



RETHINKING SINGLE-USE PLASTICS

Responding to a Sea Change in Consumer Behavior

Citi GPS: Global Perspectives & Solutions

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RETHINKING SINGLE-USE PLASTICS

Responding to a Sea Change in Consumer Behavior

“There’s no such thing as ‘away’. When we throw anything away it must go somewhere” — Annie Leonard, Executive Director of Greenpeace USA

Roughly half of global consumer packaging is made of plastic and over a third of resin that is produced by Chemical companies goes into packaging end markets. Plastics have become a staple of daily life in the modern world, steadily gaining share from other packaging materials over the last 50 years based on their low cost, durability, convenience, and malleability. However, environmental concerns around landfill contamination have grown steadily alongside increased plastics use, with a great deal of recent attention on ocean contamination and the growth of microplastics.

While debates around the sustainability and recyclability of plastics have been long-running in Europe and the Americas, the Chinese government took a revolutionary approach earlier this year, deciding it would no longer import ~50% of the world’s scrap plastic and paper. As China has been the dominant importer of plastic scrap with an annual plastics consumption of 8 million tonnes, this has led to a collapse in the price of various recovered plastics materials, and a glut of oversupply piling up in Western ports.

Echoing China’s actions, national and local governments have launched their own plastics bans. The U.K. has taken the lead position on preventing plastics waste with proposed bans on plastic cutlery, straws, and cotton buds/swabs. The EU has followed with their own ban, indicating once fully implemented in 2030 the changes could cost businesses over \$3.5 billion per year. Some of the most aggressive bans have been in emerging market countries; given these countries’ per capita plastic use is very low, the bans have the potential to sharply impact future consumption growth of plastics.

In response to increased environmental scrutiny, the plastics industry is not standing by idly. Chemical companies are adapting their portfolios and practices towards more environmentally-conscious strategies, focusing on light-weighting their products, investing in plastic recycling companies, improving recycling systems, and creating bio-based polymers. Almost 1 million tonnes of biodegradable plastics capacity has been built, and with appropriate legislation, the economic incentives could be established to build-out these higher-cost product capacities, addressing the environmental concerns.

As plastics face increased regulatory and consumer scrutiny, substrates including metal, glass, and paper may potentially be positioned to gain back some market share. We see a few potential ‘battleground’ packaging products, including soft drink bottles, coffee cups, protective packaging for e-Commerce, and retail bags. However, consumer choices are not always clear cut, as other substrates may offer more favorable recyclability and waste performance at the expense of plastics’ cost and performance advantages.

Risks and Opportunities in Single-Use Plastics

SINGLE-USE PLASTICS ARE A STAPLE OF MODERN LIFE

Roughly one-third of the **~400 million** tons of plastics produced per year is used for packaging applications



Around **52%** of global consumer packaging is made of plastic



The number of PET bottles produced each year has increased to **~500 billion** units from **~300 billion** in 2004



Source: Berry Global

There are real benefits to plastic...

Criteria	Plastic	Alternatives	Details
Energy to Produce	✓	✗	82% more energy to produce alternatives
Chemical Restrictions	✓	✗	Metals may oxidize or rust
Production Time	✓	✗	Faster cycle times lower unit cost
Malleability	✓	✗	Highly flexible vs. rigid alternatives
Weight	✓	✗	Alternatives are 3.5x heavier on average

BUT ITS DURABILITY AND AFFORDABILITY CARRY A HIGH ENVIRONMENTAL IMPACT

Degradation of plastic is between **500 and 1,000** years



Only 14% of plastic is recycled with the majority littered or ending up in landfills



PET bottles are the 3rd most common item found in ocean debris = **~15% of total marine waste**


Source: Ocean Conservancy




Caps and lids from PET bottles are the **4th most common item found in ocean debris**

CHINA'S 2017 BAN ON RECYCLED PLASTIC IMPORTS AND A GLUT OF OVERSUPPLY IN WESTERN PORTS HAS ACCELERATED PLANS FOR SINGLE-USE PLASTIC BANS


CHEMICAL AND PACKAGING COMPANIES ARE ADAPTING TO THESE CHANGES WITH NEW INITIATIVES AND STRATEGIES




China's recycling sector **growth was 23% from 2003-08** and 14% from 2009-2017




Source: IHS




Chinese plastic imports have fallen from **~8 million metric tons** (almost 50% of global trade) at the 2016 peak to nearly zero today



The U.K. and EU are leading the way on **preventing plastics waste and proposed bans**



In Africa, **25 countries have national bans on plastic bags** – 58% implemented between 2014 and 2017



Investing in plastic recycling systems and improving plastics-to-fuel programs

1

2

Investing in biodegradable plastic using plant-based materials such as sugar cane, corn or beets



Lightweighting and improving recyclability of their products

3

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Introduction

Roughly half of all global consumer packaging is now plastic

Single-use plastics are a staple of modern life, providing global consumers with convenient and cost-effective packaging for a wide range of food and beverage, home and health, and other products used daily. We estimate ~400 million tonnes of plastics are produced globally each year, and roughly half of all global consumer packaging is now plastic. Plastic packaging use mirrors a country's per capita income growth, meaning economies use more plastic packaging as they become more affluent.

The many advantages of plastic are also the cause of many environmental concerns

Plastics have revolutionized modern life and made products safer, cheaper, and easier to handle and transport, but as a material, its advantages are also its disadvantages. The widespread use of plastics has been driven by its several advantages over other substrates, including durability, weight, affordability, versatility, and amount of energy required to produce. However these features also drive the greatest environmental concern. Because plastics are so durable, it takes centuries for them to degrade. Because they are so cheap, it is often not economical to collect and recycle them. Because of this, plastics most often end up in landfills, or in bodies of water, as seen with the 'Great Pacific Garbage Patch.' Plastic contamination in bodies of water highlights the issue of microplastics, which can potentially harm humans through the consumption of seafood. Plastic packaging can also disrupt living systems in other ways that are less obvious, such as clogging drainage systems, and being consumed by cows and farm animals.

Single-use plastics are any plastic product used just once before being disposed of, or recycled — primarily PET bottles and bags

We define 'single-use plastics' as any plastic product which is used just once before being disposed of, or recycled. One of the leading uses for single-use plastic is in the production of PET (polyethylene terephthalate) beverage bottles used for water and soft drinks bottling. Nearly 500 billion units are now produced each year; an increase from ~300 billion units in 2004. Another common use for single-use plastics is for grocery and retail bags with an estimated 500 billion to 1 trillion of such bags consumed each year.

China's decision to no longer import 50% of the world's paper and plastic waste has rippled across the globe

While we've seen local, regional, and some national bans on isolated plastic packaging products over the last ~20 years, environmental actions taken by the Chinese government this year have transformed and accelerated the move out of single-use plastic. Beginning January 1, 2018, the Chinese government decided it would no longer import ~50% of the world's paper and plastic waste. With China no longer importing plastic waste and other countries unable to absorb the high level of supply, exporters will likely be forced to expand on domestic recycling infrastructure and/or cut back on the level of waste being produced. We've also seen the impact of China exiting the global recycling market pressuring profitability for recycling collectors, suppressing demand for recycled material, and leading to a glut of oversupply at European and U.S. ports. While the timing and implementation of China's bans are not certain, we believe the recycled plastics ban is here to stay, and in our view the dramatic impacts we've seen on U.S. and European plastics producers are just the beginning.

Increased scrutiny on single-use plastic has been seen across Europe and emerging markets, resulting in bans and levies

The environmental concerns highlighted by China's recent actions have echoed initiatives by governments around the world, and since the early 2000s there have been an increasing number of bans on single-use plastic. The U.K. has taken a leading position on preventing plastics waste starting with a 5p charge on disposable plastic bags in October 2015, which has been matched by efforts for the EU. In the U.S., where recycling initiatives typically trail Europe, the government hasn't pushed anything at the federal level but certain states and cities have reacted to the recent wave of news.

Global chemicals companies and plastic packagers are responding to changing public sentiment with innovation and technological advances

One of the more intense plastic bans is in Mumbai, India which has banned the use of plastic bags, cups, or bottles with penalties ranging from Rs5,000 (~\$70) for a first time offense and up to Rs25,000 (~\$350) and three months in jail for repeat offenders. Apart from government actions, individual companies are not waiting to react to changing consumer demands.

Improving plastic recycling systems would also address some of the environmental issues with single-use plastic

The ~\$1 trillion global chemicals industry is led by some of the best-capitalized and most inventive companies in the world, and Chemical producers and Plastic Packagers are responding to pressures on single-use plastic with innovation and technological advances. Recently plastics producers and packagers have focused on light-weighting their products, investing in plastic recycling companies, improving recycling systems, and creating bio-based polymers. Biodegradable plastics or polymers have been in production since the late 1990s in small commercial quantities. These polymers can be sourced from sustainable resources such as corn starch and also synthetic (mineral-based) building-blocks. Biodegradable plastic technology is available today, meeting the environmental demands required of an environmentally-friendly material. The cost and scale of capacity is likely to be the limiting factor in the rate of adoption. However, if legislators and consumers are willing to establish the price and thus the economic incentives for biodegradable plastics, then it is likely that the attractive properties of polymers vs. other materials will lead to an expanded role for these compostable products.

Improving plastic recycling systems would address some of the issues with single-use plastic, but this is not without its own challenges; in the U.S. the availability of recycling for different plastics varies widely, and the diversity of plastic types, especially flexibles, presents challenges in collection and recycling. Better alignment of public recycling systems and private partners, improved consumer education, and next-generation technologies such as those that treat non-recycled plastics as feedstock for conversion to fuels and chemicals, could potentially lead to improvements in recycling and the sustainability proposition of single-use plastics.

Substrates such as metal, glass, and paper could potentially gain back some market share as single-use plastics face increased regulatory and consumer scrutiny

As plastics face increased regulatory and consumer scrutiny, substrates including metal, glass, and paper may potentially be positioned to gain back some market share. We see a few potential 'battleground' packaging products, including soft drink bottles, coffee cups, protective packaging for e-Commerce, and retail bags, where substrate share shift could occur over the next decade. However consumer choices are not always clear cut, as other substrates may offer more favorable recyclability and waste performance at the expense of plastics' cost and performance advantages.

Citi believes that increased consumer and regulatory concern toward single-use plastic and other packaging materials is a critical investment theme, especially for asset managers with an ESG (Environmental, Social & Governance) mandate.

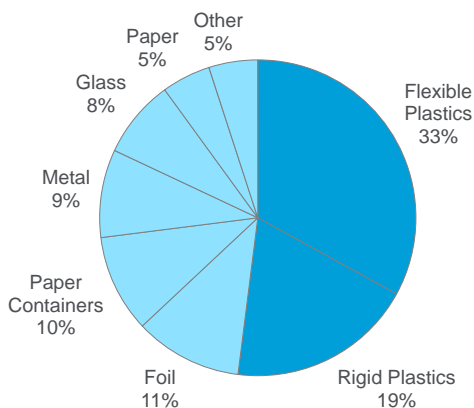
Single-Use Plastics are a Staple of Modern Life

Post-War Adoption in the U.S. and Europe

Single-use plastics are a staple of modern life

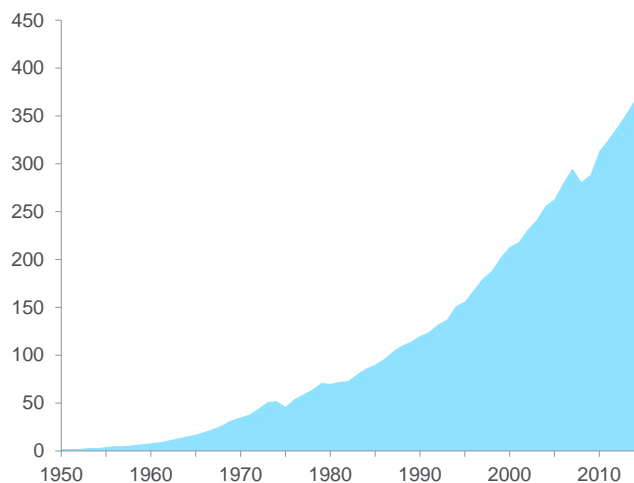
Single-use plastics are a staple of modern life, providing global consumers with convenient and cost-effective packaging for a wide range of food and beverage, home and health, and other products used daily. Whether it's the plastic bag shoppers use to carry groceries, the 20-ounce soda bottle sold at the local convenience store, or the plastic jug used for laundry detergent, single-use plastics are a global phenomenon. While the production of man-made plastics date back to the mid-1800s, plastic packaging for consumer applications was first popularized in the 1940s and 1950s when U.S. and European chemical companies turned their focus from industrial and military applications to post-war consumers who were building families and seeking an improved quality of life. The post-war period saw the popularization of products such as Tupperware — the iconic food containers that U.S. homemakers sold door to door — zipper storage bags, garbage bags and plastic spray bottles. These products revolutionized home life and plastics have been gaining share in consumer packaging at the expense of paper, glass, metal and other substrates over the past fifty years.

Figure 1. Global Consumer Packaging Market (units sold)



Source: Citi Research, Flexible Packaging Association

Figure 2. Annual Global Polymer Resin and Fiber Production (mmt)



Source: Citi Research, Geyer, Jambeck & Law 2017

Plastic packaging has grown in line with global resin production, at about an 8% CAGR since 1950

Globally we estimate ~400 million tonnes (mmt) of plastics is produced a year, with roughly one-third used for packaging applications. We estimate plastic packaging has grown roughly in-line with global resin production, which increased at a compound annual growth rate (CAGR) or ~8% since 1950. Notably the pace of plastics growth has remained fairly steady over the past five decades, with steady mid-single digit growth seen through the 1950-1970 period, the 1970-1990 period, and the 1990-2010 period. Plastic packaging comes in many shapes and sizes, but can generally be divided between flexible and rigid applications. Flexible plastic packaging includes products such as food wraps for meats & cheeses and overwraps for beverages & water bottles. These flexible applications have gained share at the expense of substrates like wax paper and paperboard boxes, while rigid plastic packages such as bottles for carbonated soft drinks and jugs for detergent have gained share from glass bottles and metal cans.

Figure 3. Plastic Substitution

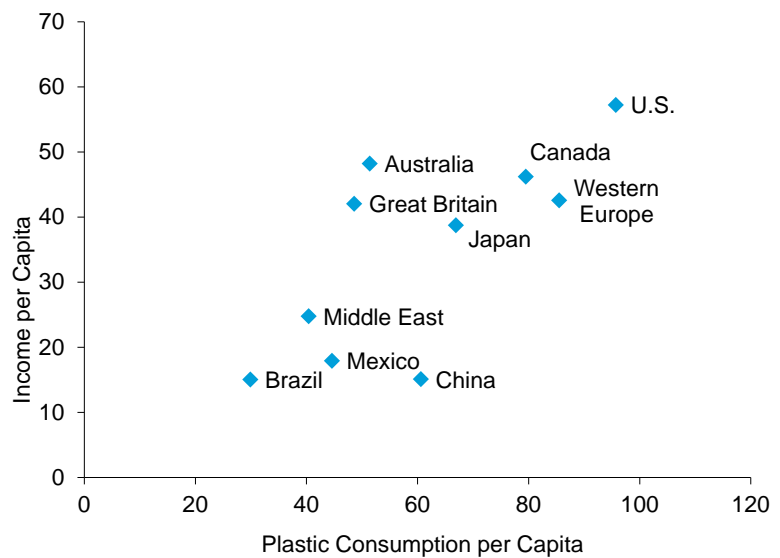


Source: Citi Research

Plastic packaging use mirrors per capita income

Plastic packaging use mirrors per capita income, meaning consumers use more plastic packaging as they become more affluent. We estimate per capita usage of plastic packaging is the highest in the U.S. at ~96 kilograms per capita, slightly above Europe at ~86 kg and compares to Brazil at ~30 kg and China at ~61 kg. The adoption curve suggests that use of plastic packaging really accelerates when per capita incomes reach \$40,000 purchase price parity (PPP) as seen by the gap in the scatter plot between the Middle East (\$25,000 PPP) & Japan (\$39,000 PPP).

Figure 4. Income per Capita vs. Plastic Consumption per Capita



Source: Citi Research, Euromap

Plastic packaging was first introduced to emerging markets by North American and European multinational corporations in the post-WWII period, however today markets like China and Latin America have become hotbeds of retail innovation, originating their own plastic packages, which in some cases make their way back to mature markets such as the U.S.

Advantages over Other Packaging Materials

The advantages of plastic include durability, weight, affordability, versatility, and lower energy required to produce

Plastic has several advantages over other substrates, including durability, weight, affordability, versatility, and energy required to produce. Looking at durability, plastic has high strength-to-weight and strength-to-stiffness ratios, which allow it to outperform some metals on a pound-for-pound basis. This creates opportunities for plastic not only in packaging, but heavier industries such as the automotive and construction markets. A typical example of plastic's strength is its ability to hold liquids. PET bottles can weigh as little as 19 grams compared to similar sized glass containers at 170 grams; plastic also holds advantages in durability as it is less likely to break or leak in transit. Increased durability at a lighter weight creates savings throughout the supply chain on freight and handling costs, while alternative substrates to plastic can weigh at least 3.5x more on average. A more extreme example of the strength of plastic is the creation of the "plastic bottle brick" which combines old PET bottles with sand & dirt to create a basis for concrete; this has been used in various part of Asia to line cement walls or support beams.

Plastics' ability to flex and bend is also a cost saver for shippers

Plastic is further able to bend into multiple shapes which makes it more efficient to ship and store. A cardboard box will always be the size and shape in which it was originally created, but flexible plastic bags can be folded, flattened, or vacuum sealed to more closely match the product it protects. For example what one truck could transport in plastic bags may take seven trucks to transport if fully replaced by paper bags. From an energy perspective, it requires 82% more energy to produce alternative products as it takes 1.82 kilowatt hours to match the 1 kilowatt hour required for plastic production. We also note that alternative products on average create 2.7x more CO₂ over their lifecycle. Accordingly plastic has several clear advantages that will make it extremely difficult to replace across different end markets.

Figure 5. Plastics vs. Alternative Substrates

Criteria	Plastic	Alternatives	Details
Energy to Produce	✓	✗	82% more energy to produce alternatives
Chemical Resistance	✓	✗	Metals may oxidize or rust
Production Time	✓	✗	Faster cycle times lower unit cost
Malleability	✓	✗	Highly flexible vs. rigid alternatives
Weight	✓	✗	Alternatives are 3.5x heavier on average

Source: Citi Research, Berry Global

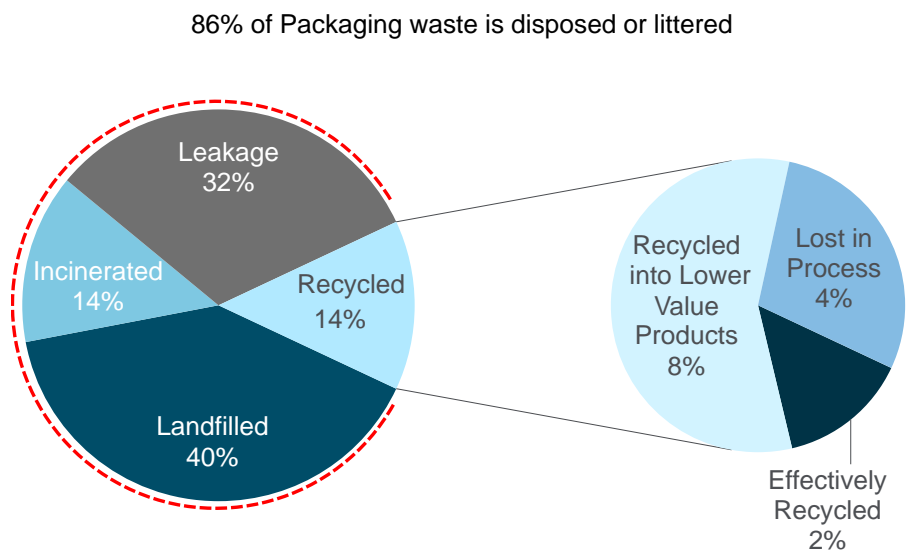
Environmental Impact of Single-Use Plastics

The Double-Edged Sword of Durability and Low Cost

Plastic' durability and affordability are positive but both create environmental concerns

Ironically, plastics' durability and affordability is also the cause of greatest concern for environmental stakeholders. Widely-used consumer plastics such as bags and bottles can take anywhere from 500 to 1,000 years to degrade, while only ~14% of plastic packaging sold ends up being recycled, meaning ~86% ends up in a landfill or in bodies of water. Despite being made from a naturally occurring material, i.e., oil and natural gas, plastic doesn't break down due to the unnatural manufacturing process that creates it. The heat and pressure required to turn a monomer, such as propylene, into a polymer, such as polypropylene, do not occur organically in nature; this process makes the new material unrecognizable to the organisms that break down simpler materials. Unfortunately most efforts that would allow plastic to decompose more easily would threaten one of its greatest advantages: durability.

Figure 6. Packaging Waste Disposal

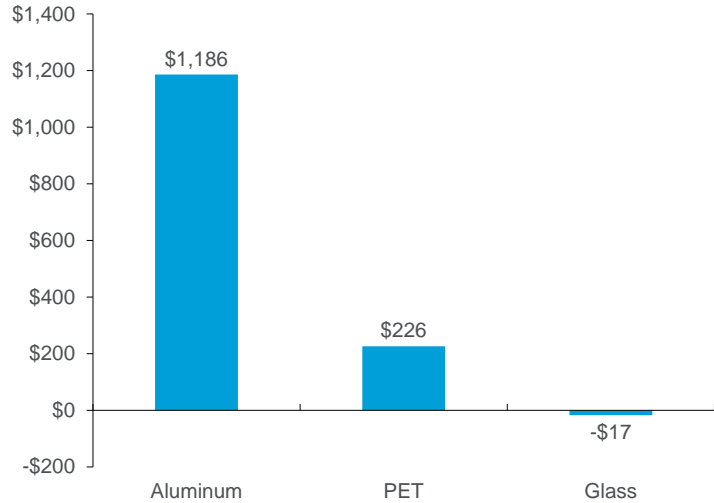


Source: Citi Research, UNEP

Plastics' affordability also makes it less economical to recycle

Similarly the affordability of plastics is also a double-edged sword. Plastic packaging's low price has helped drive widespread adoption enabling growth rates that are faster than GDP for over 50 years; however this same affordability makes it less economical to recycle plastic. In looking at the price of recycled materials from 2015-2017 per Recycling Markets, aluminum is valued at nearly ~\$1,200 per ton compared to PET at only ~\$226 and glass which has zero value. Based on the average weight of an aluminum can (14.9 grams), we estimate it would require ~61,000 cans to equal 1 ton of aluminum. Considering the ~50% recycling rate for aluminum cans, that means ~122,000 cans would be used by consumers. Given the lower per ton value (\$226) and recycling rate for PET bottles at ~30%, it would mean consumers would have to use ~1.1 million PET bottles to generate this much value.

Figure 7. Price per Ton of Recycled Material

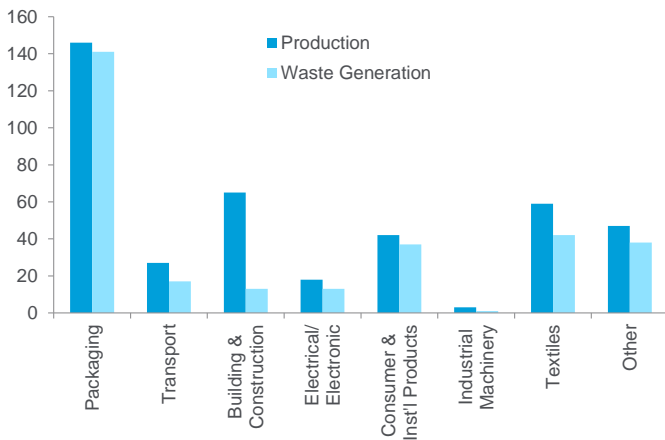


Source: Citi Research, Aluminum.org

Landfill & Marine Pollution Issues

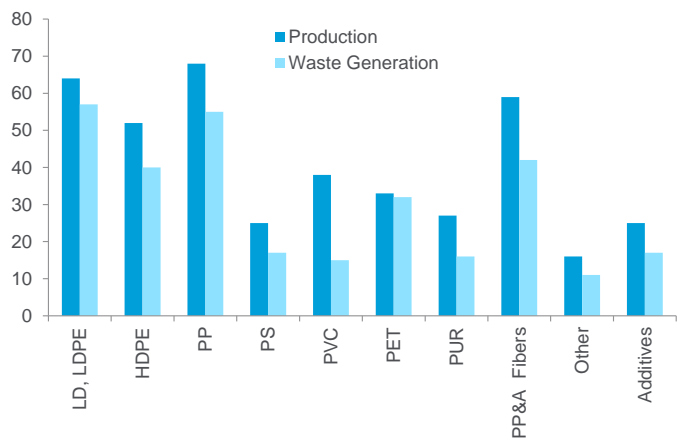
Plastics are a major source of waste in landfills, raising concerns around air pollution, groundwater safety, and quality of life issues. We estimate that ~150 million tonnes of plastic packaging waste is produced per year, and that packaging is the largest source of waste among plastic end markets, more than three times more than the next largest end use of textiles. The most common waste-generating polymers include low (LDPE) and high (HDPE) density polyethylene, polypropylene (PP) and polyethylene terephthalate (PET), which are commonly used in applications such as bottles and bags (see Figure 9). PP&A fibers (used in textiles) are also a meaningful generator of waste on an absolute basis (~42 million tonnes in 2015).

Figure 8. Plastics Production and Waste by Industrial Use Sector



Source: Citi Research, Geyer Jambeck & Law 2017

Figure 9. Plastics Production and Waste by Polymer Type



Source: Citi Research, Geyer Jambeck & Law 2017

In emerging markets, plastics can disrupt agriculture, transportation, and sanitation processes which are critical for human health

In addition to clogging landfills, plastic packaging can disrupt life in emerging economies in ways that are not always obvious to consumers in more developed markets. These include disruptions to agricultural, transportation, and sanitation processes critical for human health. For instance, in Mauritania, plastic bags were banned after more than 70% of cattle and sheep deaths were attributed to the ingestion of these products, while an official at the country's Ministry of the Environment and Sustainable Development indicated plastic makes up ~25% of total waste produced in the capital city of Nouakchott. While some may be surprised that a less developed country would implement more aggressive environmental regulation than developed nations, the problems associated with litter and poor recycling often are much more visible in countries lacking proper waste disposal infrastructure. Another rarely discussed impact of plastic bags is the risk of spreading disease; in a poorer country a bag that is left on the ground may fill with water and become a breeding ground for malarial mosquitos. Bags can also interfere with critical sanitation and irrigation functions, clogging sewers and drains. This was a prominent issue in Bangladesh during floods in 1988. Environmental groups estimated that only ~10% of the 9 million plastic bags used each day in Dhaka, Bangladesh ended up in a landfill, meaning ~90% were littered; congested drains severely exacerbated flood damages. This led to an anti-bag campaign in the early 1990's that was initially limited to only Dhaka but eventually became the world's first nationwide ban on plastic bags in 2002.

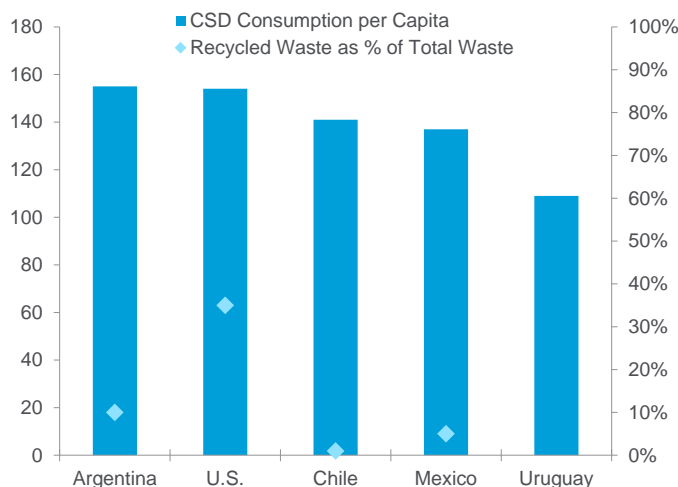
By some estimates, only 14% of plastic packaged products are recycled

We define single-use plastics as any plastic product used once before being disposed of, or recycled. This includes plastic bags, food wrappers, straws, coffee stirrers, beverage bottles, utensils, and caps/lids. We estimate ~400 million tonnes of plastic are produced each year, and while the majority of plastic packaging is technically recyclable, by some estimates only ~14% of packaging products are actually recycled. Many consumer plastics are 'down-cycled'; recycled into lower value products – for instance an aseptic food container being down-cycled to a plastic building product. And even when disposable plastics are properly recycled, virgin materials often need to be added or the product needs to be processed at a special recycling facility (i.e., coffee cups with a plastic liner).

PET beverage bottles are a leading type of single-use plastic — these bottles are also the fifth most common item found in ocean debris

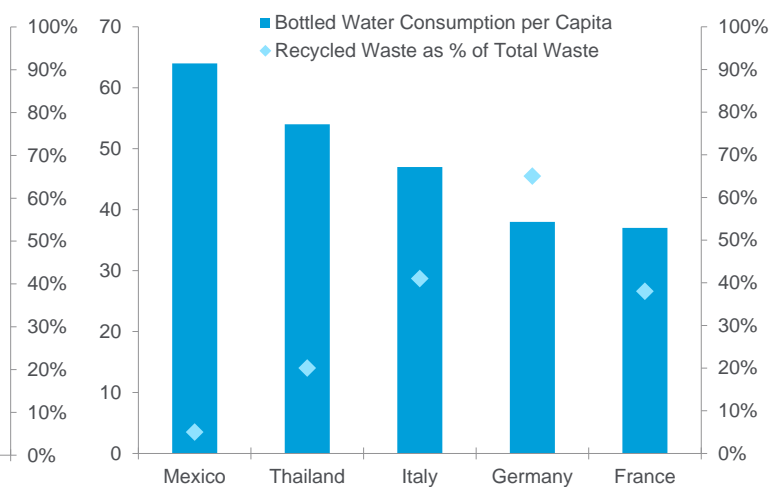
One of the leading types of single-use plastic is PET beverage bottles produced for water and soft drinks with nearly 500 billion units produced each year, an increase from ~300 billion units in 2004. This increase is driven by rising demand for bottled water (volumes up mid-single digits in recent years) along with incremental gains from substitution out of glass and metal. PET bottles are the fifth most common item found in ocean debris, comprising ~9% of total marine waste, per the Ocean Conservancy. PET bottles are in fact highly recyclable but only ~30% are actually recycled in the U.S., compared to ~60% in Europe, despite several states offering deposit refunds in the range of \$0.05-\$0.10 per container. In Figure 10 and Figure 11 we examine the recycling rates (recycled waste as a % of total municipal waste) for the top five consumers of carbonated soft drinks (CSD) and bottled water. We note that Germany is the global leader at ~65% and the average of all (Organization of Economic Co-Operation & Development (OECD) countries is ~34%. As seen below, CSD consumption can be high in less developed countries which tend to lack the necessary infrastructure to support proper recycling. Separately, we note the fourth most common item found in marine debris are caps and lids which are likely linked to PET and glass bottle consumption and recycling rates.

Figure 10. Carbonated Soft Drink Consumption vs. Recycling Rates



Source: Citi Research, OECD, BioEnergy Consult

Figure 11. Bottled Water Consumption vs. Recycling Rates



Source: Citi Research, OECD, SEA-UEMA Project

Up to an estimated 1 trillion plastic bags are consumed each year, however plastic bags make up almost 11% of total marine waste

Another common single-use plastic product is bags, with an estimated 500 billion to 1 trillion consumed each year. High density polyethylene has been the preferred substrate (over paper) for retail bags given its strength, light weight and low cost (<\$0.01 per plastic bag vs. \$0.03-\$0.04 per paper bag). Plastic bags are the 2nd most common item found in ocean debris, comprising ~11% of total marine waste, per the Ocean Conservancy. Unlike PET bottles, bags are more difficult to recycle given their flexibility as most recycling facilities are better equipped to handle rigid products (PET, glass, metal, etc.). Given the limited capabilities of most facilities, the burden is on the consumer to bring their bags to collection bins at various retail locations. This inconvenience has led to a ~7% recycling rate for HDPE bags, sacks and wraps in the U.S.; some critics have called this number “artificially high” when applied to plastic bags since it includes other types of stretch films. Critics have also pointed out that plastic bags may not even be worth the cost collection, given sorting intensity and the often disappointing quality/cleanliness of the recovered product.

Alternatives to plastic for foodservice items, such as cups, do not always provide a better alternative

Other items contributing to marine waste include foodservice items such as cups, plates, utensils, straws, and stirrers. Here plastic has received a great deal of scrutiny, but it's not clear paper always provides a better alternative. The recyclability of cups has been in particular focus recently with the U.K. discussing a potential levy on disposable coffee cups. While the cups may appear to be recyclable, the plastic lining on the inside, which prevents liquid from soaking in, actually makes the cup significantly more expensive to recycle with only 3-4 locations in the U.K. equipped to do so. Limited infrastructure has also put a damper on the move to biodegradable cups. While a biodegradable cup is more sustainable than the plastic-lined alternative, the product still may be destined for a landfill given limited capacity for proper processing. Despite these concerns, paper is still seen as the more responsible alternative to polystyrene (PS) which can sit in a landfill for centuries. Recycling PS or EPS (expanded polystyrene) isn't economical since it's not part of the circular economy, meaning that a recycled EPS cup cannot be processed and then turned back into another cup. This means there's limited demand for recycled EPS, making processing difficult and expensive.

Figure 12. Top 10 Marine Debris Items

Rank	Item	% of Total Debris
1	Cigarettes	21%
2	Plastic Bags	11%
3	Food Wrappers/Containers	9%
4	Caps & Lids	9%
5	Plastic Beverage Bottles	9%
6	Cups, Plates & Utensils	5%
7	Glass Beverage Bottles	4%
8	Beverage Cans	4%
9	Straws & Stirrers	4%
10	Paper Bags	3%
Top 10		79%

Source: Ocean Conservancy

Marine contamination from microplastics is also a key concern around single-use plastics

Beyond landfill overuse, a key concern around single-use plastics is marine contamination. For instance off the coast of Los Angeles, there are 10 metric tons of plastic swept into the Pacific Ocean each day, per Biological Diversity. Various sea creatures may eat these plastic fragments that ultimately work their way up the food chain into humans through the consumption of seafood. A study found that ~25% of fish in California contained plastic microfibers in their stomach. Accordingly microplastics, which are any piece of plastic debris less than 5 millimeters in length, have received increasing attention from environmental stakeholders. This includes broken down plastic waste, synthetic fibers and microbeads used in cosmetic & personal care products. With such a small size, they easily slip past filtration systems and end up in consumable products and tap water.

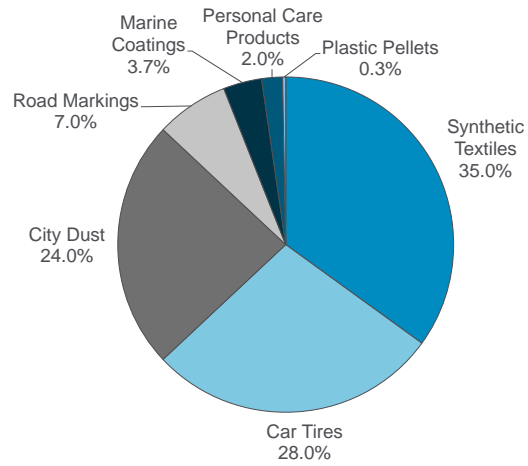
The health impacts of ingesting microplastics are not fully known at this time

A study conducted by the World Health Organization found that more than 90% of water in plastic water bottles contained microplastics. The study covered 259 bottles from 9 countries (the U.S., China, Brazil, India, Indonesia, Mexico, Lebanon, Kenya, and Thailand) across 11 brands. Around 325 plastic particles were found in every liter of bottled water; roughly twice as much as tap water. The fragments were primarily polypropylene which is used to make bottle caps; the health impacts of ingesting these plastic fragments are not fully known at this time. We also note that manufacturing single-use products is energy intensive requiring 1.4 liters of water to produce a 1 liter plastic bottle, per RecycleBank. Again when it comes to decomposition, plastics' strength can be a negative, allowing plastic fragments to travel long distances before breaking down, which can take several hundred years. Once finally breaking down, the problem continues through microplastics (discussed above) and contamination of the ocean given the petroleum base of the products and potential exposure to chemicals such as BPA (bisphenol A).

Some studies have shown the majority of microplastics come from sources other than plastic packaging, i.e., car tires and city dust

European plastic packager RPC has taken a leading position in defense of the plastic packaging industry, claiming <1% of microplastics are actually from the industry, while a majority are from other sources such as car tires and city dust. RPC further pointed out that only ~2% of marine plastic comes from the U.S. & Europe, while Asia is the leading contributor at ~82%. The leading countries in plastic leakage into the oceans are China, Indonesia, Philippines, Vietnam, Sri Lanka, Thailand, Egypt, Malaysia, Nigeria, and Bangladesh. This suggests that bans aimed at U.S. & European consumers may have a relatively minimal overall impact.

Figure 13. Global Sources of Ocean Microplastics

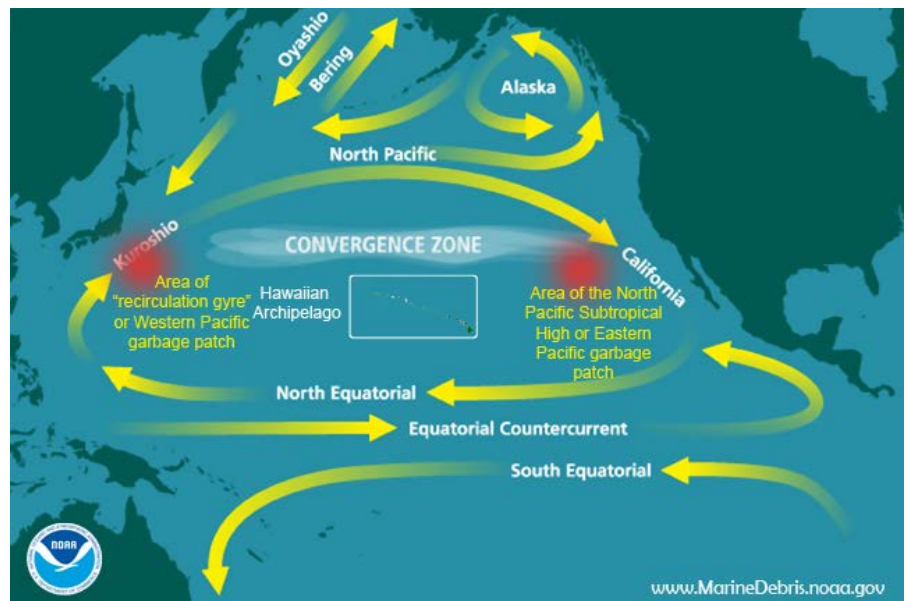


Source: Citi Research, RPC, IUCN

Although plastics are part of the ‘Great Pacific Garbage Patch’, in terms of tonnage, the majority of the patch is actually abandoned fishing gear

The ‘Great Pacific Garbage Patch’ has been a focus for many environmental stakeholders concerned with plastic waste. However a closer examination suggests consumer packaging may not be the primary cause of ‘The Patch.’ The name lends the idea that there is an actual moving island of plastic trash traveling around the ocean, but it is largely not visible to the naked eye since microplastics make up ~94% of the ~1.8 trillion pieces of garbage. In terms of tonnage (microplastics = ~8% of total tonnes), a majority of the patch is actually abandoned fishing gear, not plastic bottles or packaging, according to National Geographic. The patch was formed by an ocean current called the North Pacific Subtropical gyre which runs between California and Japan; at the center is the convergence zone. The patch is actually comprised of two pieces, the Western Patch which sits off of the coast of Japan, and the Eastern Patch which is located between California and Hawaii.

Figure 14. The Great Pacific Garbage Patch



Source: NOAA Marine Debris Program

Shifting consumer attitudes towards single-use plastics is an important investment theme, especially for ESG investors

ESG Impact & UN Sustainable Development Goals

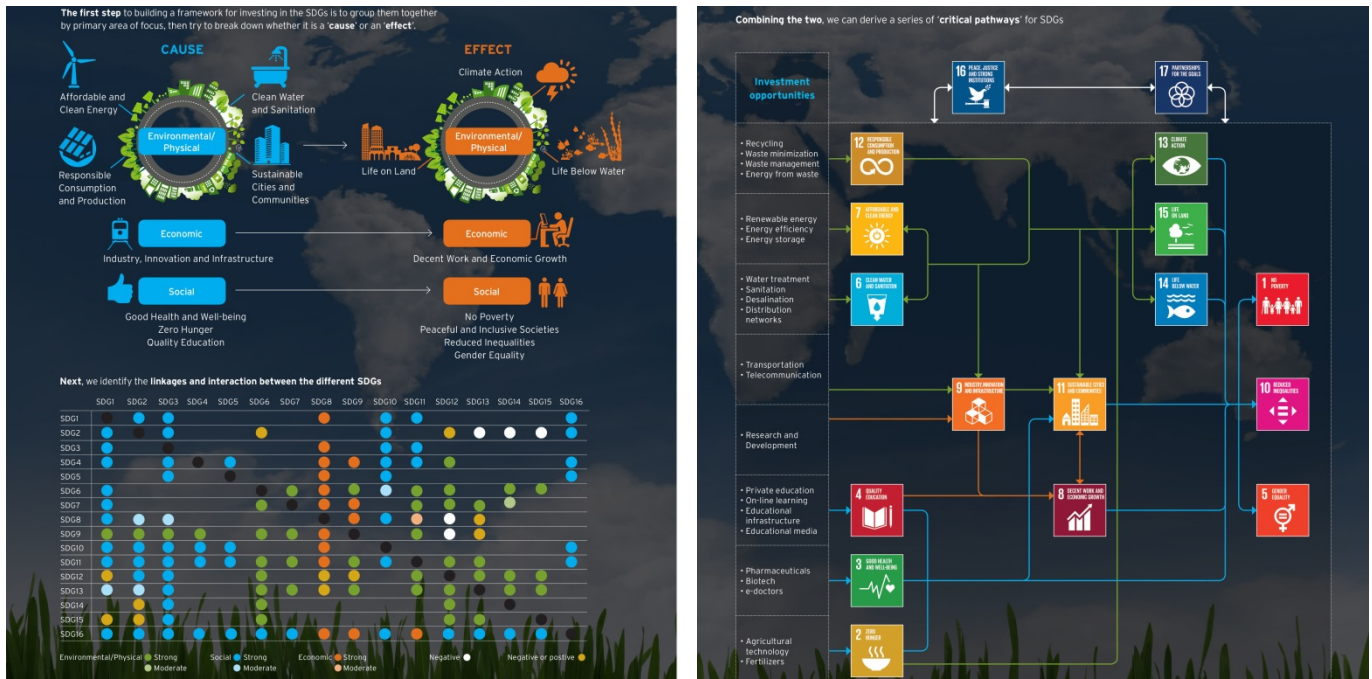
Citi believes that shifting consumer attitudes towards single-use plastic is an important investment theme, especially for asset managers with an ESG (Environmental, Social & Governance) mandate. ESG considerations are becoming more important for many large asset managers investing decisions. To assist in ESG investing efforts, Citi has created a systematic framework for approaching the UN's Sustainable Development Goals (SDGs). Plastic packaging, and its impact on the environment and ecosystem, touches upon multiple Sustainable Development Goals. SDGs directly impacted by plastic packaging include Goal 3 (Good Health & Well-being), Goal 11 (Sustainable Cities & Communities), Goal 12 (Responsible Consumption & Production), Goal 14 (Life Below Water), and Goal 15 (Life on Land).

Figure 15. The UN's Sustainable Development Goals



Source: United Nations

Figure 16. Framework for Investing in the UN Sustainable Development Goals



Source: Citi GPS: United Nations Sustainable Development Goals

Fully recyclable packaging can help in the development of sustainable cities and communities

Fully recyclable packaging can play a key role in the development of sustainable cities and communities (UN SDG #11) through increased focus on municipality recycling infrastructure and education. As urbanization continues (the UN expects ~5 billion humans living in cities by 2030 and ~6 billion by 2050) the importance of food sourcing and product logistics will only grow in importance. Food shelf life will also become increasingly important as the vast sums of produce and meats are shipped into cities to be purchased. In addition, with millions of products being shipped into cities through e-Commerce, packaging optimization will reduce waste.

Figure 17. UN Metrics and Indicators for Sustainable Goal 12 (Responsible Consumption & Production)

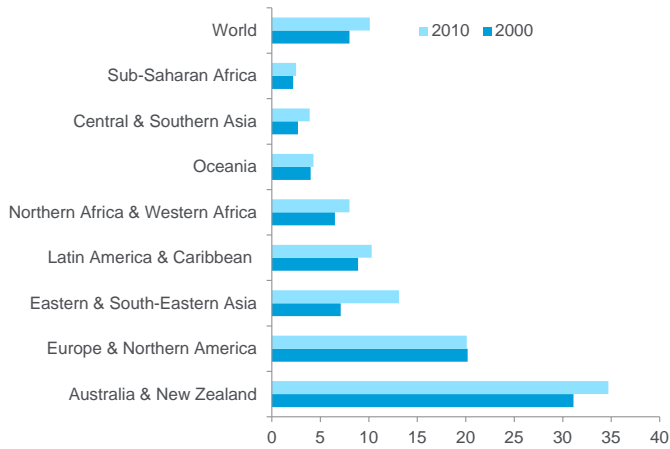
Targets	Indicators
12.1 Implement the 10-year framework of programs on sustainable consumption and production, all countries taking action, with developed countries taking the lead, taking into account the development and capabilities of developing countries	12.1.1 Number of countries with sustainable consumption and production (SCP) national action plans or SCP mainstreamed as a priority or a target into national policies
12.2 By 2030, achieve the sustainable management and efficient use of natural resources	12.2.1 Material footprint, material footprint per capita, and material footprint per GDP 12.2.2 Domestic material consumption, domestic material consumption per capita, and domestic material consumption per GDP
12.3 By 2030, halve per capita global food waste at the retail and consumer levels and reduce food losses along production and supply chains, including post-harvest losses	12.3.1 Global food loss index
12.4 By 2020, achieve the environmentally sound management of chemicals and all wastes throughout their life cycle, in accordance with agreed international frameworks, and significantly reduce their release to air, water and soil in order to minimize their adverse impacts on human health and the environment	12.4.1 Number of parties to international multilateral environmental agreements on hazardous waste, and other chemicals that meet their commitments and obligations in transmitting information as required by each relevant agreement 12.4.2 Hazardous waste generated per capita and proportion of hazardous waste treated, by type of treatment
12.5 By 2030, substantially reduce waste generation through prevention, reduction, recycling and reuse	12.5.1 National recycling rate, tons of material recycled
12.6 Encourage companies, especially large and transnational companies, to adopt sustainable practices and to integrate sustainability information into their reporting cycle	12.6.1 Number of companies publishing sustainability reports
12.7 Promote public procurement practices that are sustainable, in accordance with national policies and priorities	12.7.1 Number of countries implementing sustainable public procurement policies and action plans
12.8 By 2030, ensure that people everywhere have the relevant information and awareness for sustainable development and lifestyles in harmony with nature	12.8.1 Extent to which (1) global citizenship education and (2) education for sustainable development (including climate change education) are mainstreamed in (a) national education policies; (b) curricula; (c) teacher education; and (d) student assessment
12.A Support developing countries to strengthen their scientific and technological capacity to move towards more sustainable patterns of consumption and production	12.A.1 Amount of support to developing countries on research and development for sustainable consumption and production and environmentally sound technologies
12.B Develop and implement tools to monitor sustainable development impacts for sustainable tourism that creates jobs and promotes local culture and products	12.B.1 Number of sustainable tourism strategies or policies and implemented action plans with agreed monitoring and evaluation tools
12.C Rationalize inefficient fossil-fuel subsidies that encourage wasteful consumption by removing market distortions, in accordance with national circumstances, including by restructuring taxation and phasing out those harmful subsidies, where they exist, to reflect their environmental impacts, taking fully into account the specific needs and conditions of developing countries and minimizing the possible adverse impacts on their development in a manner that protects the poor and the affected communities	12.C.1 Amount of fossil-fuel subsidies per unit of GDP (production and consumption) and as a proportion of total national expenditure on fossil fuels

Source: UN (2018), Global Indicator Framework for the Sustainable Development Goals and Target of the 2030 Agenda for Sustainable Development

A focus on packaging can also help in SDG #12, Responsible Consumption and Production

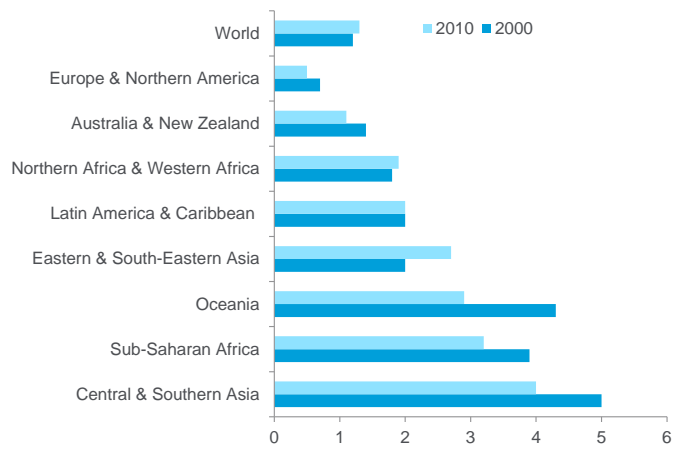
SDG #12 (Responsible Consumption and Production) is a goal closely tied to the plastic packaging industry: Packaging can make global supply chains more efficient and reduce food waste and spoilage; the UN Environment Program has estimated that ~1.3 billion metric tons of food waste is generated annually. However packaging also has the potential to create large amounts of waste in the form of single-use plastics. McKinsey estimates ~95% of plastic packaging is disposed of each year after just a single use, valued at \$80 – \$120 billion. Looking at the UN metrics in Figure 17, we believe targets 12.3, 12.4, and 12.5 correspond to improvements in global recycling systems. The EU also recently updated their Circular Economy Action Plan which includes a strategy targeted at making all plastic packaging recyclable by 2030. Figure 18 and Figure 19 show disparate levels of progress between countries and regions; overall material usage per capita and per unit of GDP has generally increased, although there have been pockets of efficiency gains in some developed and emerging markets.

Figure 18. Domestic Material Consumption Per Unit of GDP, 2000 and 2010 (Kg per Unit GDP)



Source: Citi Research, UN

Figure 19. Material Footprint per Capita, 2000 and 2010 (Metric Tons Per Capita)

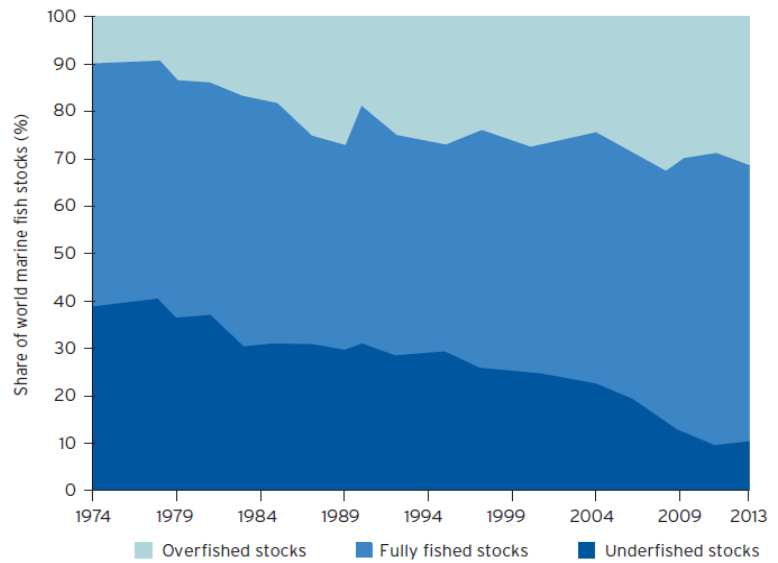


Source: Citi Research, UN

UN SDG #14, Life Below Water, can be addressed with higher scrutiny on plastic marine waste

Plastic marine waste has the potential to impact SDG #14 (Life Below Water), which is focused on the effects of pollution and overfishing on ocean wildlife. The proportion of fisheries that are fully fished, overfished, depleted, or recovering from overfishing increased from just 60% in the mid-1970s to about 75% in 2005 and to almost 90% in 2013. We have seen a 26% rise in ocean acidification since the beginning of the industrial revolution. The impact of acidification will extend up the food chain to affect economic activities such as fisheries and aquaculture. Marine pollution is also reaching elevated levels with an average of ~13,000 pieces of plastic litter found on every square kilometer of ocean.

Figure 20. State of Global Fish Stocks (1974-2013)



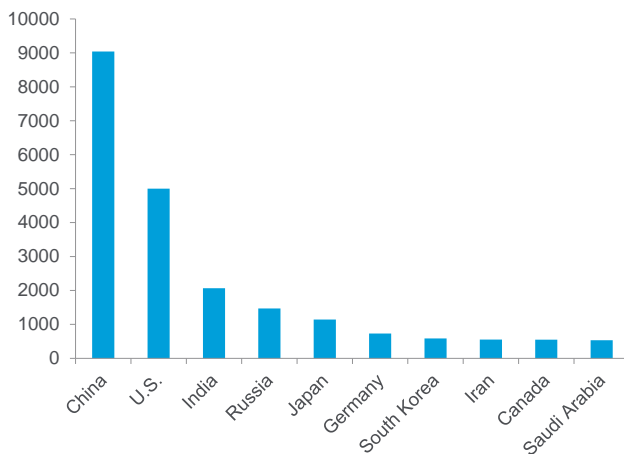
Source: FAO 2016

China Shakes Up the Sustainability Debate

China has tried to balance surging economic growth and rapid industrialization with environmental and health concerns

While we have seen local, regional, and some national bans on various plastic packaging products over the last ~20 years, environmental actions taken by the Chinese government this year have transformed and rapidly accelerated the move out of single-use plastics, in our view. China's environmental situation has historically been a fraught issue as the Chinese government has tried to balance surging economic growth and rapid industrialization with environmental and public health concerns. China is the world's largest producer of carbon emissions by far, with over 9 billion metric tons of CO₂ emissions produced in 2015 nearly double the United States (see Figure 21). China accounted for 28% of the world's CO₂ emissions in 2015 and had over four times the emissions as India with a similar population level. The high levels of pollution are largely driven by two key factors. (1) Coal use for energy consumption as China is the world's largest coal producer and accounts for almost half of global consumption. Coal accounts for over 60% of China's energy mix, although this has been trending lower in recent years; and (2) Chinese car ownership continues to increase with 194 million cars on the road in 2016, growing at a 13% CAGR rate over the last five years.

Figure 21. Top 10 Countries by CO₂ Emissions (million tonnes)

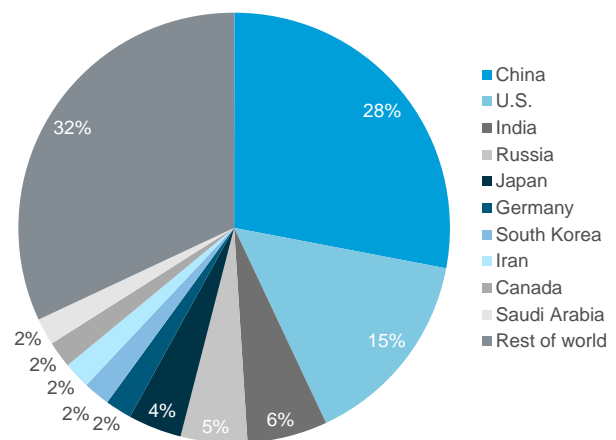


Source: Citi Research, UCUSA

Air quality and water pollution are an issue in many of China's major cities and are now being addressed

Environmental issues were a part of China's 13th Five-Year Plan

Figure 22. Share of Global CO₂ Emissions



Source: Citi Research, UCUSA

The air quality in many of China's major cities fails to meet international standards for health and safety. There have been cases of school closings and halts to factory manufacturing as a result of the pollution. Water pollution is also a major concern as China accounts for ~20% of the global population but only 7% of freshwater. China's Ministry of Environmental Protection has estimated that pollution negatively impacts the Chinese economy by over \$225 billion annually. The environmental collateral damage from China's economic boom has begun to cause popular protests as citizens worry about the long-term health impacts.

China is increasingly aware of rising environmental issues and has recently unveiled multiple policies to tackle these concerns. In the 13th Five-Year Plan, China set multiple targets to the qualities of air, water, soil, and the ecosystems. It also aimed to cut emissions of multiple harmful pollutants (e.g., reduce carbon dioxide emission by 15%). In order to achieve these goals, measures have been taken including supply-side reforms — eliminating old, inefficient, and polluting plants, and winter production controls — lowering the run-rates of heavy industries in Northern China during the winter time to address heavy smog.

As part of its war against pollution, China is also tackling the recycling industry

In its war against pollution, China is also tackling the recycling industries. China began heavily importing recycled and scrap materials in the 1980's in order to support its growing manufacturing sector, however mishandling and poor quality of some of the imported materials contributed to high levels of pollution. Shipping waste to China made sense for some countries as China, typically a net exporter, would ship manufactured goods in large containerized cargo ships but have nothing to bring back on the return trip; this made recycling abroad a more attractive proposition than building out the required infrastructure domestically. China's new policies are a broader initiative to improve air and water quality, as according to China officials, hazardous waste could be mixed into the scrap materials and cause serious harm to the environment in the recycling process.

National Sword 2017 was enacted by the Chinese government to target waste imports and halted imports of 24 types of solid waste — the program was renewed in 2018

Beginning in 2017 multiple campaigns were launched to target waste imports. In February of that year, China launched the "National Sword 2017" program to strictly prohibit the smuggling of foreign wastes, in particular industrials, electronics, and plastic scraps. This broad initiative also included agricultural products, natural resources, drugs, and guns. In April, the Central Leading Group for Comprehensively Deepening Reforms, led by China President Xi, announced the "Plan to prohibit foreign waste dumping and regulate solid waste import." This was followed by the Ministry of Environmental Protection's one-month dedicated effort to inspect recycling processors in July. Hundreds of enterprises were fined for various breaches on matters like waste discharge and had their import license revoked. Later that month, the Ministry notified the World Trade Organization that it would stop importing 24 types of solid waste under four categories (plastics, vanadium-containing slag, unsorted waste paper, and textiles) before the end of 2017. The authority issued a circular in August banning processors from operating in non-industrial park areas. In addition, the authority also tightened its control on waste import permits and only negligible volumes were allowed to be imported in 2018. In February 2018, the "National Sword 2018" program was launched to continue the previous year's effort.

Figure 23. Solid Waste Import Ban (Plastics only)

Types	Categories
Plastics (8 Categories)	PE solid waste
	Aluminized plastics film
	PS solid waste
	PVC solid waste
	PET solid waste (non-beverage)
	PET solid waste (beverage)
	Other plastics solid waste (non-CD/DVD ROM)
	Other plastics solid waste (CD/DVD ROM)

*Total 4 types (plastics, vanadium waste, papers, textiles), of solid wastes will be banned. This can be further divided into 24 categories.

Source: The Paper, Citi Research

Unlike prior attempts at environmental policy, these new policies are expected to be long term in nature

Unlike previous efforts, these policies are likely to be long term given the government's determination to fight pollution. China's recycling industry association chairman once said in a public forum that the issue pertains to the health of China's population and the employment in the recycling sector may not impact the authority's implementation of the policy. The authorities had launched a similar campaign in the past – the 'Green Fence' action – to address foreign waste smuggling. It was, however, only a 10-month program and expired in November 2013.

Government Environmental Responses

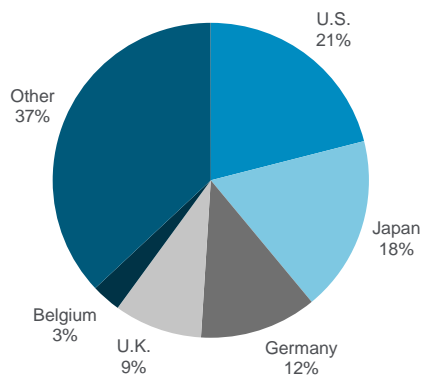
To offset China's ban on plastic scrap, scrap processing could be relocated to other countries.

Exporting countries are being forced to expand domestic recycling or cut back on waste levels being produced

A large portion of the scrap materials that had been imported by China could ultimately be processed in Southeast Asia (e.g., Vietnam, Thailand, Cambodia, and Bangladesh). In March 2018, Malaysia and Thailand imported almost 200,000 metric tonnes of plastic scrap, the same volume imported in the whole of 2016. These countries were unprepared to receive such volumes of waste given limitations to ports, storage, and processing plants. Many recycling processors are already evaluating potential relocation from China to Southeast Asia, but it will take time to install machines, secure relevant permits, and build up the logistics.

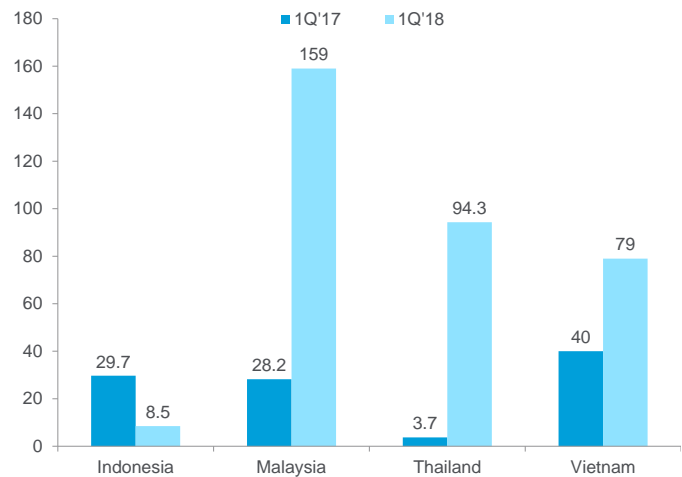
With China no longer accepting plastic waste and neighboring countries unable to deal with the high level of supply, exporting countries will likely be forced to expand domestic recycling and/or cut back on the level of waste being produced. Several Western ports have seen plastic waste pile up at storage sites following the Chinese ban, with port managers using empty storage sheds or shipping containers to store the overflow of material. While the level of contamination in the waste sent to China has been disputed by some exporters, the Chinese government has not wavered. U.S. plastic waste exports to China declined -85% from January to December 2017; plastic waste exports to all countries declined -35% as other Asian countries have only partially made up the difference, per Resource Recycling.

Figure 24. Top Exporters of Plastic Waste to China



Source: Citi Research, ISWA, UN Comtrade

Figure 25. U.S. Exports of Scrap Plastic to Southeast Asia (Mns of lbs.)



Source: Citi Research, U.S. Census Bureau, Resource Recycling

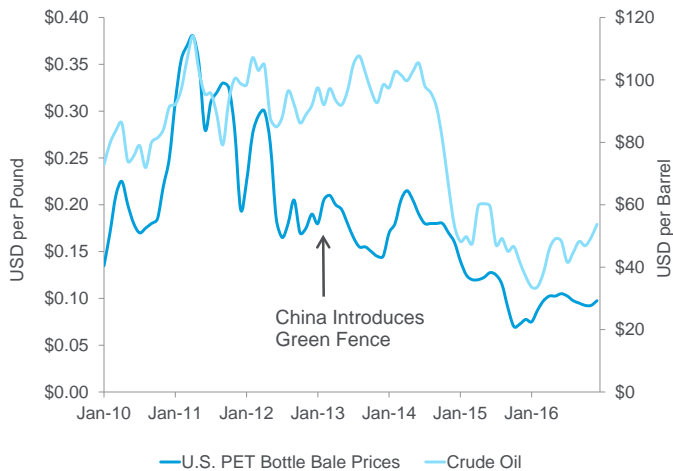
The profitability of recyclers is under pressure because of China's import ban and lower commodity prices

China's exit from the global recycling market has heavily pressured profitability for recyclers by suppressing demand and creating a glut of oversupply. For instance the average price per ton of mixed paper exported from North America to Asia has fallen from ~\$150/ton to ~\$5/ton; deeply challenging the economics of the U.S. recycling industry. Sacramento County in California used to earn \$1.2 million annually by selling recyclables to private waste management companies, now the county is paying ~\$1 million to offset those companies' costs. Private waste management companies are thus facing pressure from two sides: plummeting commodity costs which is lowering the resale value of processed materials, while China's strict quality standards on the small amount of recycled material that can be imported is driving up operating costs. Further, shipping to other Asian countries besides China has driven up transportation costs. These factors have led to some consumers being charged more in order to have their recyclables picked up by their municipality or county, which could potentially dissuade recycling efforts.

One effect has been a steep reduction in PET bale prices in the U.S. which could deter further recycling

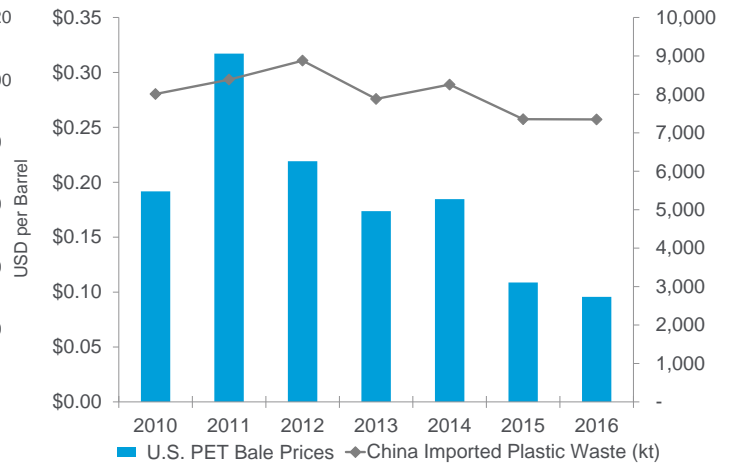
An example of the far-reaching nature of China's policies on U.S. markets is PET bottles. When PET bottles are recycled they are typically pressed into bales and then sold to recycling companies. The National Association for PET Container Resources (NAPCOR) tracks the price per pound of those PET bales in the U.S. Bale prices have been declining since 2011 consistent with crude oil prices (oil can dictate virgin PET prices) and Chinese demand for recycled plastic waste, as seen in Figure 26 and Figure 27 below. While 2017-18 U.S. PET bale prices haven't been released yet, it is likely prices fell further in accordance with China's stance on imported plastics, although crude oil has been firmer of late. Per NAPCOR, when PET bale prices drop, smaller commercial collectors can sometimes reduce or eliminate collections as the business case for recycling becomes less attractive. China's exit from the plastic waste market not only eliminates a key source of processing, but could potentially drive down recovered PET prices in the near-to-medium term which may deter recycling.

Figure 26. U.S. PET Bale Prices vs. Crude Oil



Source: Citi Research, NAPCOR, FactSet

Figure 27. U.S. PET Bale Prices vs China Plastic Waste Imports

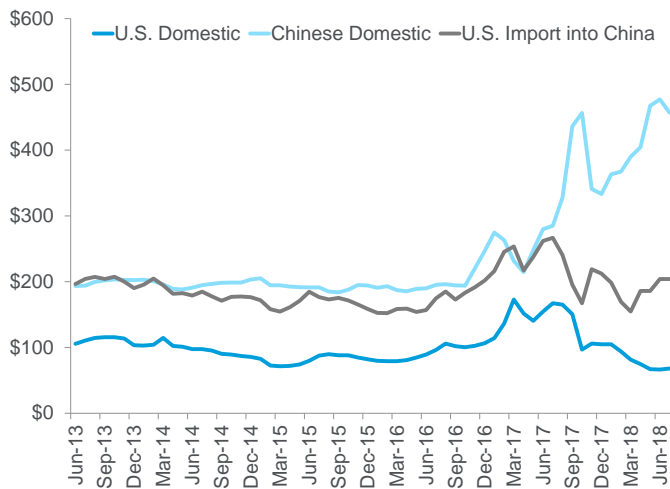


Source: : Citi Research, NAPCOR, UN Comtrade

The quality of mixed paper being imported was also targeted in the National Sword program which could affect paper recycling and old corrugated container imports

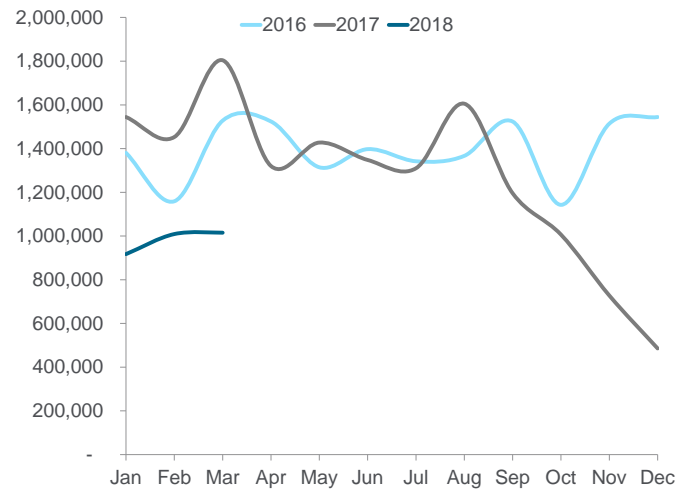
The National Sword 2017 program is an example of Chinese environmental regulations radically impacting recycled material costs. As part of the program Chinese customs cracked down on the quality of mixed paper being imported, setting a 1.5% contaminant limit (most mixed paper from the U.S. pre-National Sword had been cleared with 3-5% contaminants). In accordance with the new program, authorities stopped issuing licenses to importers of recovered paper in China in May of 2017. As a result, old corrugated container (OCC) imports into China collapsed 47% in the fourth quarter of 2017 and continue to track ~40% lower year-over-year in 2018; OCC pricing in both the U.S. and China has diverged as a result. The gap between Chinese domestic OCC and U.S. domestic OCC averaged ~\$130/ton over the last five years, but is currently at a historical record of \$400/ton as Chinese buyers scramble for recycled fiber for their mills and U.S. mills are flooded with material. As seen in Figure 28 and Figure 29 below, U.S. domestic OCC prices recently hit their lowest levels since 2009 while 2018 year-to-April monthly imports are tracking well below 2016-17 levels. Waste Management has said that ~30% of the containerboard they recycled used to go to China but that has dropped to ~2% post the enactment of National Sword.

Figure 28. U.S. and China OCC Prices (\$/ton)



Source: Citi Research, RISI

Figure 29. Monthly OCC Imports From U.S. to China

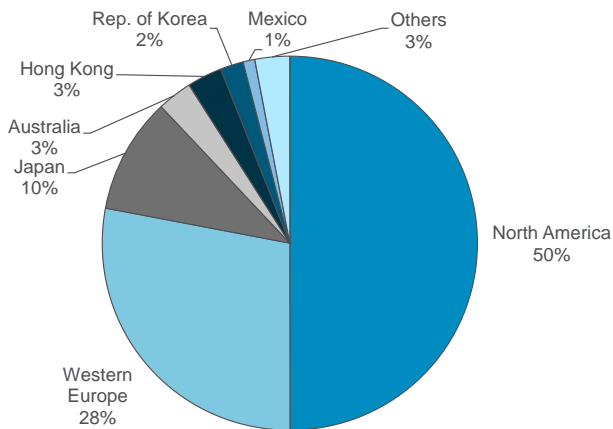


Source: Citi Research, RISI

Recent statements by Chinese officials indicate all solid waste imports could be banned by the end of 2020

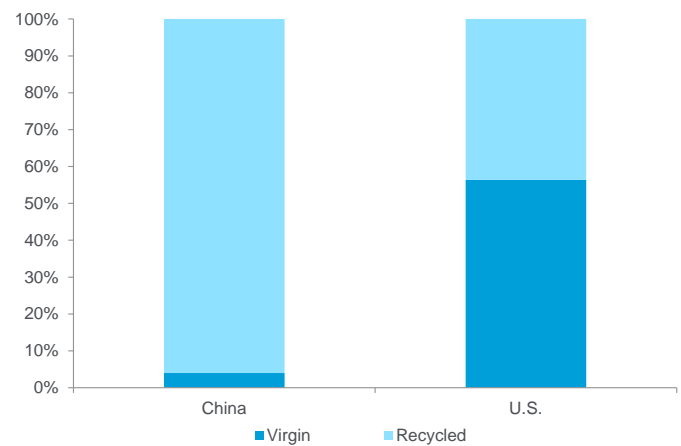
To illustrate the commitment the Chinese government has to improving the environmental situation, we would point to the recent statement by the State Council that the Chinese government is working toward implementing a complete ban on imports of all solid waste by the end of 2020. To put that in perspective, China imported just under ~30 million tonnes of recovered paper in 2016, primarily from North America, Europe, and Japan. This recovered paper accounts for ~95% of the fiber China needs to create containerboard (cardboard boxes). As an export-focused economy, cardboard boxes play a key part in the economic chain, so disrupting this key supply chain so aggressively is a testament to the commitment the Chinese authorities have towards pollution reduction.

Figure 30. Chinese Recovered Paper Imports By Region



Source: Citi Research, RISI

Figure 31. Containerboard Fiber Breakdown (China vs. U.S.)



Source: Citi Research, RISI

Impact from the Recycling Ban

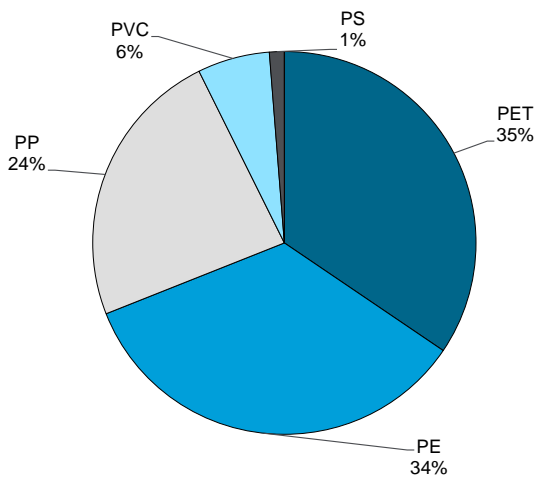
The China recycling sector accounted for almost half of the global recycling trade at its peak

The China plastics recycling market emerged in the 2000s when plastics prices in China surged, led by rising crude oil feedstock price and tight product supply-demand balances. Recycled plastics materials offered a much more affordable alternative than virgin plastics as the price was cheaper than virgin materials consistently throughout the period. According to IHS, the China recycling sector had grown significantly at 23% CAGR from 2003-08 and 14% after. Imports of plastic scrap peaked in 2016 at roughly 8 million metric tonnes, accounting for almost half of global trade. PET and PE accounted for more than half of the total volume, with each accounting for roughly 2.5 million metric tonnes. Imports started to fall rapidly in 2H17 and the volume was negligible in 2018.

One effect of the Chinese import ban could be higher demand for virgin staple fiber and polyester condensation feedstock

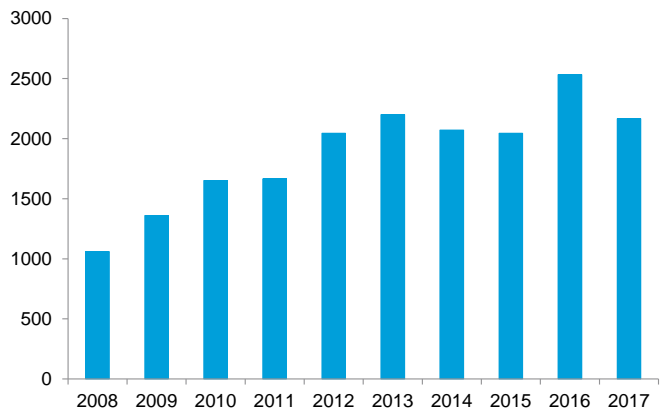
This has had a positive demand impact to the primary resins market for both PET and PE due to substitution effect. In PET, recycled materials were previously processed into polyester staple fibers. The policy could not only boost demand for virgin staple fiber, but also polyester condensation feedstock – paraxylene (PX), purified terephthalic acid (PTA) and monoethylene glycol (MEG).

Figure 32. China Plastics Scrap Import Breakdown 2016



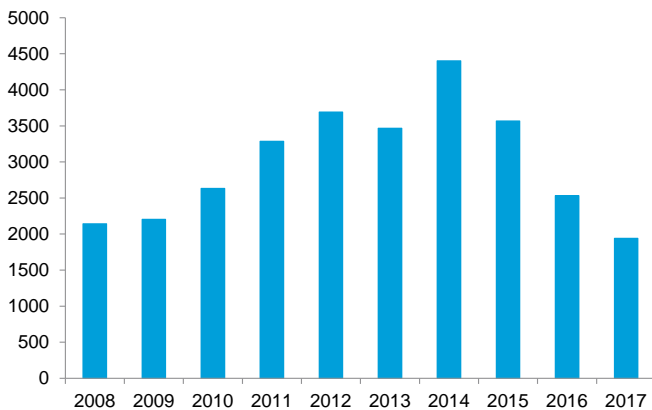
Source: China Customs, Citi Research

Figure 33. China Scrap PET Import ('000 metric tonnes)



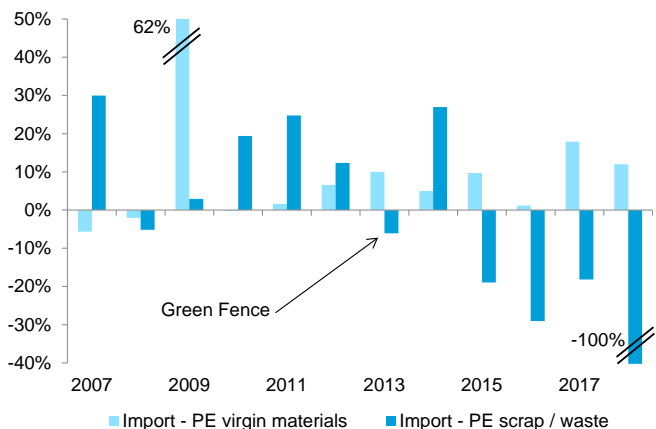
Source: China Customs, Citi Research

Figure 34. China Scrap PE Import ('000 metric tonnes)



Source: China Customs, Citi Research

Figure 35. China Virgin and Scrap PE Import Growth



Source: China Customs, Citi Research

The substitution of virgin polyethylene for recycled PE could boost domestic virgin resins demand

Regarding the PE market, import replacement could also boost domestic virgin resins demand significantly, as recycling PE was roughly 8% of the total market size in 2016. In 2017, China scrap PE import dropped 23% but virgin PE import rose 18%. The substitution trend has continued into 2018. IHS estimates another 1 million metric tonnes demand boost in 2018, which accounts for 1% of global PE demand, or 4% of China demand. This could partially offset the incremental PE supplies from the U.S. in 2018 and improve the global supply-demand fundamental picture. However we believe over time, the impact could gradually diminish as recycling processors relocate to other countries.

While the timing and implementation of specific regulatory actions by Chinese authorities is not always certain, we believe the recycled plastics ban is not going away, and in our view the dramatic impacts we've seen on U.S. and European plastics producers may be just beginning.

Digging Deeper on Single-Use Plastic Bans

A Summary of Global Initiatives

The first national ban on plastic bags was signed in Bangladesh in 2002 ... this was followed by bans in several other African nations

While Chinese regulatory actions have dramatically altered global trade flows of recycled plastic material, we've seen an increasing number of domestic bans and restrictions on single-use plastics dating from the early 2000's. Notably, many of the first national restrictions on single-use plastics have come from emerging economies in Africa and Asia. The first national ban was Bangladesh's 2002 plastic bag ban, which followed devastating floods in 1988 that were found to have been made worse by plastics blocking drainage systems. Africa has seen numerous national bans including actions in Rwanda (2008), Mali (2012), and Kenya (2017). In terms of implementing bans, we see authorities generally pursuing 4 options: (1) an outright ban on the production, sale, and use of plastic bags; (2) a tax on suppliers, producers, importers of plastic bags, this is likely passed onto retailers and consumers; (3) a tax on retailers — if a retailer chooses to use plastic bags then they pay a tax; and (4) a tax on consumers — at the point-of-sale consumers pay a tax.

The U.K. took a leading position by implementing a 5p charge on disposable plastic bags in 2015

In Europe, the U.K. took a leading position on preventing plastics waste starting with a 5 pence (5p) charge on disposable plastic bags in October 2015. This program has seen meaningful success, reducing the use of plastic bags by ~83%. A recent House of Commons report detailed 11 recommendations to prevent plastic bottle waste including expanding access to free water fountains, starting a deposit return scheme, implementing "a producer responsibility fee" structure that stimulates the use of recycled plastic, rewards design for recyclability, and increases costs for packaging that is difficult to recycle or reuse. The report further suggested shifting recycling incentives from tonnage, which may dissuade recycling lightweight materials, to an outright goal of a ~65% recycling rate. The U.K. government later published a 25-year environmental plan which announced intentions to eliminate all "avoidable plastics waste" by year-end 2042, extend the 5p plastic bag charge to small retail shops and encourage "plastic-free aisles" at supermarkets.

Taiwan announced its intention to ban single-use plastics by 2030

In February 2018, a month after the U.K.'s 25-year plan was proposed, Taiwan announced its intention to ban single-use plastics by 2030. The plan layers in over several decades: In 2019 fast-food chains must stop providing plastic straws for in-store use, while the following year plastics straws are banned from all food and beverage stores. Beginning in 2025 consumers will be required to pay for plastic straws for takeout purposes and in 2030 the full ban goes into effect. Plastic bags, food containers, cups & utensils face a similar ramp with a retail ban in 2020, fees in 2025 and an all-out ban in 2030.

The EU proposed a continental solution to plastic waste in May 2017

Also in February, Scotland became the first U.K. nation to ban plastic straws, as part of a greater effort to cut down on single-use plastics. This announcement followed a ban on plastic cotton buds/swabs in January. Further, Scotland plans to appoint an expert panel to advise on ways to reduce single-use plastics going forward. In May, the EU proposed its first continental solution to plastic waste with potential bans on cutlery, straws, and cotton buds/swabs. Once fully implemented in 2030, the EU estimates that the changes could cost businesses over €3 billion (\$3.5bn) per year.

Figure 36. Select Single-Use Plastic Bans



Source: Citi Research

In the U.S., initiatives have been more on the state and local level vs. national level

In India, a national ban on single-use plastics will start in 2020 but some cities have already adopted the bans with substantial penalties for infractions

In the U.S., where recycling initiatives often trail Europe, the government hasn't pushed anything at the federal level but certain states and cities have reacted to the recent wave of news. In September 2017, Seattle, Washington announced a ban on plastic straws and utensils set to begin in July 2018. Several other cities have made announcements including Davis, Malibu, and San Luis Obispo in California and Miami Beach and Fort Myers in Florida. In April 2018, New York called for a statewide ban on plastic bags. In total, over a dozen U.S. cities have completely or partially banned foam cups, bowls, plates, and trays.

In June, India became the latest country to move forward with a ban on single-use plastics including bags, utensils, and certain PET bottles; the effective start date is 2022. Some Indian cities have adopted these bans in advance of the national ban; one of the more notable plastic bans is in Mumbai which has banned the use of plastic bags, cups, or bottles with penalties ranging from Rs5,000 (\$70) for a first-time offense and up to Rs25,000 (\$350) and 3 months in jail for repeat offenders. The size of the fines is notable, with the first-time fine (Rs5,000) translating to ~\$70 in a country with average annual income of ~\$620. Similar to Bangladesh, one the reasons for the ban was an attempt to reduce the impacts during floods. In 2005 record rains killed over 1,000 people in Mumbai and environmental groups pointed out the negative impact of plastic bags choking off drainage systems.

The plastic bans are likely to impact India's long-term demand for plastics: plastics companies have had bullish growth expectations for India given the country's strong GDP growth (+5-7%) and relatively low income per capita. Plastic usage in India is also very low at only ~11kg per year per capita compared to the U.S. at ~96 kg per year per capita. For competing substrates the bans may create an opportunity for growth; we estimate the soft drink pack mix in India is ~68% plastic, ~30% glass & ~2% cans. Notably foreign metal canmakers have expanded their India footprints in recent years.

Figure 37. Mumbai Plastic Ban



Source: Citi Research, Maharashtra Pollution Control Board

Some corporates have proactively adapted to changing consumer preferences on single-use plastics

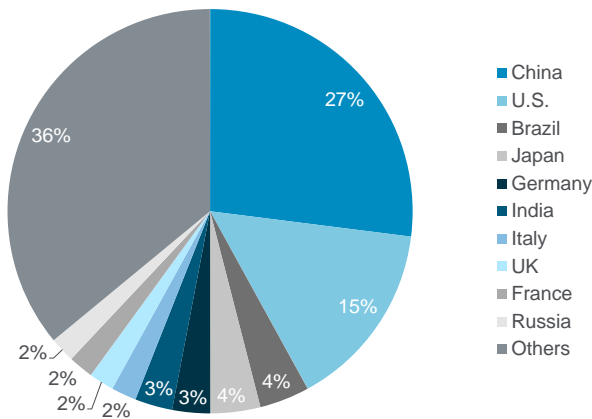
Apart from legislative requirements, restaurants and retailers are proactively adapting to changing consumer perceptions of single-use plastics. Notably Dunkin Donuts, which has a ~25% market share in U.S. coffee with ~8,500 retail locations in North America, announced it will move away from polystyrene cups; the transition is expected to take from spring 2018 to 2020. The company plans to use paper cups moving forward; Dunkin estimates it uses ~2 billion cups annually company-wide, of which ~1 billion are foam. Separately, McDonalds, with ~14,000 locations in North America, announced it will eliminate foam packaging and cups by the end of 2018.

The Current State of the Recycling Industry

Of the ~800 million of waste collected globally, only about 17% is recycled

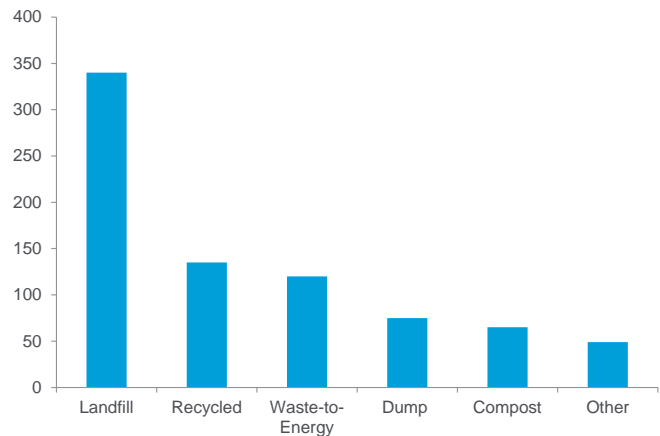
Improving recycling systems could address many of the issues with single-use plastics, and has been a focus for Chemical companies in North America and Europe. Municipal solid waste (MSW) is generally considered any trash/garbage or recyclable that is collected from urban areas to be processed or disposed of. China is by far the largest MSW producer followed by the U.S. and Brazil (see Figure 38). High-income countries generally have well-developed municipal collection systems and as such have collection rates above 95%. As the average income of a country decreases, the waste collection rate also decreases, with upper middle-income countries at ~80%+ collection rates followed by 65% in lower middle-income countries and ~40% in low-income countries. Of the ~800 million tonnes of waste collected globally, only about 17% ends up being recycled with the vast majority ending up at landfills. Landfills are problematic because of land usage issues and pollution: while a large portion of waste (35-50%) collected is organic and largely biodegradable, a significant amount (~10%) is composed of plastics which can take centuries to decompose.

Figure 38. Municipal Solid Waste Generation By Country



Source: Citi Research, World Bank

Figure 39. Total Municipal Solid Waste by Disposal Method (mmt/Yr)



Source: Citi Research, World Bank

The availability of recycling for various plastics varies widely in the U.S.

In the United States, the availability of recycling for various plastics varies widely. For instance, recycling of high density PE (HDPE) bottles and jugs is available to 92% of the Continental U.S. population while availability of recycling for HDPE tubes is available to only 1% of the population (see Figure 40). We note that availability is measured as curbside recycling being available at the place of residence or a drop-off recycling location located within the municipality where the resident lives.

Figure 40. Availability of Recycling Programs by Material

Plastic Product	% of U.S. population with recycling program available
HDPE bottles/Jugs	92%
PP bottles/jugs	81%
LDPE bottles/jugs	80%
Other bottles/jugs	79%
PVC bottles/jugs	78%
Bottle Caps	76%
PP tubs containers	70%
LDPE tubs	69%
PP clamshells	62%
PP cups	61%
PS containers	60%
PVC clamshells	59%
PP lids	54%
LDPE lids	54%
PS clamshells	54%
PS lids	45%
PS cups	44%
Plastic Buckets (5gal+)	43%
PVC non-bottle rigid packaging	40%
Bulk plastic (crates/baskets/etc.)	31%
PP cutlery	5%
PS cutlery	5%
HDPE tubes	1%
LDPE tubes	1%

Source: Citi Research, Sustainable Packaging Coalition

The recycling business in the U.S. is a \$235 billion+ industry

In the U.S. recycling is a \$235 billion+ industry, which includes consumer recycling through municipal systems, as well as the collection and processing of industrial waste streams. Once collection has occurred, sorting of collected materials is performed at recycling centers both through manual and automatic methods. Automatic sorters using infrared are often used to separate plastic streams from other packaging substrates (glass, metal, paper etc.). These optical detectors can often sort by polymer type as well as color as well depending on the amount of detectors used. Despite the progress made in sorting between rigid packaging substrates, flexible packaging has been a much harder problem to solve with many facilities choosing not to actively collect post-consumer flexibles due to the difficulty. There have been some technological developments in recent years though such as ballistic separators and hydrocyclones which may improve recycling rates for flexible packaging in the future.

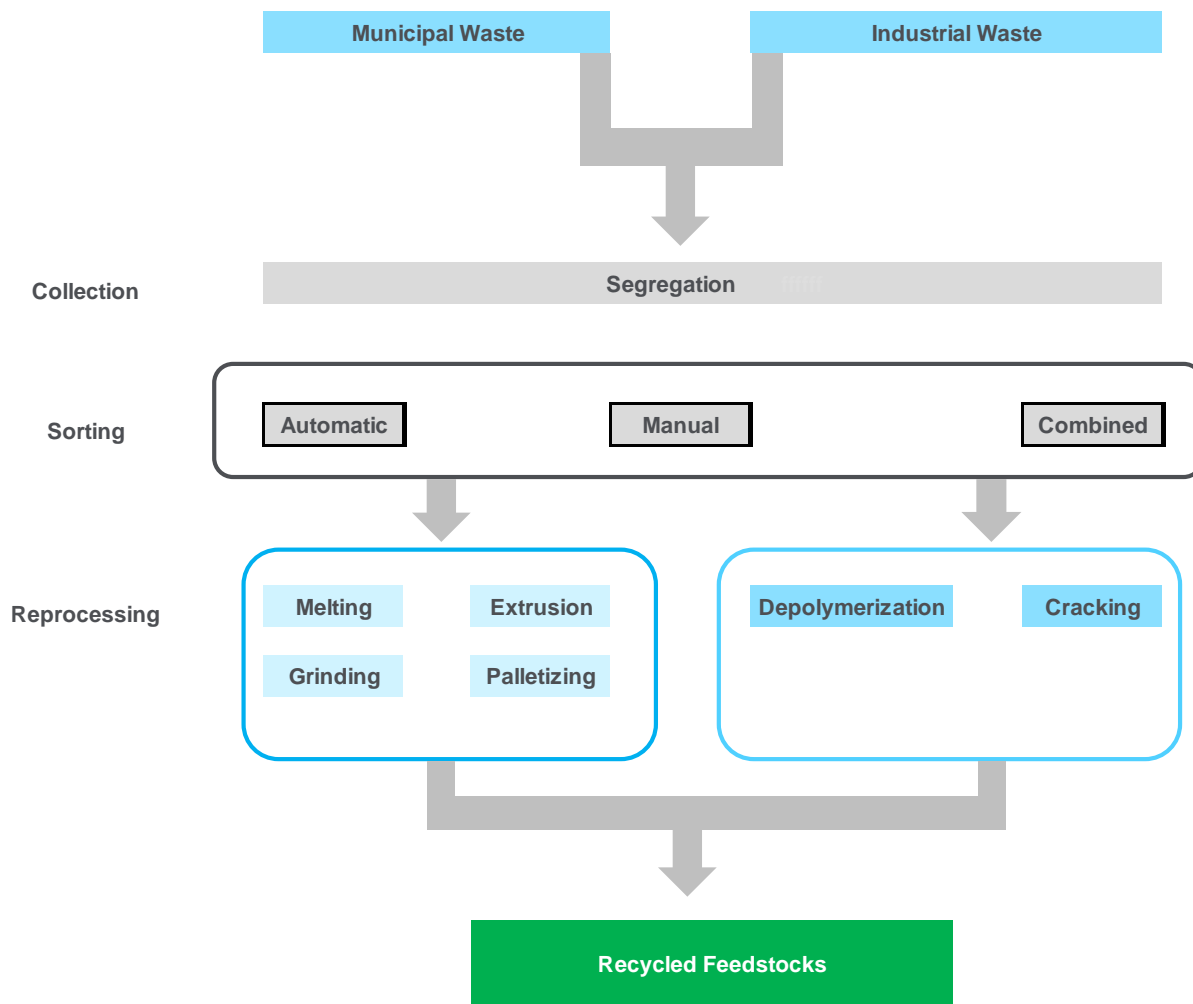
Mechanical recycling uses cutting or shredding to generate flakes that are then melted and pelletized

Following sorting, material goes through a mechanical or chemical recycling process (see Figure 41). Mechanical recycling usually begins with cutting or shredding of large plastic parts into small plastic flakes: the flakes are separated in a flotation tank according to the different densities of plastics being recycled. The flakes are then washed and dried before being fed through an extruder to be melted and pelletized for use in new products.

Chemical recycling breaks down plastic polymers through depolymerization

Chemical recycling is a series of processes in which plastic polymers are broken down into the base monomers through the process of depolymerization. Chemical recycling is on average more expensive than mechanical recycling. While chemical recycling has the advantage of recovering the petrochemical feedstock components of the polymer, it can be cost prohibitive as it reverses the energy-intensive polymerization phase. If a package cannot be recycled into its previous form it can be used to replace some of the virgin resin in similar products (this is referred to as 'primary recycling'). Alternatively recycled resin can be used to make products that would not normally use virgin resin, such as plastic lumber or plastic carpet fibers (this is referred to as 'secondary recycling').

Figure 41. Plastics Recycling Chain



Source: Citi Research

Challenges with Recycling Plastics















The diversity of plastic types makes collection and recycling a challenge

The diversity of plastic types presents challenges in collection and recycling. In the U.S. all recycled plastics are divided into seven groups corresponding to an ACC (American Chemistry Council) code (see Figure 42). Number one (#1) is polyethylene terephthalate (PET) which is most commonly used in soft drink bottles and is highly recycled. Number two (#2) is high density polyethylene (HDPE) which is often used in milk and juice bottles and is often recycled. Number 3 (#3) is polyvinyl chloride (PVC) which is used in clear food packaging applications, as well as shampoo bottles and food trays, and cannot easily be recycled. Number four (#4) is low density polyethylene (LDPE) which is commonly used in grocery bags, bin liners, and bread bags and is not easily recycled. Number five (#5) is polypropylene (PP) which is used in microwave meal trays, ketchup bottles, yogurt containers, and medicine bottles and can be difficult to recycle as few recycling centers can process these products. Number six (#6) is polystyrene (PS) which is used in foam trays as well as coffee cups and takeout boxes, similar to PP few recycling centers can process these products. Number seven (#7) is for all other plastics that do not fall into the prior six categories and usually have to be thrown away due to the heterogeneous nature of these products.

Industrial packaging currently holds the highest rates of recycling but post-consumer waste represents the largest opportunity

Due to these difficulties, the post-consumer plastic waste streams that have seen very high rates of recycling are PET bottles typically used for carbonated soft drinks (CSD) and HDPE jugs used for milk and juice, due to their uniform nature. Plastic waste from industrial packaging currently holds higher rates of recycling as the streams are generally pure and come in higher, more uniform volumes from factories, distribution centers, and other industrial facilities. The volumes from post-consumer waste however still represent the largest opportunity, with up to 5x more waste generated than in the industrial sector. In order to achieve high overall recycling rates, the post-consumer streams need to be dealt with more efficiently.

Figure 42. Plastic Resin Types – Uses & Applications

Plastic Resin Types		Descriptions	Properties	Applications
 	PET	<ul style="list-style-type: none"> PET is clear & tough Mainly used in beverage bottles When recycled, primarily used for carpet yarn 	<ul style="list-style-type: none"> Clear & smooth Great barrier against oxygen, water & CO2 Shatter resistant 	<ul style="list-style-type: none"> Beverage bottles for CSD's, water, juice etc. Food jars for peanut butter, jelly, pickles Also used in textiles and films
 	HDPE	<ul style="list-style-type: none"> HDPE has excellent chemical resistance Mainly used in milk & household chemical bottles 	<ul style="list-style-type: none"> Resistant to most solvents Good tensile strength 	<ul style="list-style-type: none"> Bottles for non food items (shampoo, household cleaners, antifreeze, etc.) Plastic lumber Tiles, film & sheet
 	PVC	<ul style="list-style-type: none"> PVC has excellent chemical resistance as well as stable electrical properties & weatherability 	<ul style="list-style-type: none"> High impact strength Resistant to oil & most chemicals 	<ul style="list-style-type: none"> Pipe, decking, tiles, garden hose & gutter On the flexibles side, films & sheets
 	LDPE	<ul style="list-style-type: none"> LDPE is used mainly in film due to its heat sealing properties 	<ul style="list-style-type: none"> Resistant to most acids & bases Flexible & transparent 	<ul style="list-style-type: none"> Garbage can liners Film & sheet, floor tiles Shrink wrap and stretch film
 	PP	<ul style="list-style-type: none"> PP has a high melting point making it good for hot fill applications 	<ul style="list-style-type: none"> Excellent optical clarity Tough & flexible 	<ul style="list-style-type: none"> Auto uses like signaling lights, battery cables, oil funnels Containers for yogurt, takeout meals & deli food
 	PS	<ul style="list-style-type: none"> PP is versatile with a low melting point 	<ul style="list-style-type: none"> Excellent moisture barrier Excellent insulation in foamed formed Significant stiffness 	<ul style="list-style-type: none"> Cups, plates, bowls Protective foam packaging for furniture & electronics
 	Other	<ul style="list-style-type: none"> Resin other than the 6 listed above or made of more than one type 	<ul style="list-style-type: none"> Depends on resin or combination 	<ul style="list-style-type: none"> Reusable water jugs Custom packaging

Source: Citi Research, ACC

Opportunities to Improve Recycling Systems

One improvement to recycling could be to treat non-recycled plastics as feedstock for conversion to fuels and chemicals

Consumer perceptions towards single-use plastics could be upgraded with improvements to the recycling system, which has been a major focus of Chemical companies and industry groups. In the U.S., the Chemical industry has encouraged municipalities to leverage partnerships for grants, loans, and technical assistance, as well as treat non-recycled plastics as feedstock for conversion to fuels and chemicals. One such plastics-to-fuel technology creates biofuels through waste gasification. Waste Management has invested in a startup called InEnTec which, along with several competitors, is attempting to commercialize plasma-gasification technology. This is done by feeding waste into a gasifier where it is partially oxidized. It is then dropped onto a molten glass bed where an electrically-generated plasma arc heats it to over 10,000 degrees Fahrenheit. The heat breaks the chemical bonds so molecules can be recombined and converted into useful materials such as hydrogen-rich synthesis gas; any inorganic material is combined and used to create construction products such as cinder blocks or bricks. The syngas can be created into ethanol, hydrogen, and other fuels that all meet U.S. Environmental Protection Agency (EPA) standards. By recycling waste into a revenue-generating raw material, there would be a powerful financial incentive to collect all used products before they end up in a landfill or the ocean.

Other technological innovations like RFID tagging could also improve recycling efforts

Other technological innovations could improve recycling rates long-term: one proposition for improving recycling efforts is through the use of RFID or radio frequency identification. If an RFID tag is placed on each household's recycling bin and a reader is placed on each garbage truck then governments will be able to track who is participating in recycling; this will allow for more efficient and targeted educational efforts. Governments could further use the data obtained from RFID readers to charge households for the amount of trash they generate; conversely communities could reward households that recycle more.

Risks and Opportunities for Plastic Producers

Overview of the \$1 Trillion Plastics Industry

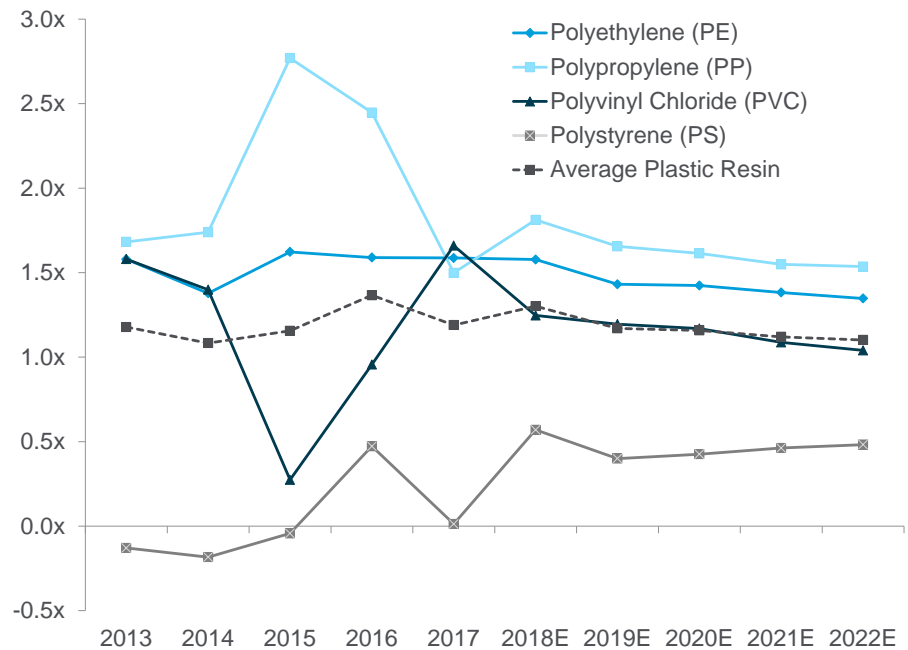
The global plastic market is expected to grow to ~\$1.2 trillion by 2020

The U.S. and China are the largest markets for plastics while Brazil and India are the fastest growing markets

Plastics were a >\$1 trillion global market in 2016, and are expected to grow to ~\$1.2 trillion by 2020 (~3% CAGR). Chemical companies are among the most well-capitalized and inventive in the world, and are responding to pressures on single-use plastics with innovation and technological advances. Recently Plastics producers and packagers have focused on light-weighting their products, investing in plastic recycling companies, improving recycling systems, and creating bio-based polymers.

The U.S. and China are currently the largest markets for plastics — each accounted for ~18% of the world’s value in 2016. While small in comparison to the U.S. and China, the plastics markets in Brazil and India are expected to grow the fastest, with each expected to average ~7.5% growth per year through 2020. China’s market is expected to grow at ~5% per year through 2020 while the U.S. is expected to grow at ~2% per year. Historically, plastics demand in developed economies has grown at 1.0x – 1.2x of GDP while developing economies have seen demand grow at 1.2x – 1.8x of GDP.

Figure 43. Ratio of Plastic Resin Demand Growth to GDP

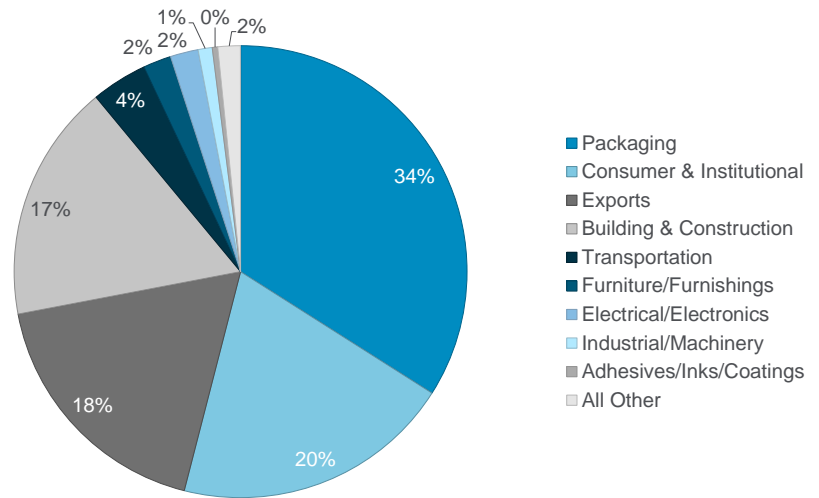


Source: Citi Research, IHS

The plastics industry is the third largest manufacturing sector in the U.S.

In the U.S., the plastics industry is one of the top manufacturing sectors in the country, ranking third as recent as 2016. Plastic resin production, the main raw material for downstream plastic products, was ~79 billion lbs. in 2017. The largest end markets in terms of volume consumed were plastic packaging (~34%), consumer/institutional (~20%), and building and construction (~17%). Given the U.S.’s low cost position globally, U.S. plastic resin producers exported ~18% of their production in 2017 however Citi expects this figure could increase to nearly 25% by 2020 as more production capacity on the U.S. Gulf Coast starts up.

Figure 44. U.S. Plastic Resin Distribution by End Market*

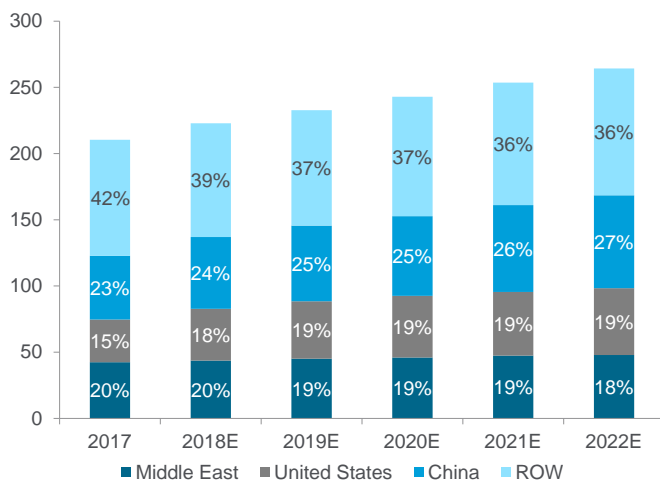


* Includes polyethylene, polypropylene, polyvinylchloride, polystyrene, and expandable polystyrene
Source: Citi Research

Polyethylene (PE), used primarily in packaging, is the most common plastic resin by volume worldwide

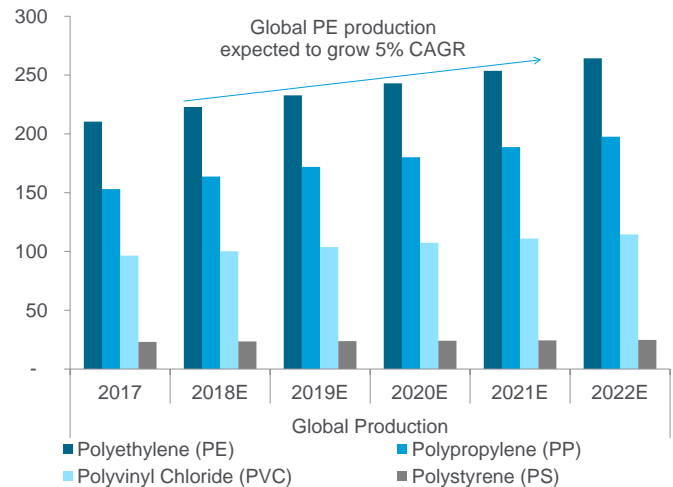
Worldwide, polyethylene (PE) is the most common plastic resin by volume and is primarily used in packaging, (bags, films, containers, and bottles). In 2017, PE production was ~210 billion lbs. globally and is expected to reach ~264 billion lbs. by 2022. The Middle East, the United States, and China are the worldwide leaders of PE production, accounting for ~20%, 18%, and 17% of global 2017 output, respectively. Over the next five years, both the U.S. and China are expected to surpass the Middle East in terms of production market share as the U.S.'s low-cost shale gas position incentivizes further investment in new capacity and China builds more domestic capacity to supply its growing economy.

Figure 45. PE Production by Country/Region (Bn lbs.)



Source: Citi Research, IHS Markit, % reflects share of global production

Figure 46. Global Production of Major Plastic Resins (Bn lbs.)

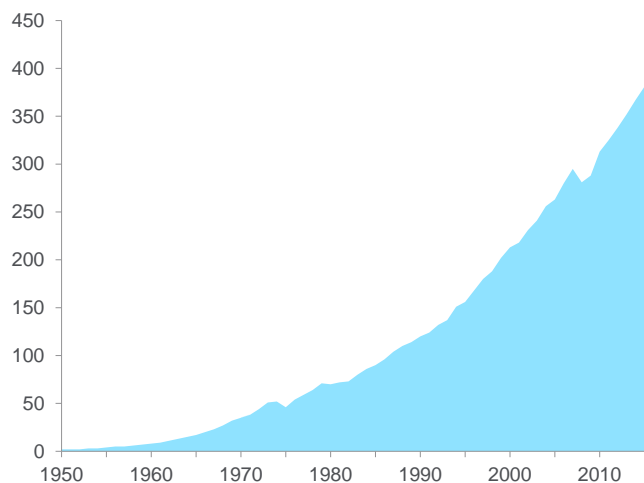


Source: Citi Research, IHS Markit

Plastic packaging is over 40% of industrial sales for the Chemicals industry

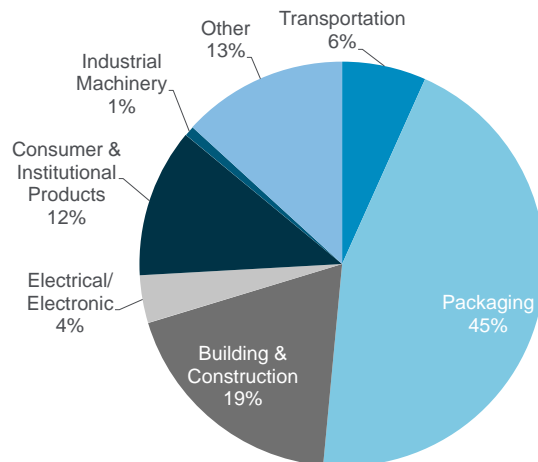
Plastic packaging is a primary end market for the Chemicals industry, comprising >40% of industrial sales and roughly one-third of U.S. domestic plastic resin distribution.

Figure 47. Annual Global Polymer Resin and Fiber Production (mmt)



Source: Citi Research, Geyer, Jambeck & Law 2017

Figure 48. Share of Polymer Production by Industrial Use Sector



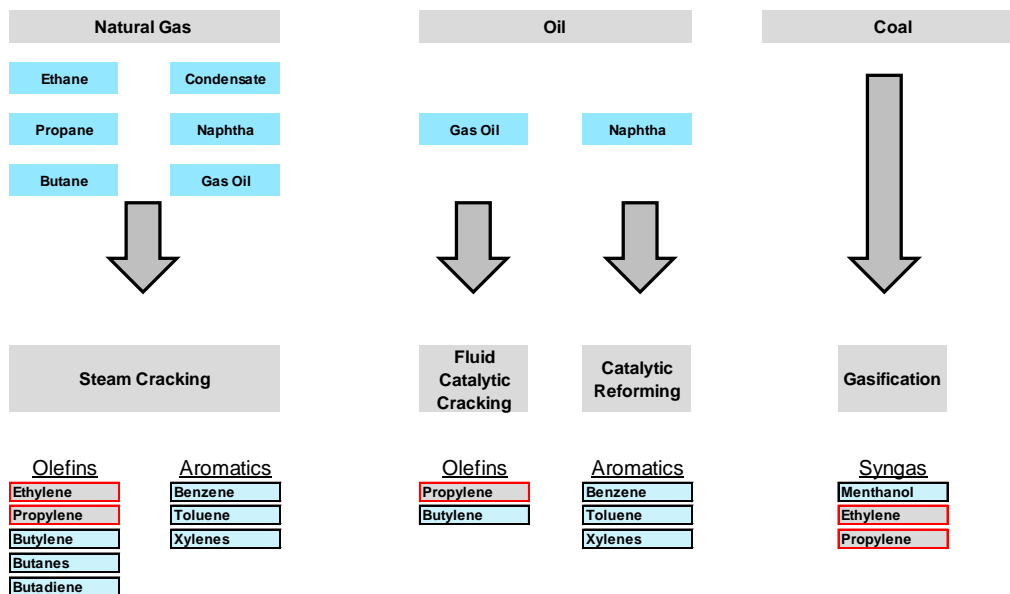
Source: Citi Research, Geyer, Jambeck & Law 2017

The Plastics Supply Chain

Ethylene and propylene are the two most important petrochemicals produced for the plastics supply chain

Resin is made primarily from either oil or gas depending on the process (see Figure 49). Ethylene and propylene are the most important petrochemicals with ~325 billion lbs. and ~215 billion lbs. being produced in 2016, respectively. North America is the largest producer of ethylene with over 81 billion lbs. in capacity, and China is the largest producer of propylene with over 67 billion lbs. of capacity.

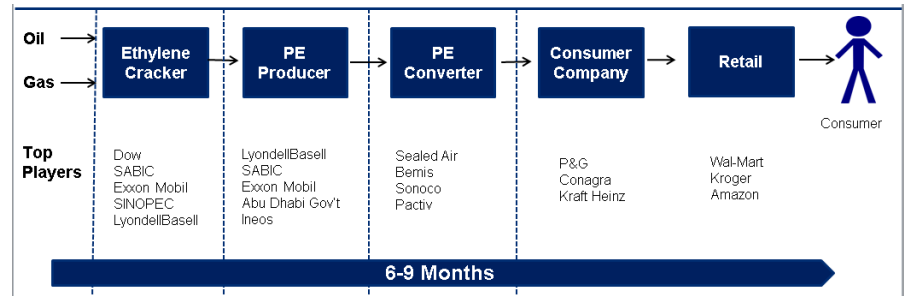
Figure 49. Raw Materials, Processes, and Chemical Building Blocks



Source: Citi Research, ACC

It can take up to nine months from the extraction of raw materials (oil & gas) for the end consumer to come into contact with the end plastic product or product packaged in plastic (see Figure 50).

Figure 50. Plastics Supply Chain



Source: Citi Research, IHS

Plastic packaging can be made via blow molding, film extrusion, thermoforming, or injection molding

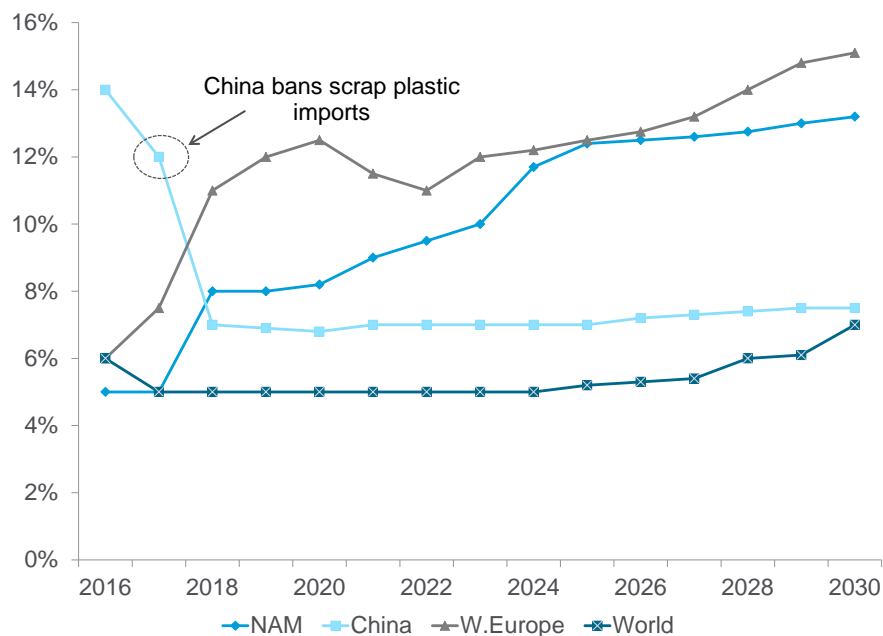
Plastic packaging is made through four primary production processes depending on the required shape and rigidity of the final product. The first manufacturing process we identify is blow molding; this is most commonly used to produce hollow plastic bottles (water, laundry detergent, etc.). Blow molding is the process of heating resin, typically polyethylene terephthalate (PET) or high density polyethylene (HDPE) into a malleable form, placing it inside of a metal mold and pushing air through it so it expands and takes on the shape of the mold. It is then cooled, trimmed of excess material and tested for leaks with pressurized air. Another common production method is blown film extrusion which is commonly used to make stretch film or plastic bags. Film extrusion is done by feeding low density polyethylene (LDPE or LLDPE) into a mix where it is heated and blended; this is then fed into an extruder where it is heated further. The heated resin is then pushed upwards by a force of air and smoothed out by rollers, it can then be cut to the desired width with excess material trimmed off and fed back into the extruder. The smoothed and trimmed film is then gradually rolled up and sent to printing. The film will then be unwound and run through a flexographic printer (metal rolls with various engravings on them run through ink) and then rewound and fed through a slitter where the film is cut into the desired size. The third primary production process is thermoforming. This is done by heating resin into a thin and malleable form and pressing it against a metal mold so it takes on the desired shape. This is commonly used to create takeout containers or more solid products such as industrial crates, pallets or lawn mower hoods. The fourth plastics production process we identify is injection molding; this is typically used to manufacture smaller parts or components. A metal mold is made in two parts with a hollow space in the middle which is the desired shape of the plastic product. Resin is heated into a liquid and is injected into these empty spaces. The resin is then cooled and the newly-created plastic product is removed.

Plastic Recycling – Current State and Outlook

Worldwide demand for recycled PE is expected to grow to 7% by 2030 from 5% in 2017 with Western Europe expected to lead the initiative

Globally recycled polyethylene (PE) demand accounted for ~5% of total worldwide PE consumption in 2017 at ~10 billion lbs., according to IHS. Recycled PE demand is expected to grow slowly to ~7% of total PE demand by 2030. Currently, Western Europe is expected to lead the global initiative in plastics recycling with its goal for all plastic packaging in the EU market to be recyclable or reusable by 2030. For PE alone, IHS sees recycled PE consumption in the region growing from ~7.5% of its total PE demand in 2017 to >15% by 2030 and ~25% by 2040. For total plastics (PE plus PP, PET, PS, among others) recycled material is expected to increase by nearly 175% from ~4 million tonnes in 2016 to ~11 million tonnes by 2030. As a result, recycled plastic resins could replace up to ~6 million ton of virgin resin demand in Europe by 2030 (~14% local demand), up from ~1 million tonnes in 2016 (~3% local demand).

Figure 51. Polyethylene Recycle Demand (% of Total Region Demand)



Source: Citi Research, IHS Markit

Demand in China for recycled PE is expected to fall to 7% from 12% in 2012 following the country's ban of scrap plastic imports but remain at these levels through 2030

Until 2018, China relied heavily on recycled plastics, with scrap PE accounting for ~12% of total consumption in 2016. However, recycled PE's share of the Chinese market is expected to dwindle to ~7% (~2 million tonnes) in 2018 following the country's ban of scrap plastic imports, which started gaining traction last year as part of the government's broader effort to reduce pollution. Citi believes the Chinese government's effort to ban scrap plastics import remains strong as scrap PE quotas in the beginning of the year were as small as ~1,000 tonnes. Given minimal quotas, Citi expects virgin PE demand globally could increase by ~1 million tonnes or ~0.5%. Looking ahead, IHS expects recycled PE as a share of total demand in China to remain between 7%-8% through 2030.

Plastic resin producers recognize both opportunities and threats from the emerging recycling market

Europe is leading the global initiative in plastics recycling

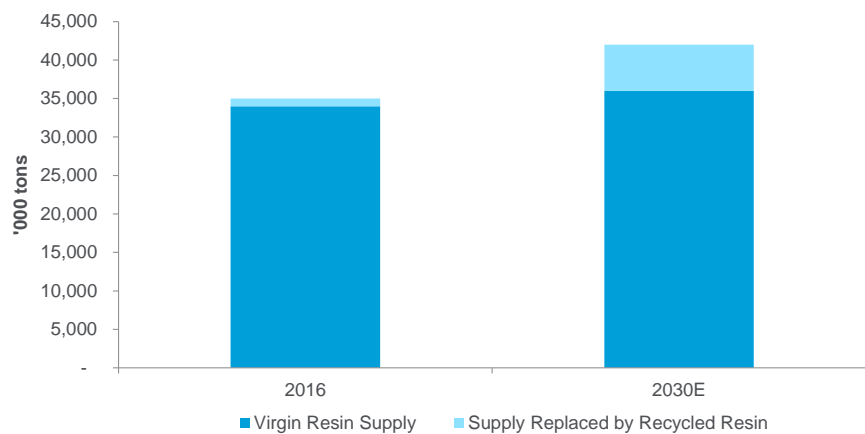
Given a lack of transparency, standardized pricing mechanisms and better clarity of cost structures across the recycled plastic resin market could help

Opportunities for Upstream Plastic Producers

While the impact of recycled plastic adoption may be modest over the medium term, plastic resin producers recognize both opportunities and threats from the emerging recycling market. Some have started making investments in Europe as part of their overall response. Borealis recently acquired MTN Plastic, a producer of recycled post-consumer plastic waste. LyondellBasell recently acquired a 50% stake in Quality Circular Polymers, a plastic recycler based in the Netherlands. In addition to this, plastic producers as a group seek to reduce waste by: (1) designing new products for greater recycling and reuse; and (2) developing new technologies for collecting and sorting materials. Examples of new products for improved recyclability include lighter-weight plastics, replacing rigid containers with flexible pouches, and refillable plastic bottles. Looking ahead, U.S. plastic resin producers who are members of the American Chemistry Council's Plastics division have set the following goals to recycle or recover all plastic packaging in the United States: (1) 100% of plastic packaging will be re-usable, recycled, or recovered by 2040; (2) 100% of plastic packaging will be recyclable by 2030, and (3) 100% of U.S. manufacturing facilities by members will participate in Operation Clean Sweep Blue by 2022. Operation Clean Sweep's goal is to help plastic production sites achieve zero pellet, flake, and powder loss.

Europe is leading the global initiative in plastics recycling with its goal for all plastic packaging in the EU market to be recyclable or reusable by 2030. In 2016, 4 million tonnes of plastic products were recycled in Europe and IHS expects this figure to increase to 11 million tonnes by 2030. As a result, IHS predicts that recycled plastic resins could replace up to ~6 million tonnes of virgin resin demand in Europe by 2030 (~14% local demand), up from ~1 million tonnes in 2016 (~3% local demand). We expect the impact to be relatively small as ~6 million tonnes of virgin resin displacement in Europe would account for just ~2% of 2016 global demand.

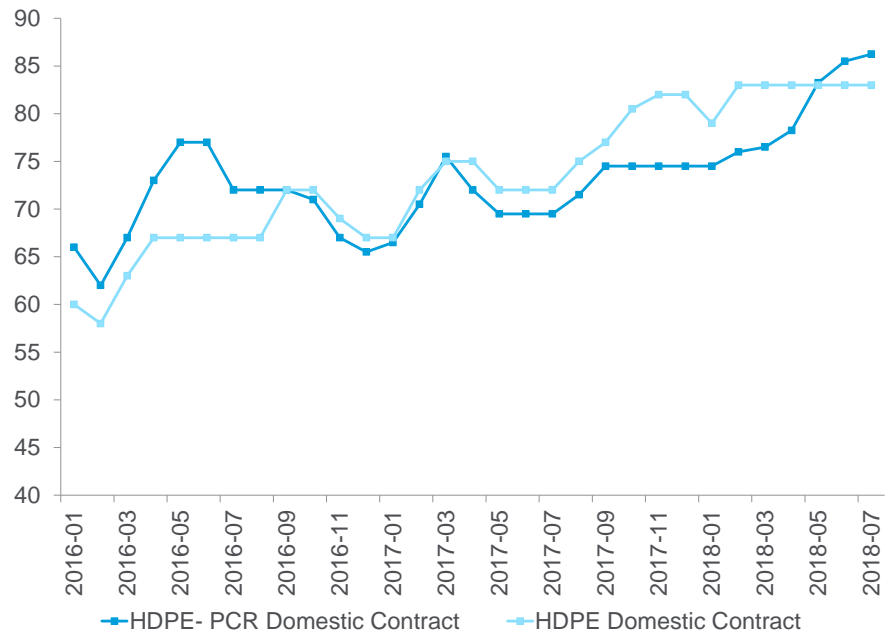
Figure 52. Impact of Plastic Recycling — Europe



Source: Citi Research, IHS Markit

One of the key challenges in the plastic recycling market is the lack of transparency in recycled resin prices. Standardized pricing mechanisms and better clarity of cost structures across the recycled plastic resin market can pave the way for greater liquidity and improvement in trade flows.

Figure 53. North American Post-Consumer Recycled (PCR) HDPE Contract Prices

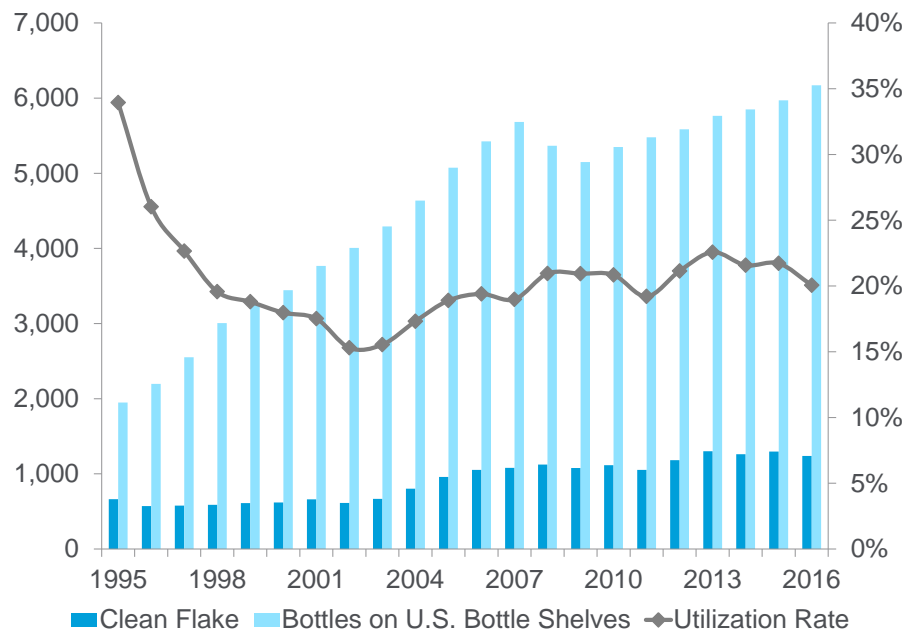


Source: Citi Research, IHS Markit

Recycled PET (rPET) has gained minimal traction as a percent of total plastic bottle production but one benefit of increased rPET use for industry is to help improve carbon footprints

Leading soft drinks producer Coca-Cola has cited packaging as the second largest component of its carbon footprint (25-30%) behind refrigeration. Pepsi is using more recycled polyethylene terephthalate (rPET), increasing usage by 3% in 2016. However across the industry, rPET usage is gaining minimal traction as a percent of total plastic bottle production. In Figure 54 below we compare the amount of 'clean flake' production in the U.S. (the material from recycled PET that is suitable for remanufacture) to total PET usage in the U.S. While the utilization rate has been steadily rising since 2001, 2016 was ~250 basis points below 2013 levels. To boost clean flake production, the overall recycling rates needs to rise. In 2016, the U.S. used ~6.2 billion lbs. of PET bottles but only ~1.8 billion lbs. were recycled (~28% recycling rate). Of the ~1.8 billion lbs. of recycled material, ~1.2 billion lbs. of clean flake were produced; a ~71% recovery rate of the underlying material. While this is below aluminum and glass which are infinitely recyclable, it implies that the industry could meaningfully improve its carbon footprint if consumers and recycling facilities emphasize recovering more bottles. In Europe, the European Federation of Bottled Waters has set recycling targets for 2025. The organization is aiming for 25%+ rPET in each bottle and a 90% recycling rate.

Figure 54. U.S. Clean Flake Production vs. PET Bottle Usage (million lbs.)



Source: Citi Research

Biodegradable Plastics – One Solution

Biodegradable plastics are made from sustainable resources and decompose at the same rate as other compostables

Biodegradable plastics or polymers have been in production since the late 1990s in small commercial quantities. These polymers can be sourced from sustainable resources such as corn starch and also synthetic (mineral-based) building-blocks. The key property being that biodegradable means that both synthetic and sustainable based polymers undergo microbial decomposition to carbon dioxide and water in industrial or municipal compost facilities. Moreover, they are able to decompose at the same rate as other compostables — ~180 days. There are also polymers that can decompose in domestic and seawater environments. At the same time these plastics have the same attractive application (largely centered around strength, weight and durability) characteristics as their mineral-based equivalents.

The production and consumption of biodegradable plastic remains in its infancy

The production and consumption of biodegradable plastics remains in its infancy. To give further context, according to Europa, in Europe 57 million tonnes of primary plastics were produced in 2016, with the share of bio-based plastics being only 0.5% and 1% of EU annual plastic consumption. Global consumption stood at 335,000 tonnes of biodegradable polymers in 2017, according to IHS, with Europe the largest consumer at ~52% and the U.S. at 22%. IHS expects the market to grow at 9%, or about 2.5x GDP, over the next 5 years. The total global installed capacity of biodegradable polymers is around 1 million tonnes per year. The products in Europe largely focus around polylactic acid (PLA). The production of heavy molecules from lactic acid is technically challenging, which results in the price of PLA in the region of \$2,100-\$2,600 compared to polyethylene (HDPE) at \$1,400-\$1,800 per tonne. That said, increasing the use of bio-based plastics could provide greenhouse gas savings in the EU in 2020 of 9 – 27 million tonnes of CO₂ which given the rising price of carbon credits could help to offset this cost.

The potential applications are interesting. BASF has two biodegradable polymer offerings under the brand names ecoflex and ecovio. Ecoflex is certified compostable, water and tear resistant, able to be processable with PE film equipment and suitable for food contact. The polylactic acid can be sourced from corn and compounded with starch, lignin (wood) and cellulose to achieve specific characteristics. Ecovio is a finished compound with bio-based content that is certified compostable worldwide. These products are suitable for biodegradable for the plastic films for coffee cups, carrier-bags and mulch films (a 1 million tonne per year market of films applied to fields to protect crops, which is causing soil pollution).

Despite the obvious benefits of biodegradable plastics, the consumption volumes are very modest in the context of the conventional single-use plastics in circulation today. Historically biodegradable polymers are more complex to produce and therefore more expensive, noting that products need to be competitively priced but also available in sufficient quantities to minimize supply chain risks. In this context, we judge that it has been quicker and cheaper to utilize existing capacity. If the source of inputs is from sugars then there is a clear corn price versus oil price equation and thus a low-oil price environment will also deter switching to biodegradable.

Changing consumer trends and the potential for new regulation could act as catalysts that make biodegradable plastics more cost competitive

The changing consumer trends, together with the potential for a change in legislation, look set to be the catalysts that could establish a price at which these products could better compete, in our opinion. That said, it takes around four years minimum to add meaningful capacity and even then the size and scale of the disposable plastics market is so large that it would possibly take many more years for these products to offer the scale required on a global basis to have a significant impact. We judge that there is also a level of education that would need to take place to inform consumers of the properties of biodegradable plastics. However, given the attractive properties of plastics to food and beverage producers and distributors, this role would likely be taken on by the provider. Certainly the standards are in place to classify these products as 'nature-equivalents'.

Biodegradable plastic is available today and is environmentally-friendly

In summary, biodegradable plastic technology is available today with a solution to the environmental demands required of an environmentally-friendly material. The cost and scale of capacity is likely to be the limiting factor in the rate of adoption. However, if legislations together with consumer appetite is willing to establish the price and thus the economic incentives for biodegradable plastics, then it is likely that the attractive material properties of polymers vs glass, paper and aluminum based products will lead to an expanded role for these compostable products.

Using plant-based materials in the place of petrochemicals in plastic bottles is one biodegradable option

Another avenue for the plastic industry to improve its environmental impact is the use of plant-based materials in the place of petrochemicals. Coca-Cola has been a leader in this area with its PlantBottle which uses up to 30% plant-based materials and is the first ever fully recyclable PET bottle. By being 100% recyclable, PET bottles enter the same closed loop economy as aluminum and glass containers. The bottle is currently made of sugarcane but could also use plant stems, fruit peels, and tree bark in the future. In 2015 Coca-Cola was using PlantBottles for 30% of packaging volume in North America and 7% globally; the company's goal is to convert all new PET bottles to PlantBottles by 2020; the PlantBottle was expected to reach price parity with regular PET bottles by 2018. Further, Coca-Cola is working to roll out a 100% plant-based bottle but hasn't provided details on a timeline.

Major bottled water producers Danone and Nestle have also taken steps towards bio-based packaging by forming NaturALL Bottle Alliance in March 2017. The goal of the newly-formed company is to create a PET bottle made of 100% sustainable resources such as cardboard and sawdust. The pushback against these products is that it does little to solve plastic pollution. While it is a step forward to use renewable resources as opposed to oil-based inputs, the PlantBottle is still not biodegradable and may end up in a landfill or the ocean.

In the U.S., packager Sealed Air has also made a step towards plant-based alternatives by entering into an agreement with Kuraray America, a leading manufacturer of resins, chemicals, and textiles. In their partnership announced in June 2018, the companies plan to offer food packaging materials in North America derived from Plantic™ bio-based resins. The agreement furthers Sealed Air's presence in roll stock barrier films, which is primarily used in meat & cheese categories.

The use of polylactic acid (PLA) is yet another biodegradable plastic substitute

Another response from the chemicals industry has been the increasing use of polylactic acid (PLA). PLA is a biodegradable plastic substitute made from plants such as corn, cassava, sugar cane, or beets that can be used to make cartons, electronics, food and beverage packaging, foodservice products, and hygiene products. NatureWorks, a joint venture between Cargill and Teijin, is a leading producer of PLA and has a proprietary product called Ingeo that is produced through a three-step process: (1) plants are put through a milling process that extracts the starch (glucose), enzymes are added to convert the glucose to dextrose; microorganisms then convert it into lactic acid; (2) lactic acid is converted into lactide through a proprietary process; and (3) lactide is turned into Ingeo PLA through polymerization which creates a long chain of lactide, now a polylactide polymer. Based on our findings, biodegradable cups carry a significant price premium with a 50 pack of 16oz PLA cups costing ~\$10 compared to a 50 pack of 18oz standard plastic cups that costs ~\$4; it's possible prices will come down as adoption becomes more widespread.

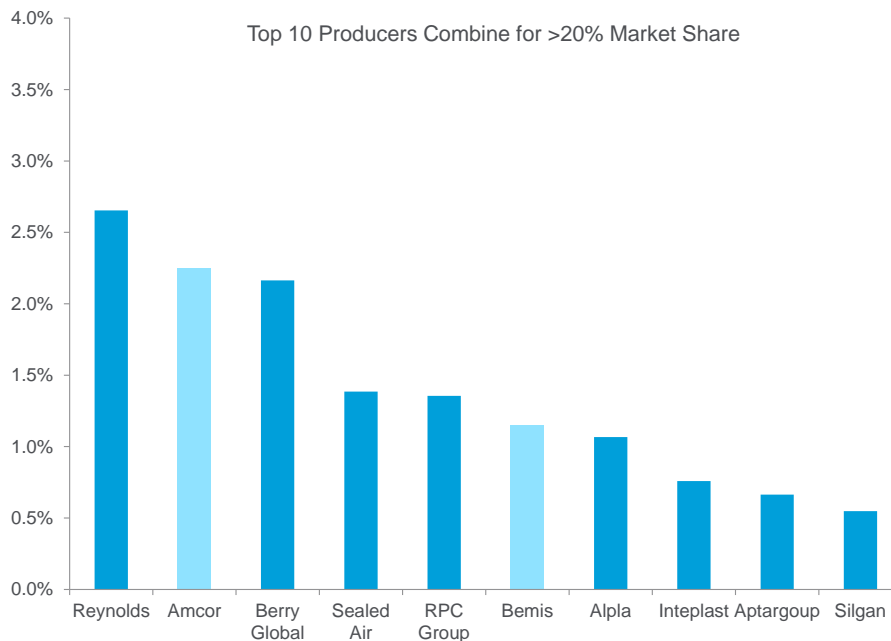
Figure 55. Select Bioplastic Initiatives

Company	Product	Material	Biodegradable?	Description	Status
Coca-Cola	PlantBottle	Sugercane	No	Replacing standard PET bottles with plant-based bottles	7% of Coca-Cola's global bottles
NatureWorks	Ingeo	Polylactic acid	Yes	Biodegradable plastic alternative made from plant-based materials	~10% share of global bioplastics
Kuraray	Plantic	Corn	Yes	Plant-based food & beverage packaging	Targeting ¥10 billion in sales by the end of 2018

Source: Citi Research, Company Reports

As consumers and retailers demand more environmentally sustainable and innovative products, one potential impact of regulatory scrutiny of single-use plastics could be to accelerate consolidation among plastic packagers. Larger firms are able to invest the research and development (R&D) required to develop biodegradable and recyclable packaging and manufacture them at scale. Large-scale consolidation among plastic packagers has picked up in recent years, with Australian Packaging giant Amcor agreeing in August to acquire leading U.S. flexible packager Bemis in a ~\$6.5 billion deal, creating a leading global plastic packager with a significant market share in every major region. In discussing the strategic rationale of the deal, Amcor management indicated the combination was not defensive in nature, but rather aimed at capturing new opportunities and becoming better positioned to address sustainability concerns, with chances to combine and accelerate overlapping initiatives.

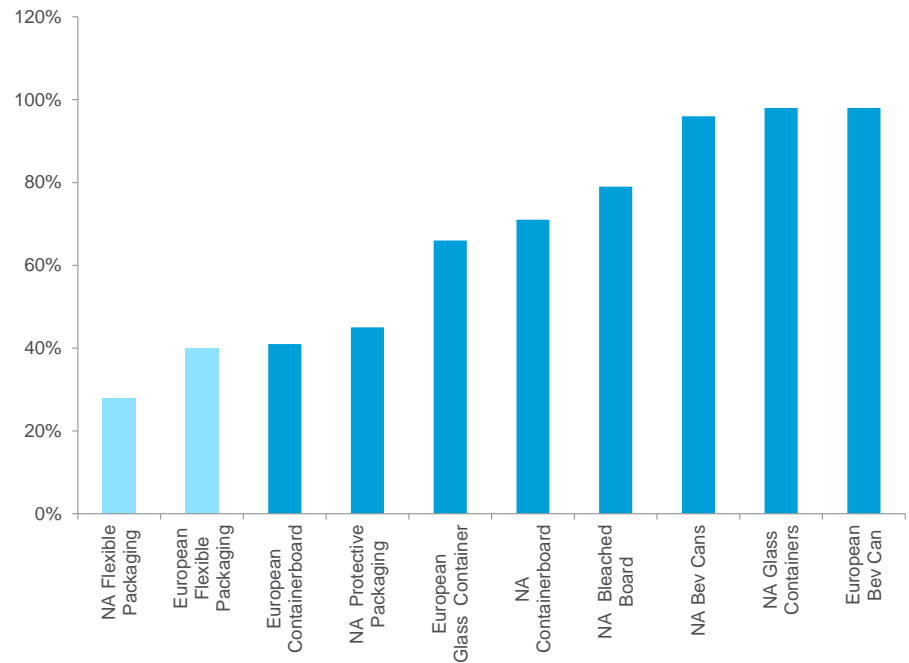
Figure 56. Global Plastic Packaging Market Share



Source: Citi Research, Company Reports

In addition to potentially advancing innovation capabilities, plastic packaging mergers and acquisitions typically generate meaningful cost synergies, often driven by resin procurement. Resin can be 50%+ of cost of goods sold for plastic packagers, and notably the top 10 plastic packaging producers globally hold less than 20% market share, which compares to the top 10 producers of polyethylene holding ~45% market share globally. While there are a perhaps a half dozen large plastic packagers that procure >1 billion lbs. of resin annually, this pales in comparison to the output of the global Chemical industry with annual PE and PP production of >350 billion lbs. Consolidation could further improve packagers' pricing power in selling to large global consumer packaged goods companies, which are usually their largest customers and have seen waves of global consolidation themselves.

Figure 57. Four-Firm Ratio for Paper & Packaging End Market

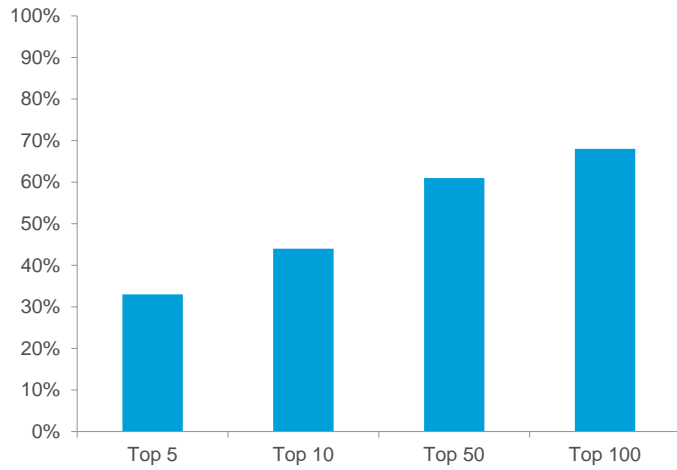


Source: Citi Research, Company Reports

Plastic packaging is an extremely fragmented industry

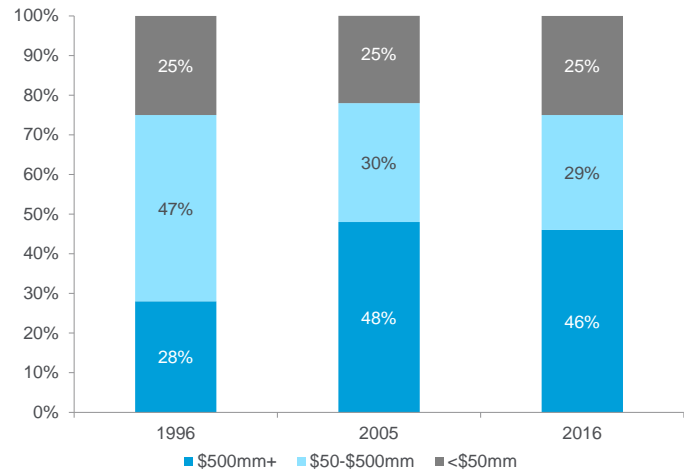
Compared to other packaging substrates such as metal beverage and food cans, glass containers, cardboard and paperboard boxes and cartons, Plastic packaging is extremely fragmented. Looking at Figure 57, we estimate North American flexible plastic packaging has a four-firm ratio of 28%, compared to North American glass containers with a four-firm ratio of 95%+, and beverage cans with a four-firm ratio of 90%+. European plastic packaging, while more consolidated than North America, also remains significantly more fragmented than metal and glass substrates. There are a few reasons while plastics may not become as consolidated as metal, glass, and paper grades: by comparison, plastic packaging encompasses a more heterogeneous group of products and forms, such as stretch film, pouches, rigid containers, caps, etc. Accordingly we believe there will likely always be room for smaller niche players, i.e., packagers running dedicated lines under long-term contract for a large customer or entrepreneurs with new technology or a patented process. That said, we think the benefits of innovation and scale could push industry consolidation further in the coming years.

Figure 58. North American Flexible Packaging Market Share



Source: Citi Research, Flexible Packaging Association

Figure 59. North American Flexible Packaging by Company Size



Source: Citi Research, Flexible Packing Association

Alternatives to Single-Use Plastics: Metal, Glass, and Paper

Single-Use Beverage Containers

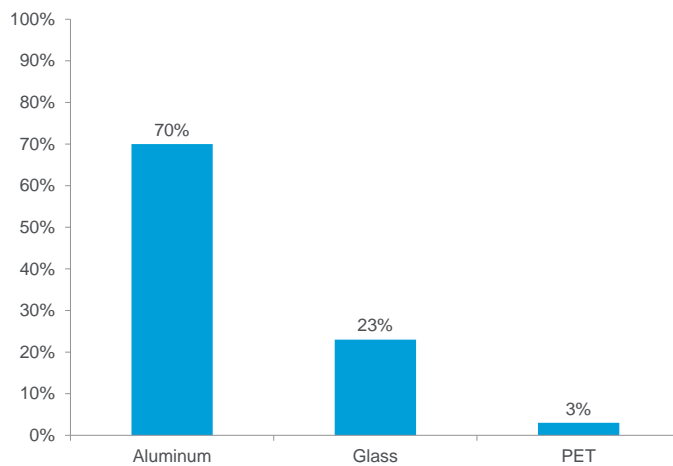
Plastics, glass, and paper have positioned themselves to regain some of the share they lost to plastics over the past few decades

As plastics face increased regulatory and environmental scrutiny, substrates such as metal, glass, and paper have positioned themselves to regain some of the share lost over the past few decades. Per a recent Nielsen global survey, environmental concerns are increasingly important to consumers with nearly ~75% of shoppers aged 15-20 indicating they would pay more for a product that comes from a company committed to making a positive social & environmental impact; this is up from ~55% in 2012. Older consumers also express a preference for environmentally-conscious products, with Baby Boomers indicating concern about the environment and willing to pay more when making purchasing decisions up from ~44% to ~51%. Moving forward we see a few potential “battleground” packaging products, including bottles for carbonated soft drinks & sparkling water, drink cups for coffee and other hot and cold beverages, protective packaging for E-commerce applications, and retail and food bags, which could see share shift between various substrates.

Aluminum has share gain potential especially in single-use beverage containers

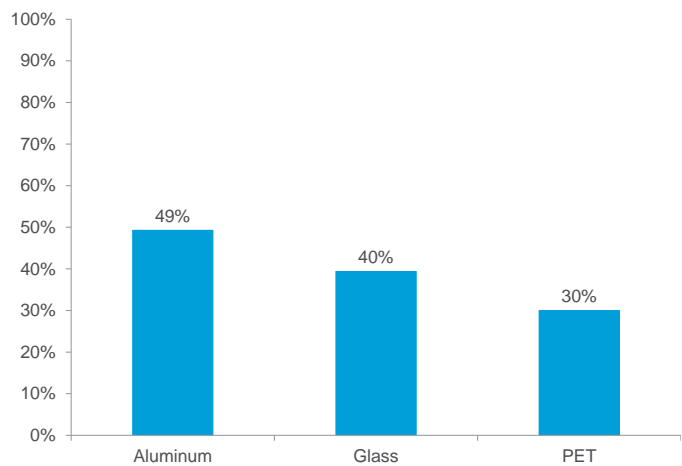
Single-use beverage containers for soft drinks, sparkling water, teas, and energy drinks are one application where aluminum has the potential to regain share from plastic. The appeal of aluminum stems from its greater recyclability, as an average aluminum can is comprised of ~70% recycled content compared to PET at ~3%, and glass at ~23%. Consumers are also more likely to recycle cans, with ~50% of US cans recycled as opposed to alternative products at ~30-40%. Making a can out of recycled aluminum is further less energy-intensive, requiring only ~8% of the energy needed to produce a new can, per Recyclebank. While historically beverage can producers have been hesitant to publically criticize competing substrates (which may be perceived as criticizing the choices of their top customers), we've seen Metal Packaging management teams recently become more vocal on the environmental advantages of the beverage can.

Figure 60. Average Recycled Content of Beverage Containers



Source: Citi Research, The Aluminum Association

Figure 61. U.S. Recycling Rates: Beverage Containers

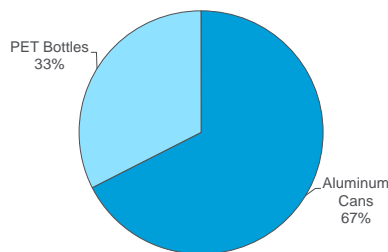


Source: Citi Research, The Aluminum Association

The aluminum beverage can market is largest in North and Central America and Europe

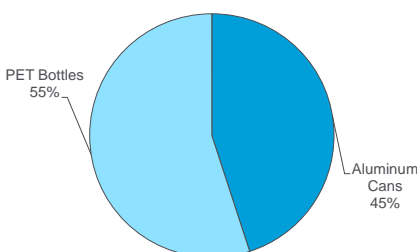
The global aluminum beverage can market is ~320 billion cans with North and Central America (~107 billion units) and Europe (~66 billion units when including Russia) being the largest markets; this compares to PET bottles just shy of ~500 billion units globally. In Figures 62-64 below, we detail the U.S. soft drink market, comparing aluminum cans to PET bottles. While cans have greater market share in units, they have lower share on a volume basis with PET having essentially the entire multi-serve market (>24oz per container). While aluminum can sizes beyond 24oz are rare, the larger single serve market (~78% of PET bottles) could see increased competition from beverage cans typically sized at 12-24oz.

Figure 62. CSD Packaging Mix by Unit Volume



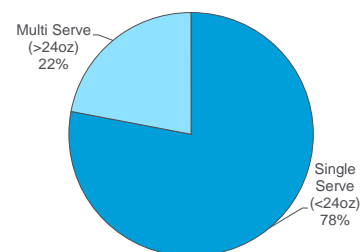
Source: Citi Research, Amcor

Figure 63. CSD Packaging Mix by Fluid Oz



Source: Citi Research, Amcor

Figure 64. CSD By Bottle Type



Source: Citi Research, Amcor

The potential shift to plastic-to-metal substitution is higher in Europe given limited penetration of aluminum cans there relative to the U.S.

In European non-alcoholic beverages, the potential for plastic-to-metal substitution may be larger given the limited penetration of aluminum cans relative to the U.S. In CSDs, PET has ~82% share in unit volume compared to ~33% in the U.S.; for beer PET has ~12% share vs. 0% or 1% in the U.S. We estimate a ~100 basis point share shift from plastic to cans (in both beer & CSDs) would represent a ~3 billion unit opportunity; enough to fill two beverage can plants. We see the largest opportunities for share shift in Eastern Europe (55-60 billion beverage container market; PET ~95% share in CSDs, ~11% in beer) & Germany (~125 billion beverage container market; PET ~65% share in CSDs, ~7% in beer). Beverage can producers have in recent years debuted new specialty can sizes, such as mini-cans, sleek cans, and metal bottles, which may increase their overall commercial appeal.

Figure 65. Can vs. PET Market Share in Europe

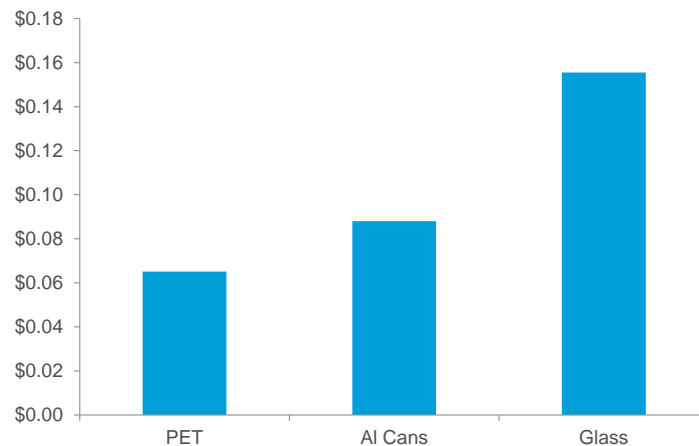
CSD Market		Beer Market		Country
% Plastic	% Bev Can	% Plastic	% Bev Can	
95%	2%	11%	31	CEE
92%	6%	50%	20	CIS+Russia
92%	7%	1%	51	Poland
91%	5%	1%	36	Austria
87%	7%	2%	34	Turkey
83%	12%	0%	32	Netherlands
76%	16%	0%	21	Italy
73%	24%	0%	36	France
71%	25%	1%	64	U.K.
71%	6%	1%	82	Norway & Ireland
69%	25%	3%	81	Sweden
65%	2%	7%	4	Germany
63%	25%	0%	33	Belgium
61%	27%	1%	41	Spain & Portugal
59%	31%	0%	34	Greece
13%	37%	1%	68	Denmark
82%	8%	12%	23	Europe

Source: Citi Research, BCME

In choosing beverage containers, drink manufacturers and consumers may ultimately have to choose between cost and performance

In choosing beverage containers, drink manufacturers and consumers may ultimately have to choose between cost and performance, which seem to favor plastic containers, and recyclability and waste impact, which would seem to favor metal containers. By analyzing segment sales for leading packagers relative to unit production volume, PET bottles hold a cost advantage over other beverage containers (see Figure 66). And while global consumers have expressed a willingness to pay more for environmentally responsible and sustainable packaging in a period of global economic growth, if economic conditions were to worsen producers and consumers may become more incentivized to prefer the lowest cost option. Another cross-factor in the cost competitiveness of metal versus plastic containers is price trends in the underlying raw materials, aluminum, and resin. While the costs of these commodities tend to move together over time, a sharp deviation between the two (sharply higher metal prices and low resin prices, or vice versa) may also influence purchasing decisions.

Figure 66. Implied Price Point per Container

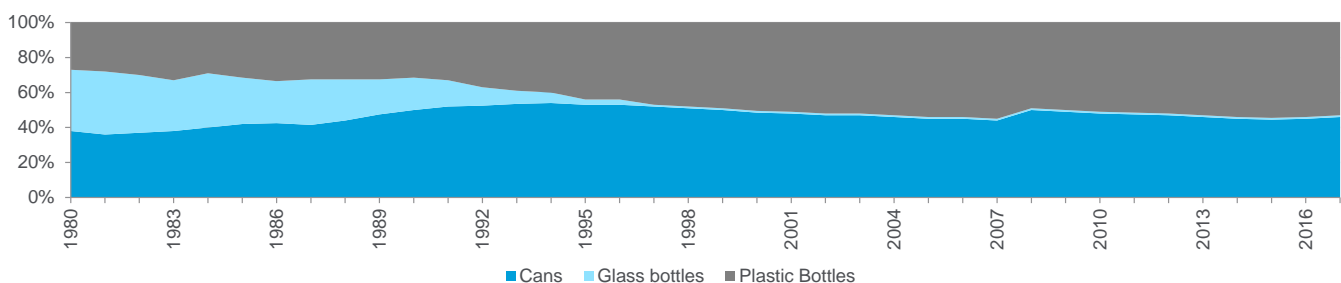


Source: Citi Research, Company Reports

In the U.S., plastics have nearly completely displaced glass in CSDs

Plastics have grown from ~25% of U.S. carbonated soft drinks in 1980 (see Figure 67) to over ~50% currently, nearly completely displacing glass. Carbonated soft drinks have been bottled in plastic bottles since the early 1950's, since HDPE was invented. Plastic bottles steadily gained market share from glass, and to a lesser extent cans through the 1960-80s. Two key turning points that accelerated the mix shift was the 1978 introduction of the 2-liter PET bottle for carbonated soft drinks and the 1994 introduction of the sleek 20oz plastic bottle by Coca-Cola which mimicked the iconic Coca-Cola glass bottle. Coca-Cola's introduction of the 20oz plastic bottle in 1994 saw the share of carbonated soft drinks in plastic bottles move from 40% in 1994 to 49% in 1999.

Figure 67. Carbonated Soft Drink Market Share Across Time

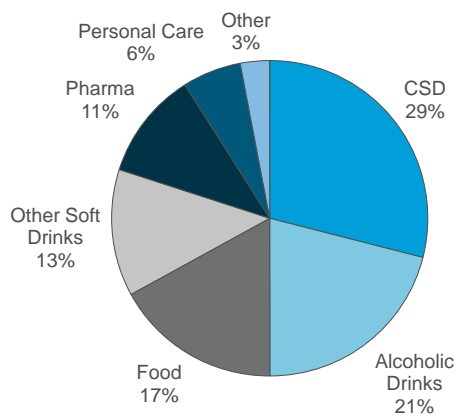


Source: Citi Research

A shift to aluminum from plastic would also affect the caps and closures producers

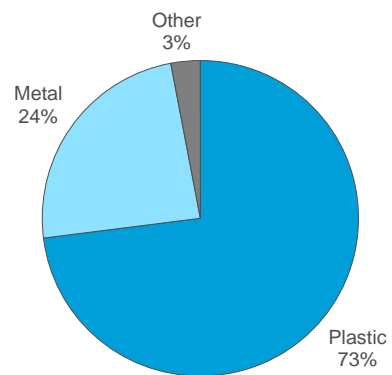
Share shift between aluminum and plastics also potentially impacts caps and closures producers. Plastic bottles typically use caps, while cans use aluminum lids and ends; the Ocean Conservancy has indicated these caps and closures and among the most common items found in marine debris. As seen in Figure 68 below, ~42% of caps and closures are used on soft drink products globally. A majority of caps are made of polypropylene which has a smaller recycled market than other plastic products making them significantly more difficult to recycle than the underlying bottle. Recycling services for PP caps are not offered at all locations. Notably some caps are made of HDPE (such as sports drinks) and are easier to process. In the U.S., only ~11% of PP is recycled.

Figure 68. Caps and Closures End-Market Exposure



Source: Citi Research, Company Reports

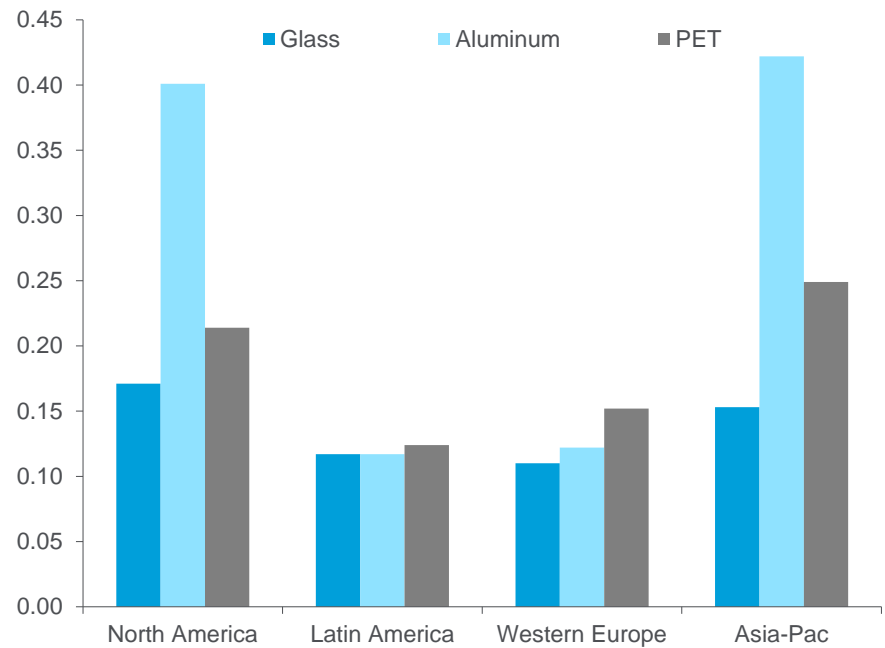
Figure 69. Caps and Closures Production Materials



Source: Citi Research, Company Reports

For higher-end products, glass may fill niche roles over plastic and aluminum

While we see aluminum cans as a potential beneficiary of substrate mix shift in beverage containers, glass may also fill niche roles for higher-end products. While drink manufacturers, shippers, and retailers have in some cases moved away from glass because of its higher weight, production costs, and breakage issues, glass maintains a perception among consumers as a premium, higher quality product. Glass bottles have various advantages and disadvantages from an environmental standpoint: glass is endlessly recyclable, meaning the quality does not decline when old bottles are converted into new ones. However glass has little, and sometimes negative, value as a recycled material since its main raw material input, sand, is so abundant in nature. Some U.S. cities have accordingly decided to stop collecting glass altogether given, after including freight costs, it can be a negative value generator for recycling facilities. In terms of decomposition in landfills, glass is one of the longest-lasting man-made materials and can take centuries to decompose like plastics, however a positive attribute is that with glass decomposition there isn't a risk of petrochemicals leaching into the environment. Figure 70 illustrates glass' favorable carbon footprint compared to different beverage containers; this is especially true in regions such as Latin America with advanced collection and recycling systems, where consumers use refillable glass bottles which can be used ~30 times.

Figure 70. Carbon Footprint per Container (kg CO₂ per 355ml container)

Source: Citi Research, Company Reports

Drink Cups, Protective Packaging & Retail Bags

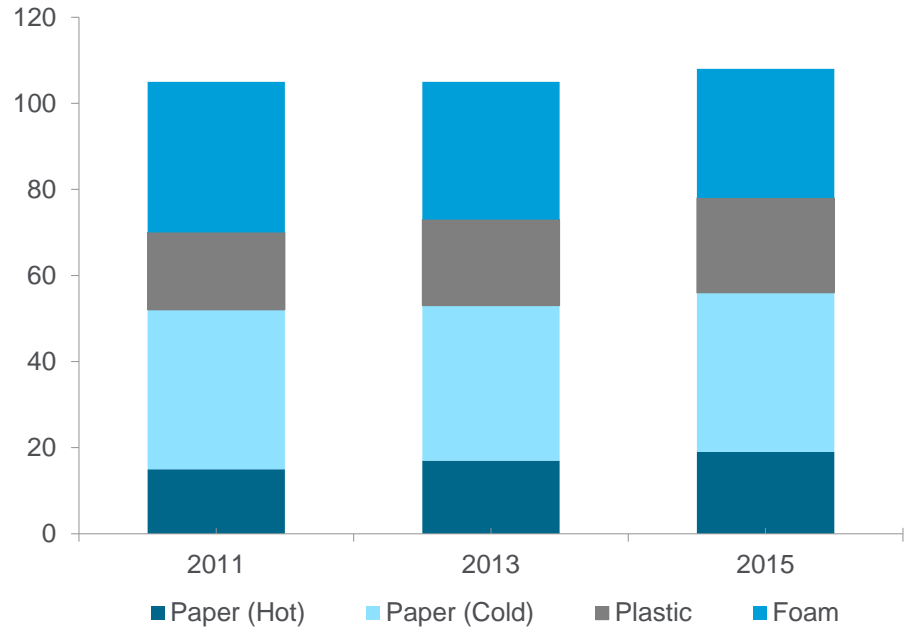
The majority of single serve cups in the U.S. are paper

One potential battleground packaging application where the sustainability and recyclability story is not clear cut is single serve drink cups for coffee and other hot and cold drinks. In the U.S., the single serve cup market is ~110 billion units; paper has leading market share with ~52%. Within paper ~18% of cups are hot fill and ~34% are cold fill, with hot seeing strong volume growth (+5-6%) in recent years while cold has grown more in-line with GDP. Foam (Polystyrene, or PS) is the second leading substrate with ~28% share, however PS has seen pronounced volume declines in the -3% to -4% range in recent years.

With a decline in foam cups and issues with recycling plastic-lined paper cups, recyclable plastic cups could gain share

The decline has largely been driven by environmental concerns as PS isn't biodegradable and cannot be recycled. Other plastic materials have ~20% share, which has grown in recent years. While we see continued declines in foam cups, the advantages of paper cups are far from clear-cut. Cups used in large coffee chains use a polyethylene lining on the inside of the container that makes the entire cup difficult to recycle, with some estimates claiming less than 1 in 1,000 cups are actually effectively recycled. Accordingly while paper has a more environmentally-friendly image in the minds of many consumers, the recycling performance can be poor. Tackling the recyclability problems of PS and paper, leading cup producer Berry Global has developed a PP cup called Versalite, which is fully recyclable and offers strong performance for both hot and cold beverages. Versalite is made of #5 polypropylene, which is recyclable, with many U.S. communities accepting #5 plastics curbside.

Figure 71. U.S. Cup Market by Substrate (Billion Units)



Source: Citi Research, Company Reports

Protective packaging made of plastic film is only recycled 15% of the time and while protective paper can be substituted with recycled paper....

Protective packaging, such as bubble wrap used in e-Commerce, is another potential battleground between plastic & paper substrates. In the U.S. plastic film is only recycled ~15% of the time, well below that of PET bottles or aluminum cans. Plastic film is defined as stretch wrap, poly bags, agricultural film, bubble wrap, and other PVC or PP films. The low recycling rate is partly attributed to the amount of effort required by consumers. For example, protective packaging (bubble wrap and air pillows) cannot be recycled at many recycling facilities, as it may cause jams or even damage processing machinery. Instead, these products need to be recycled at a drop-off point, similar to plastic bags, or can be mailed back to the manufacturer. Bubble mailers may need to be disassembled by the consumer (separating the internal bubble wrap from the paper exterior) before they can be recycled. An alternative to plastic protective packaging is recycled paper, which can also be used to fill extra space in a package and prevent items from moving in transit. Some producers have begun using paper that is 100% recycled, recyclable, and biodegradable.

Figure 72. Fact Sheet: Bubble Wrap vs. Recycled Kraft Paper

	Bubble Wrap	Kraft Paper
Cost	~\$45/roll	~\$29/roll
Recycle Rate	~15%	~67%
Material	Polyethylene	Recycled paper
Weight	15 lbs.	24 lbs.
Size	24" wide, 500' long	24" wide, 1,500' long

Source: Citi Research, Scientific American, International Plastics, ABC

...other PE-based wraps used to secure items in transit or stack goods on pallets are less at risk for substitution

Other plastic stretch films, including PE-based wraps used to stack goods on pallets and secure items in transit, are perhaps less at risk for substitution, as they are primarily used in manufacturing and distribution processes out of sight of the consumer. Stretch film can be one of the largest sources of waste in distribution centers, and takes centuries to breakdown in a landfill. Similar to other film products, the material cannot be recycled in standard facilities. However stretch film has seen low-to-mid single digit growth largely driven by pallet utilization (storage and distribution = ~70% of demand) given the cost advantage over alternatives such as metal strapping which has seen volume declines in the 0% to -1% range in recent years. Another alternative is stretch hooding, which uses less material than spiral wrapping (the most common use of stretch film) but requires more standardized pallet sizes. Industry forecasts expect hooding to show the strongest growth in the near term (+high-single digits). Despite the limited recyclability of film, its cost advantage likely makes demand relatively inelastic, even if consumers take a sharper view on single-use plastics.

The 'paper or plastic' debate does not have clear winners and losers as both have advantages and disadvantages

The question "Paper or Plastic" is well known to U.S. shoppers, with both substrates having their advantages and disadvantages. Paper bags have higher recycling rates and decompose significantly faster, but can require more than twice the energy to produce; they also carry a higher price point and are generally less durable than plastic bags. They also have greater mass and weight than plastic, so they are more costly to transport. In the United States ~30 billion plastic bags are used each year compared to only ~10 billion paper bags. Paper bags are made from kraft paper, which is made from renewable softwood chemical pulp. Other than paper grocery bags, kraft paper is commonly used for multiwall sacks (for things like concrete, fertilizer, and flour) and cheap lining for things like particleboard, tiles and countertops. We estimate the North American kraft paper market is ~2 million tonnes with the vast majority being unbleached grades, bleached grades are primarily used in some fast-food takeout bags although bleached bags have been in decline in recent years.

Figure 73. Fact Sheet: Plastic vs. Paper Bags

	Plastic Bag	Paper Bag
Cost	<\$0.01	~\$0.02-\$0.03
Recycling Rate	<5%	~20-30%
Decomposition	Centuries	Decades
Material	Petrochemicals	Fiber
Weight (1k bags)	15 lbs	140 lbs
Size (1k bags)	~980 in ³	~7,200 in ³

Source: Citi Research, Scientific American, International Plastics, ABC

Kraft paper has potential in other industrial and housing applications; the two main types of kraft paper are natural/multiwall and extensible. Multiwall is used extensively in grocery bags as well as fast-food takeout bags and directly competes with plastic. We have also begun to see interest in using crushed kraft paper in void fill applications for e-Commerce, which is another area that is currently dominated by resin based packaging, in the form of inflated plastic pouches as well as expanded polystyrene (foam peanuts). Extensible kraft paper is primarily used for concrete bags and other heavier materials as the reinforced paper is very tear resistant.

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The most common source of plastic resin used in packaging is polyethylene, which takes up to a century to decompose. / [Biodegradable plastic technology using plant-based materials is available today as a solution to the environmental demands required of an environmentally friendly material. Economic incentives could help expand the role of these compostable products.](#)



SUSTAINABILITY

The push for local, regional, and national bans on isolated plastic packaging products have been increasing over the past 20+ years with heightened environmental awareness. / [Recent regulation by China on recycled material imports has accelerated the move out of single-use plastic across the globe resulting in an increase in the number of bans and levies.](#)



INNOVATION

Only 14% of plastic packaging gets recycled with the rest going to landfills or is littered — couple with plastics' low cost, it's not always economical to recycle. / [New recycling efforts including plastics-to-fuel technology that create biofuel through waste gasification and the use of RFID that makes recycling efforts more efficient could improve long term recycling rates.](#)



