	15	11	6	990	8	3	$19.95	$14.70
Shoe Box with E-commerce Overbox	16	13	6	1,248	9	3	$23.95	$17.14

Insight: In an extremely lightweight category of shoes, a flexible secondary package selection reduced the dimensional weight and resulted in a $4.00 reduction (17%). This was due to the flexible e-commerce shipping mailer taking up less dimensional space vs. a corrugated case. Dimensional space reduction is imperative in lightweight product categories such as shoes, because the cubic volume will be used to calculate weight. In this case, the product actual weight is 3 pounds, but is charged as a billable weight of 8 pounds, which is the calculated dimensional weight. Even small dimensional gains with flexible secondary wrap yield shipping savings through an improved dimensional weight (billable in lightweight categories).

Detergent Dimensional Weight and Economic Comparison

Item Description	L (in.)	W (in.)	H (in.)	Cubic inches	Dim Weight (lbs.)	Actual Weight (lbs.)	Flat Rate (Carriers)	UPS (STD)
Flexible Pouch w/ Fitment (84 Loads)	11	6	11	726	6	11	$19.95	$19.51
HDPE Bottle (64 Loads)	16	10	7	1,120	9	8	$23.95	$17.14
Rigid Pod Container (81 Loads)	15	8	8	960	7	5	$19.95	$14.70
Flexible Pod Pouch w/ Overbox (108 Loads)	13	8	11	1,144	7	7	$23.95	$16.12
Flexible Pod (No Overbox) (108 Loads)	13	8	9	936	7	7	$19.95	$16.12
Bag-in-box (96 Loads)	10	7	5	350	3	8	$14.95	$17.14

Insight: In a medium-heavy weight product category of detergent, the most efficient dimensional cube package was the liquid detergent bag-in-box. This optimal package design leverages the flexible interior format with a secondary case that eliminates any excessive headspace while protecting the product in distribution. This format yielded the best dimensional weight and resulted in billable by actual weight. Due to its excellent dimensional weight and cube efficiency, it had the best shipping cost as it took advantage of flat rate shipping that carriers reward dimensional weight on anything under 50 lbs. actual weight. This is an opportunity for medium-heavy product categories, where a holistic design can capture savings in a flat rate shipping rate.

The next two options with the lowest dimensional cube were the liquid detergent in stand-up pouch with fitment and well as the laundry pods in a flexible pouch (with the overbox eliminated). Both of these packs yielded lower dimensional weights but also had more opportunity to further leverage flexible format for lower shipping costs through secondary case design that reduces dimensional weight. These demonstrate the importance of secondary package sizing in order to realize the flexible advantages in dimensional weight.

Summary - Conclusions

Flexible packaging formats demonstrate clear and distinct advantages in reducing dimensional weight across many product category types (lightweight to high density) when used as either a primary or secondary/tertiary pack format. A flexible pack can help optimize space for a number of products and be a technique to reduce shipping size and costs. Various carrier rates and rules should be factored in order to obtain the best absolute rates, but a flexible format can contribute to a reduced dimensional weight along with shipping costs.

In conclusion, brands and retailers should consider the flexible format as a driver and tool in delivering optimal shipping costs for appropriate products and ultimately profitability in the growing e-commerce channel.

The Flexible Packaging Association is the voice of the U.S. manufacturers of flexible packaging and their suppliers. The association's mission is connecting, advancing, and leading the flexible packaging industry. Flexible packaging represents over $31 billion in annual sales in the U.S. and is the second largest and one of the fastest growing segments of the packaging industry. Flexible packaging is produced from paper, plastic, film, aluminum foil, or any combination of those materials, and includes bags, pouches, labels, liners, wraps, rollstock, and other flexible products.

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