INCREASING ENGAGEMENT IN THE HDPE RECYCLING VALUE CHAIN IN THE UNITED STATES

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April 2015

Masters Project submitted in partial fulfillment of the requirements for the Master of Environmental Management degree in the Nicholas School of the Environment of Duke University.

Executive Summary

Global production of plastics has increased dramatically in the past 70 years, from 1.9 million tons in 1950 up to 330 million tons in 2013. The United States, the world's second largest producer of waste, generated 32 million tons of post-consumer plastic waste in 2012, and only 8.8 percent of it was recovered. The rest was discarded in landfills and in smaller portions along roads, beaches, and in waterways where it may travel to the ocean. Plastic does not quickly decompose like organic matter but instead disintegrates into smaller pieces, such as micro particles the size of plankton. An estimated 44,000 to 120,000 tons of U.S. plastic waste entered oceans in 2010. This amount represents a small portion of the plastic waste that enters oceans globally and the amount by which the total amount is projected to grow.

This research aims to understand issues with the current recycling system in the United States and identify ways to increase recycled content in packaging and consumer products. A wide variety of plastics can be recycled. However, each resin has unique characteristics and special market dynamics. Therefore, this research dives into the recycling value chain for one type of plastic—high-density polyethylene (HDPE)—and starts with an empty shampoo bottle discarded from a residential home. HDPE is one type of polyethylene (PE), the most common plastic worldwide. Forty percent of thermoplastics sold in the United States are HDPE, with the largest end-use market being packaging (i.e., milk jugs and detergent bottles). For recycled HDPE, the largest end market globally is for plastic pipes, such as those used in construction in China. Because a shampoo bottle is a rigid plastic container, the report's analysis focuses on collection, processing, and conversion of HDPE into new rigid products—and not films.

Despite generally high demand for recycled HDPE content (e.g., from consumer packaged goods manufacturers), there are disconnects between many recyclers, product manufacturers, and other actors that result in suboptimal design for recyclability and insufficient supply of quality material for recycling. Guided by this dynamic, the research has two objectives: (1) identify opportunities to increase engagement in the value chain for recycling rigid HDPE and (2) serve as a reference guide on the value chain covering key market dynamics, challenges, and influential organizations in each segment. The research is intended for all actors in the HDPE recycling value chain—in both the public and private sectors—especially those who design, manufacture, or handle rigid bottles and containers. It is inspired by circular economy concepts that connect recycling to sustainable flows of materials from products designed to be safe for humans and the environment.

The analysis presented in this report is primarily qualitative and draws from the global value chain (GVC) framework. The GVC approach uses the firm as the point of reference and allows for exploration of linkages between global industries, trade, regulations, and other actors. The report centers on recycling in the United States because most of the plastic material being collected is also processed and manufactured into new products in the United States. The research included interviews conducted in the fall of 2014 with 14 experts from throughout the value chain, information gathered at the Resource Recycling Conference in New Orleans, and online research.

The report describes how there is a the huge supply of material generated and wide-ranging access to collection services but that HDPE is recycled at relatively low rates—e.g., around 10 percent for all post-consumer HDPE (and 16 percent for HDPE packaging). The value of just HDPE packaging wasted in the United States was estimated to be $2.85 billion in 2010. In part, it is going to waste because the value chain for recycling rigid HDPE appears to be marginally profitable. The biggest challenges for strengthening the industry are: (1) competition with virgin HDPE, which is produced in vastly greater

quantities and at a consistently high quality; (2) the need for greater economies of scale to reduce the costs of recycling; and (3) the strong need for improved coordination. Disconnects throughout the value chain include lack of awareness, misperceptions, and entrenched interests that inhibit change.

A key finding of this research is that improved understanding of the whole value chain would lead to increased coordination. Opportunities to increase engagement identified in the report include:

- Municipalities adopting common terminology for recycling programs
- Collectors and MRFs applying a market-based mechanism to assign a value to desirable materials so that they show up in curbside bins
- Product manufacturers working directly with reclaimers on resin specifications
- Retailers working with consumer product goods companies (CPGs) to standardize packaging by product segments (e.g., all HDPE in the dairy aisle)—to reduce diversity of plastics in stores
- Non-profit industry groups or consulting firms conducting coordinated analyses to inform the development of an industry-wide strategy.

With these measures, it is hoped that CPGs and retailers, equipped with improved understanding of the value chain, will continue to encourage consumers to participate in recycling programs, which will lead to a financially healthier value chain, more recycled HDPE in products and packaging, and less plastic waste in the environment.

Table of Contents

Acronyms

ABS	acrylonitrile butadiene styrene
ACC	American Chemistry Council
APR	Association of Postconsumer Plastic Recyclers
C2C	cradle to cradle
CPG	consumer packaged goods
CSPA	China Scrap Plastic Association
CVP	Curbside Value Partnership
DfR	design for recyclability
EoL	end of life
EPR	extended producer responsibility
EPS	expanded polystyrene
FFRG	Flexible Film Recycling Group of the American Chemistry Council
HDPE	high-density polyethylene
rHDPE	recycled high density polyethylene
ISRI	Institute of Scrap Recycling Industries, Inc.
LCA	life cycle assessment
LDPE	low density polyethylene
LLDPE	linear low density polyethylene
MRF	materials recovery facility
MSW	municipal solid waste
NCEAS	National Center for Ecological Analysis and Synthesis
NC DENR	North Carolina Department of Environment and Natural Resources
NRDC	Natural Resources Defense Council
NWRA	National Waste & Recycling Association
PAYT	pay-as-you-throw
PE	polyethylene
PET	polyethylene terephthalate
PCR	post-consumer resin
PP	polypropylene
PRF	plastics recovery facility
PS	polystyrene
PTO	plastics-to-oil
PVC	polyvinyl chloride
SAN	styrene acrylonitrile
SPC	Sustainable Packaging Coalition
SPE	Society of Plastics Engineers
UNEP	United Nations Environment Programme
U.S. EPA	United States Environmental Protection Agency
VOC	volatile organic compound
WM	Waste Management, Inc.
WTE	waste-to-energy
WEF	World Economic Forum

INTRODUCTION

It is estimated that 4 percent of the world's annual consumption of petroleum is used as feedstock for plastics, and more than one third of plastics are consumed as packaging that is discarded quickly (Thompson, Moore, vom Saal, & Swan, 2009). In 2013, 330 million tons (299 million tonnes) of plastics were produced globally, valued at $600 billion (see Figure 1). Production of plastics around the world has grown by an average of 8.7 percent per year from 1950 to 2012; and since the 1970s, plastics have been replacing glass, metals, and paper in automotive and packaging applications (Johnson, 2015b). As the size of the global middle class continues to expand, consumption of plastics will also grow. It is estimated that consumption of nine major thermoplastics[1] will grow by 4.5 percent annually from 2013 to 2017, or by more than 40 million tons (Galiè & Trabucchi, 2014).

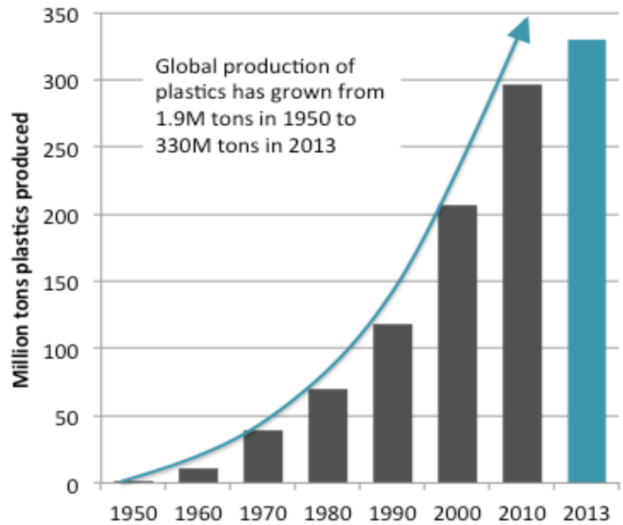

Figure 1. Global Plastics Production, 1950-2013

Source: Johnson (2015b); PlasticsEurope (2015)

Among plastics' many attractive characteristics, such as low weight, strength, and flexibility, they are also desirable because of their affordability. However, resin prices are volatile. Prices for the input material, petrochemicals, are tied to those of petroleum and natural gas. In some regions, such as for ethylene production in the United States, supply limitations put upward pressure on plastics prices. Since 2000, sharp price increases in commodities, including petroleum, have "erased all the real price declines of the 20th Century" (WEF, 2010).

Paper recycling has shown that recycling can dampen price volatility for material inputs and even reverse the trend of rising prices (Pegasus Capital Advisors, 2013). Recycling plastic scrap also provides economic benefits. According to the United Nations Environment Programme (UNEP), plastics recycling and energy recovery provide annual savings of $4 billion to consumer goods companies around the world (UNEP, 2014). Yet recovery rates for used plastic products and packaging is still low (e.g., around 13 percent for plastic packaging), reducing potential savings for recyclers from economies of scale and resulting in significant value lost through disposal (U.S. EPA, 2014).

In addition to the economic benefits of recovering plastics, there are huge environmental and social costs of current plastics production and disposal practices. The UNEP has reported that the total natural capital costs of plastics used in the consumer good industry exceeds $75 billion per year.[2] This includes the loss of landfilled material, damage to fisheries and tourism from ocean plastics, and the impact of greenhouse gas emissions from petrochemical production (UNEP, 2014). The National Center for Ecological Analysis and Synthesis (NCEAS) at the University of California, Santa Barbara, estimates that

[1] LDPE, LLDPE, HDPE, PP, PVC, PS, EPS, ABS and SAN

[2] Natural capital is defined as "renewable and non-renewable natural resources that companies rely on to produce goods and deliver services" (UNEP, 2014).

between 1.5 and 4.5 percent of plastics produced globally—approximately 5.3 million to 14 million tons—washed into oceans in 2010 (Jambeck et al., 2015; Loepp, 2015).[3] Finally, there are health impacts of toxic additives in plastics (e.g., plasticizers, pigments, flame retardants) that have yet to be fully understood and quantified.

There is growing consumer awareness of the environmental and social effects of plastics waste and a resulting increase in demand for sustainable management of dwindling resources. In response, some consumer product manufacturers, retailers, and others have redesigned products to reduce resource use—through extending product lives, enabling disassembly, encouraging reuse, and improving recyclability. According to McKinsey & Company, "forward-looking companies should begin investing in the 'circularity' of their products, for the benefit of society and for their bottom line" (McKinsey & Company, 2014).

Policymakers are also responding to concerns through mandates, market mechanisms, and by increasingly placing responsibility on producers for the life cycle impacts of their products—such as through extended producer responsibility (EPR) laws and regulations. The European Union (EU) has several directives in place to manage disposal of plastic packaging, but there is growing sentiment that plastic is still under-regulated in Europe (UNEP, 2014). China's government is taking an incentives approach by encouraging the formalization of its recycling industry as indicated by its 2008 circular economy law and a target in its 12th Five-Year Plan (FYP) for its recycling industry to reach a market value of $287 billion by 2015 (The Climate Group, 2013).

Given that the United States is the world's second largest generator of waste, opportunities are vast for closing loops to harvest lost value, reduce resource constraints, and hedge against energy and commodity price fluctuations. This paper investigates the recycling value chain for one type of plastic waste in the United States—high density polyethylene (HDPE).

Objectives of This Report

The objectives of this report are to identify opportunities to increase engagement in the HDPE recycling value chain—to ultimately increase recycled HDPE (rHDPE) use in packaging and consumer products—and to serve as a reference guide on the value chain. The research is guided by the fact that, despite generally high demand for rHDPE content, there are disconnects between many recyclers, product manufacturers, and other actors that results in suboptimal design for recyclability and insufficient supply of quality materials for recycling.

A significant finding is that product manufacturers would be more engaged with the rHDPE industry if they had more insight into the upstream value chain. Therefore, this report also aims to serve as a reference guide on the value chain for recycling rigid HDPE bottles and containers—covering the multiple overlapping industries and entities involved. As such, the report includes a value chain map and characterization of value chain segments, key market trends affecting their activities, and current challenges. It also analyzes current efforts and future opportunities for increasing engagement.

The research is intended for all actors in the HDPE recycling value chain, especially those who design, manufacture, or handle rigid bottles and containers—in both the public and private sectors. It is inspired by circular economy concepts that connect recycling to sustainable flows of materials from products designed to be safe for humans and the environment (see the Background section for more).

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[3] An estimated 44,000 to 120,000 tons of U.S. plastic waste found their way to the ocean in 2010.

Research Approach

The research includes interviews with industry experts, information gathered at an industry conference, and a review of current news and literature to map the rHDPE value chain and identify market dynamics, challenges, and opportunities for increasing engagement. Interviews were conducted from October to December 2014 with 14 experts from across the value chain, including state recycling directors, industry consultants, and representatives from a MRF operator, reclaimer, packaging producer, product manufacturers, and a non-profit industry working group (see Appendix 1: Interviews).[4] Experts were identified for interviews through introductions made at the 2014 Resource Recycling Conference in New Orleans, LA, the researcher's personal contacts, recommendations by those interviewed, and email outreach without prior communication. Information was also collected from experts' presentations made at the conference.

The report's analysis is qualitative and utilizes the global value chain (GVC) framework, a major paradigm that is increasingly applied by a wide variety of institutions (e.g., the World Bank, United Nations), governments, and other organizations to "highlight the ways in which new patterns of international trade, production, and employment shape prospects for development and competitiveness" (Gereffi, 2014). The GVC approach uses the firm as the point of reference and allows for exploration of linkages between global industries, trade, regulations, and other actors (Gereffi, 2014). This report centers on recycling in the United States because most of the plastic material being collected is also processed and manufactured into new products the United States.

To narrow the focus of the research, an empty, used shampoo bottle made of 100 percent HDPE serves as the point of entry to the value chain.[5] The shampoo bottle is a rigid plastic bottle, so analysis in this report focuses on collection, processing, and conversion of HDPE (both unpigmented and colored) into new rigid packaging. The findings of this report may not be representative of all end use markets, such as HDPE films (e.g., plastic bags) and post-industrial plastic waste. In addition, although a wide variety of plastics can be recycled, each resin has unique characteristics and special market dynamics. Therefore, this paper focuses on HDPE where possible to allow for a more in-depth perspective.

Many other studies and technical resources covering various aspects of the HDPE and recycling industries are available. No other reports like this one were found through a review of the literature, which included papers on sustainable materials management (OECD, 2012), sustainable product design (Luthe, Kägi, & Reger, 2013), recycling supply chains (Pagell, Wu, & Murthy, 2007), global recycling networks (Crang, Hughes, Gregson, Norris, & Ahamed, 2013), and other topics.

A handful of studies were used as key references for this report:

- UNEP. (2014). *Valuing Plastics: The Business Case for Measuring, Managing and Disclosing Plastic Use in the Consumer Goods Industry.*
- ACC and APR. (2014). *2013 United States National Post-Consumer Plastic Bottle Recycling Report.*
- APR. (2012). *Design for Recyclability Guide.*
- U.S. EPA. (2014). MSW Generation, Recycling, and Disposal in the United States: Facts and Figures for 2012.[6]

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[4] Many more experts were identified for interviews that could not be conducted due to time constraints.

[5] Image source: Freeimages #27685

[6] Proprietary industry analyses were not used.

BACKGROUND

High Density Polyethylene

HDPE is one type of polyethylene (PE), the most common plastic worldwide. The three main types of PE are HDPE, low density (LDPE)—known under resin codes #2 and #4 respectively—and linear low density (LLDPE). HDPE, defined as having a density of 0.941 g/cm^3 or more, is an input for both rigid products, like plastic pipes, crates, detergent bottles, as well as plastic bags. HDPE is a thermoplastic, meaning that it melts when heated and solidifies when cooled. Forty percent of thermoplastics sold in the United States are HDPE, with the largest end-use market being packaging (Carteaux, 2013). Packaging includes both food and beverage (e.g., milk jugs) and non-food (e.g., laundry detergent) bottles and containers. HDPE is preferable in applications such as shower products due to its durability and crack resistance (Anonymous, 2014b).

Other thermoplastics include: PET, used in carbonated beverage bottles and fleece fabric; LDPE, used in trash bags and outdoor lumber; PVC, used in pipes and garden hoses; PP, used in dairy tubs and bottle lids; PS, used in packing peanuts and egg crates; ABS, used in Lego bricks and automotive bumpers; and acrylic, used in plexiglass (see Figure 2). Thermoset resins include: epoxy resins, such as adhesives and insulation on electrical wiring; melamine-formaldehyde resins, such as heat resistant laminate kitchen counters; and phenolics, such as heat resistant handles for pans (e.g., silicon).

Figure 2. Overview of Plastic Resin Codes

Source: Walmart (2013)

HDPE is referred to as a polyolefin, a group of polymers produced from simple olefins, and is produced from long chains of ethylene through polymerization. Ethylene (C_2H_4) is a colorless gas created in the petrochemical industry by steam cracking hydrocarbon feedstocks, such as naphtha, liquefied petroleum gas, ethane, and propane or butane, with pyrolysis furnaces. HDPE can also be created from plant-based inputs, such as sugarcane (Bouckley, 2014). Sonoco claims that its PlantPlastic resin has the same properties as petroleum-derived HDPE (Leif, 2014).

HDPE Recycling

HDPE can be recycled and used in a variety of applications. Recycled HDPE is derived from pre-consumer industrial scrap, known as post-industrial resin (PIR), and post-consumer resin (PCR), which includes packaging and other HDPE products collected primarily from residences and commercial buildings. The largest end market for rHDPE around the world is for plastic pipes, such as those used for construction in China (Anonymous, 2014d). In the United States, the primary market for natural (i.e., uncolored) HDPE PRC is in non-food applications, such as bottles for laundry detergent, motor oil, and household cleaners. For colored HDPE produced from PCR, the main markets are for pipes, plastic lumber (e.g., decking and railroad ties), and bottles (ACC and APR, 2014).

Americans generated 250.9 million tons of municipal solid waste (MSW) in 2012, of which 12.7 percent was plastics (31.75 million tons). The U.S. EPA estimates that 34.5 percent of the MSW generated was recovered for recycling and composting. Only 8.8 percent of the plastic waste was recovered; the remaining 29 million tons of plastic waste were discarded in landfills and in smaller portions along roads, beaches, and in waterways (U.S. EPA, 2014). In Europe, the recovery rate of plastics for recycling was 26 percent in 2012 (PlasticsEurope, 2015). The United States has among the highest per capita consumption of plastics at more than 240 pounds per person per year, compared to China's consumption at less than 100 pounds (Andre, Chan, & Greenberg, 2014).

Containers and packaging comprised the largest portion of U.S. MSW by weight (30 percent). Plastic packaging represented 5.5 percent of the total weight of MSW generated and was the largest portion of containers and packaging discarded (see Figure 3). For at least the last five years, recovery rates of plastic packaging have hovered around 13 percent (see Figure 4) (U.S. EPA, 2014).

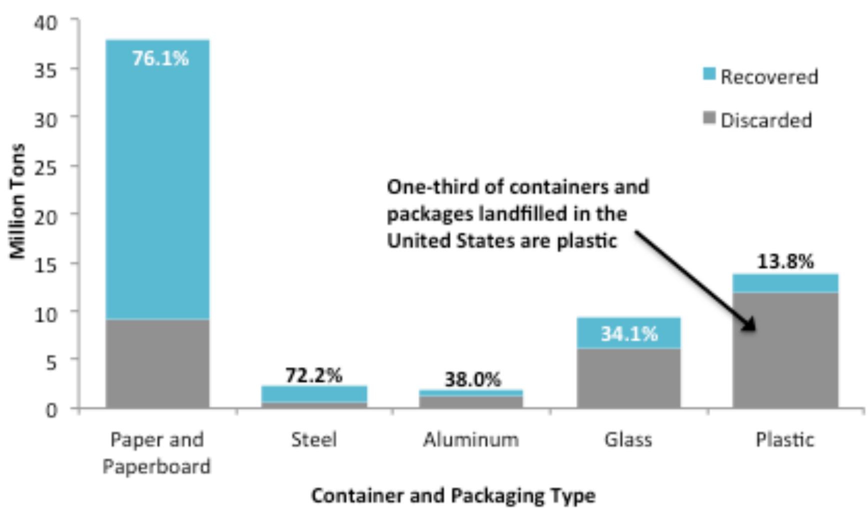

Figure 3. U.S. Generation and Recovery of Selected Containers and Packaging Materials, 2012

Notes: Recovered materials are reported purchases of post-consumer recovered material plus net exports (if any) of the material; preconsumer scrap is not counted towards the recovery estimates. Within plastic containers and packaging, rates of recovered PET (24.2%) and HDPE (16.0%) are higher than LDPE/LLDPE (11.5%), PP (2.1%), and PS (3.8%).

Source: U.S. EPA (2014)

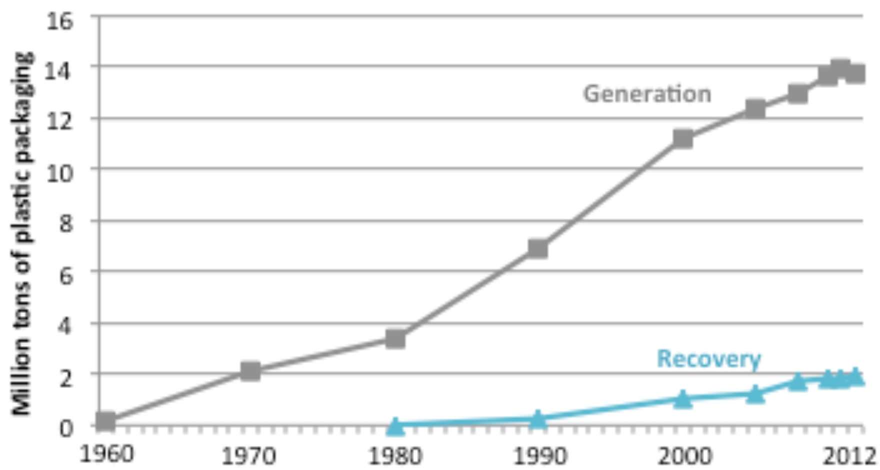

Figure 4. U.S. Generation and Recovery of Plastic Containers and Packaging, 1960-2012

Source: U.S. EPA (2014)

8.8 million tons of HDPE were sold in the United States in 2012, out of 19.3 million tons of PE sales (ACC, 2014). The U.S. EPA estimated that 5.5 million tons of post-consumer HDPE waste were generated in 2012. Only 10.3 percent (0.57 million tons) of HDPE waste generated was recovered, which included recovery of 16 percent of HDPE packaging (U.S. EPA, 2014). The estimate for overall recovery is not known as the EPA figure does not include post-industrial resin (PIR), plastic waste from industrial facilities, or other plastic recovered from commercial operations, such as plastic crates (ISRI, 2015).

The most valuable component of the HDPE waste stream, natural HDPE bottles, was recovered at a slightly higher rate of 28.2 percent (see Figure 5). According to the *2013 United States National Post-Consumer Plastics Bottle Recycling Report,* 31.6 percent of all HDPE bottle waste (both natural and colored) generated was recovered in 2012, which equates to 0.51 million tons, up from 0.49 million tons in 2010 (ACC and APR, 2014).

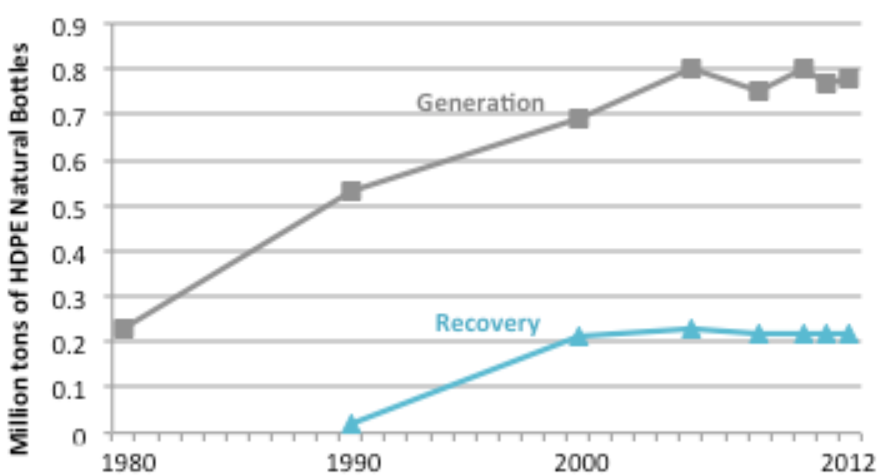

Figure 5. U.S. Generation and Recovery of Natural HDPE Bottles, 1980-2012

Source: U.S. EPA (2014)

The value of the material thrown into landfills each year is significant. As You Sow's shareholder advocacy program estimated the value of just wasted HDPE packaging in the United States to be $2.85B in 2010 (MacKerron, 2012).

There is a wide range of definitions for recycling. The largest collector and sorter of recyclable material in the United States, Waste Management, Inc., states that "recycling involves the separation of reusable materials from the waste stream for processing and resale or other disposition" (Waste Management, 2014). The EU's Waste Framework Directive 2008/98/EC (under Article 3(17) defines recycling as "any recovery operation by which waste materials are reprocessed into products, materials or substances whether for the original or other purposes. It includes the reprocessing of organic material but does not include energy recovery and the reprocessing into materials that are to be used as fuels or for backfilling operations" (EU Directorate-General for the Environment, 2012). The U.S. EPA uses a similar definition to the EU's, also excluding use of material to produce energy or serve as a fuel substitute, that it adopted from the National Recycling Coalition: "the series of activities by which materials that are no longer useful to the generator are collected, sorted, processed, and converted into raw materials and used in the production of new products" (Pillsbury, 1997). This report uses the U.S. EPA definition for recycling.

Circular Economy Concepts

Recycling is one approach to generate circular systems. A circular, or closed loop, system is defined as "a conceptualization of a sustainable approach to managing the entire life-cycle of a consumer product, whereby all material not safely consumed in the use of the product is designed to be a value input into the same or other processes" (WEF, 2014). The circular economy and cradle-to-cradle concepts offer more specific visions.

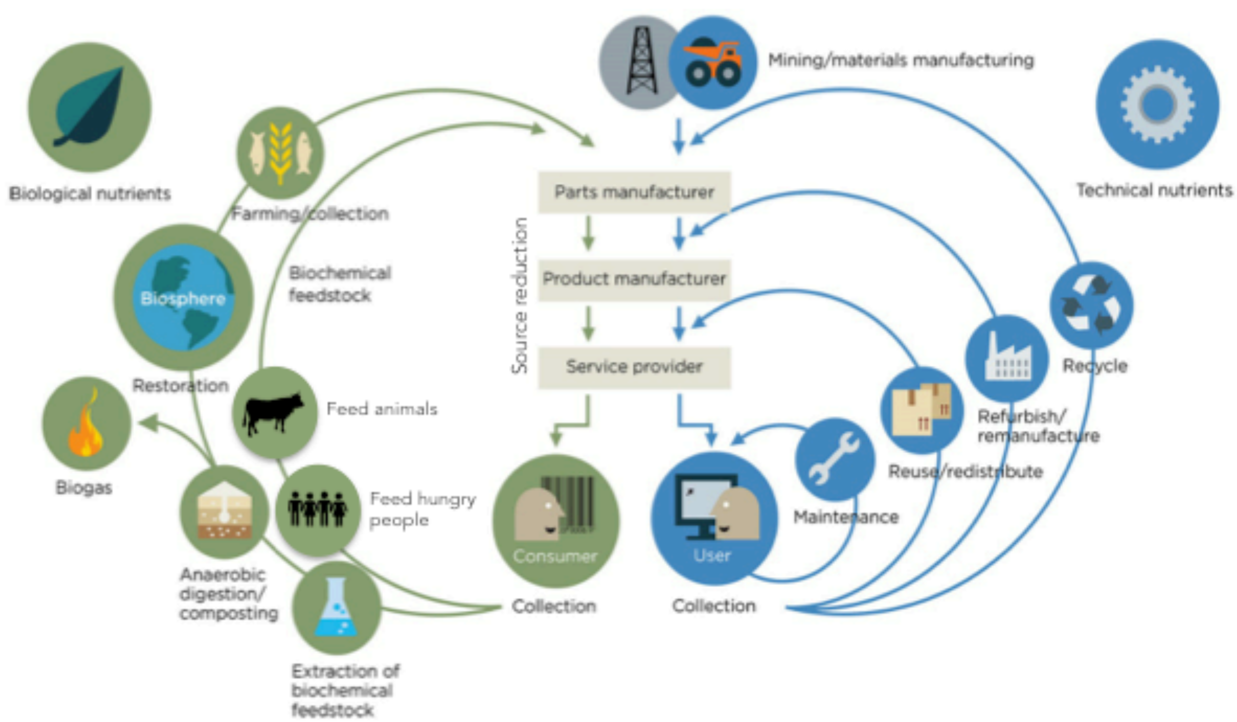

Figure 6. Conceptualization of closed loop systems

Source: Ellen MacArthur Foundation drawing from Braungart & McDonough; adapted to include feeding animals and hungry people from U.S. EPA Food Recovery Hierarchy.

Circular economy is "a generic term for an economy that is regenerative by design. Materials flows are of two types, biological materials, designed to reenter the biosphere, and technical materials, designed to circulate with minimal loss of quality, in turn entraining the shift towards an economy ultimately powered by renewable energy" (WEF, 2014). (See Figure 6.) According to the 2014 *Towards the Circular Economy* report, there are four components of a circular economy: (1) product design, (2) new business models, (3) global reverse networks, an (4) system changes that enable circularity (WEF, 2014). The concept does not specially assign ownership of material to producers, as is done with extended producer responsibility (EPR) laws. Two main aims of a circular economy are reliability in supply and price stability (Black, 2014). The concept is greatly influenced by several other models: regenerative design, performance economy, the cradle-to-cradle framework and certification process, industrial ecology, biomimicry, and the Blue Economy movement (Ellen MacArthur Foundation, 2013).

Examples of Circular Systems

Several business models around the world create and enable circular production systems:

- Materials marketplaces:
  - Austin Materials Marketplace
  - Reuse Opportunity Collaboratory (ROC) Detroit
  - RecycleMatch in Houston, TX
  - Hebei By-Product Synergy Project in China
- Closed loop production through in-store drop off programs:
  - HP's inkjet recycling
  - Nike's "Nike Grind" products
  - Patagonia's "Common Threads" product take-back initiative
  - Interface Inc.'s conversion of used carpet into new carpet tiles
- Open loop recycling of PCR into new products:
  - Unifi Inc.'s PET recycling into Repreve fibers
  - Preserve's GIMME 5 program to process #5 PCR into household products

Cradle-to-cradle (C2C) describes a framework that designs for abundance. Within this framework products are designed for continuous recovery and reutilization in a way that imitates "nature's highly effective cradle-to-cradle system of nutrient flow and metabolism, in which the very concept of waste does not exist" (McDonough & Braungart, 2002). The final materials of Cradle to Cradle Certified™ products are assessed on five quality categories: "material health, material reutilization, renewable energy and carbon management, water stewardship, and social fairness" (Cradle to Cradle Products Innovation Institute, 2014). Within the reutilization category, recyclability is favored over use of recycled content (i.e., provided twice the weighting in scoring) to optimize formulations for safety and to avoid encouraging use of recycled content with unsafe additives (Fendley, 2014). Plastics additives could include trace toxins such as phalates, chlorinated pigments, and brominated flame retardants that are persistent, bioaccumulative, and biomagnify up the food chain. Additives in HDPE tend to be fairly benign, such as stabilizers (e.g., antioxidants and UV stabilizers) (Fendley, 2014).

HDPE is a key candidate for circular systems because it starts as a non-toxic material and can be remelted after use.
However, the addition of plasticizers and other additives degrades material quality when heated for recycling (Fendley, 2014). In addition, HDPE degrades over time from sunlight, heat, and severe cold. Current collection streams do not separate chemically optimized material from the rest, so lower quality HDPE scrap reduces the quality of entire batches of recycled resins and requires the addition of more stabilizers to maintain material performance. An optimized circular system would prevent or overcome the degradation of HDPE and other plastics through each stage of reclaimation and reprocessing. A cradle-to-cradle system would take that a step farther and ensure safety of the material to humans and the environment through each use (Fendley, 2014).

Key Findings

Overview of U.S. rHDPE Value Chain

The U.S. recycling market, including the value chain for recycling rigid HDPE bottles and containers, is incredibly complex. Overall, it is an additive industry because it starts with waste materials that undergo a series of processes to become secondary raw material inputs for a variety of other industries (Kaplinsky & Morris, 2014). In the value chain for rHDPE, actors include generators of scrap (or waste) plastics, collectors, sorters (or material recovers), reclaimers (or reprocessors or secondary materials producers), converters, product manufacturers, distributors, and retailers (see Figure 7).

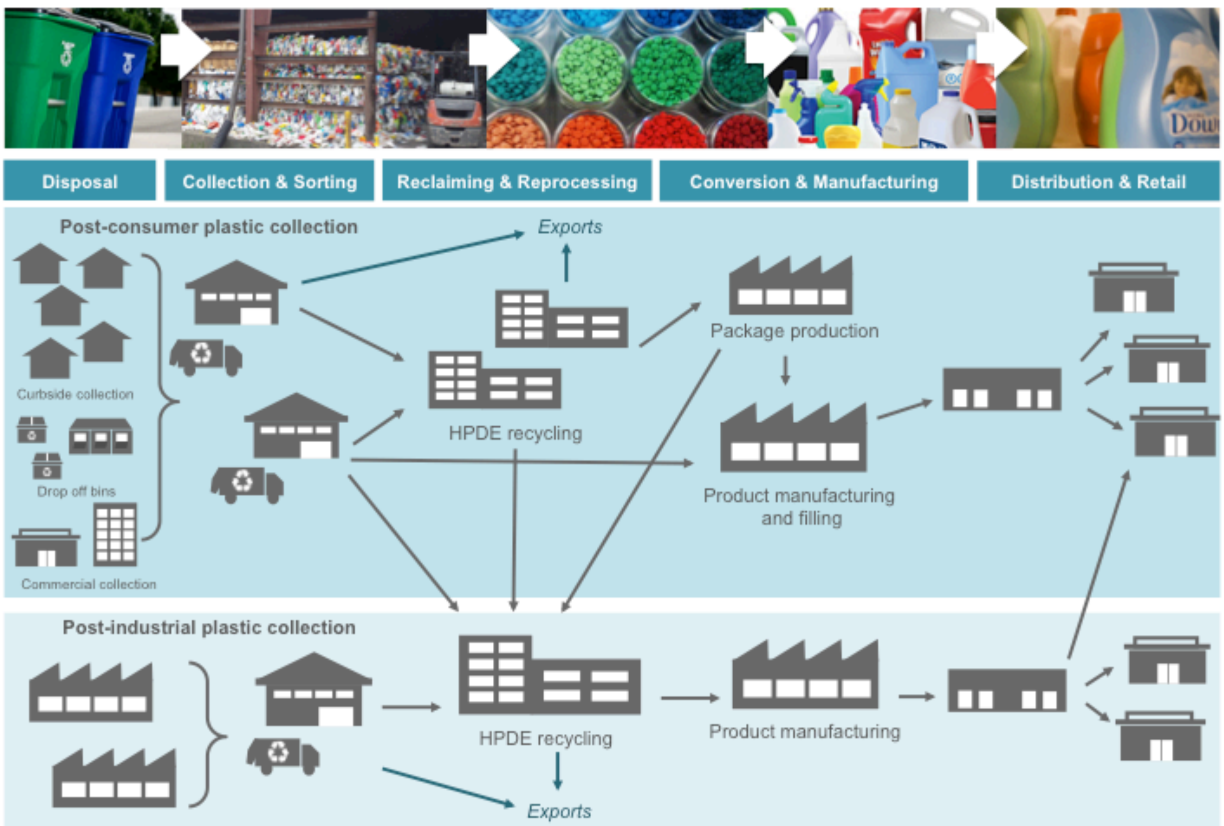

Figure 7. Flow of material in the rHDPE supply chain in the United States

Note: Global trade occurs at each segment in the chain after sorting, primarily the sorting and secondary material production segments.

Source: Kara Jones, informed by research and discussions with plastics recycling experts in 2014.

Waste HDPE is generated all over the country, collected locally, and predominantly processed into new resin in two plastics recycling clusters: in California and the U.S. Southeast. These clusters were formed by reclaimers co-locating with manufacturing customers and ports for export markets. Materials are collected, sorted, and baled at municipal or privately owned material recovery facilities (MRFs). HDPE bales are then transported via rail or truck to reclaimers, who process it into pellets, flake, or other forms for further conversion. Converters melt the recycled resins and use it to produce new packaging (e.g., blow molded bottles) and products (e.g., plastic decking). Through intermediate steps, rHDPE is also blended with virgin resin, colorants, or additives (known as compounding) to achieve desired properties before being converted. Finally, plastic packages are filled, and products are marketed and distributed around the country. (See Figure 8 and sections below for more detail on entities involved.)

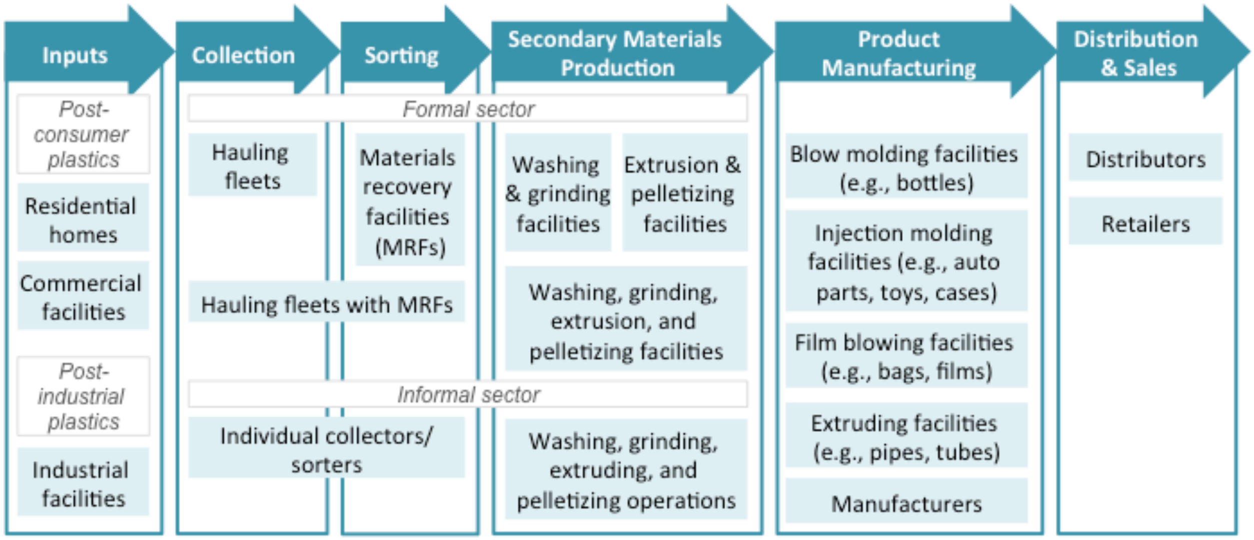

Figure 8. Value Chain for Recycled HDPE

Notes: some vertically integrated firms cross several segments of the value chain, such as secondary materials production, product manufacturing, and distribution and sales.

Sources: Kara Jones, informed by research and discussions with plastics recycling experts in 2014; Neidel and Jakobsen (2013).

The majority of the HDPE scrap processed into resin domestically is converted into new products and sold domestically. The U.S. value chain is connected to other regional chains, primarily to those in Canada and Mexico through imports of unprocessed scrap HDPE and to the Chinese market through export of HDPE material generated in the United States. Some processed HDPE flake and recycled pellets are also imported due to high demand from end use markets (Butler, 2014).

Key Market Dynamics

The U.S. recycling industry for rigid HDPE bottles and containers is marginally profitable. Despite the huge supply of material generated and wide-ranging access to collection services, HDPE is recycled at relatively low rates (ISRI, 2015). This decreases economies of scale and results in costly under-utilization of infrastructure (see Appendix 2: HDPE Bottle Recycling Facts & Figures for look at excess bottle wash capacity). In addition, value is degraded through contamination of the material stream—e.g., from inks, labels, degradable additives, and increasing levels of materials that are not easily recyclable but are baled with HDPE scrap—which reduces quality throughout the value chain.

PET and HDPE were the target of the first household plastic recycling efforts—due to sufficient supply, funding for collection programs, and availability of cost-effective technology to process them. For HDPE in particular, milk jugs made of natural, non-colored resin were highly desired. The low supply recovered is surprising given the high demand for rHDPE resin, e.g., from consumer packaged goods companies aiming to reduce input costs and overall resource use. However, the path from the supply side to the demand side is convoluted and involves thousands of entities. For post-consumer HDPE scrap, price signals from product designers back up to generators of HDPE waste do not work (Anonymous, 2014a; Moore, 2014). Collection of material is considered a public service so is funded through taxes and fees rather than through the market setting a price and paying generators for their waste.

The three biggest challenges for strengthening this value chain are: (1) competition with virgin HDPE, (2) the need for greater economies of scale, and (3) the need for improved coordination throughout the value chain.

1) Competition with virgin HDPE: The virgin HDPE industry produces higher quality material in vastly greater quantities than rHDPE resins. While prices for rHDPE resin fluctuate greatly, rHDPE tends to be priced below that of virgin. However, that relationship could reverse as billions of pounds of new ethylene capacity is being built again in the United States due to low-priced natural gas (Esposito, 2014; Mouw, 2014). While coming online later than originally planned—i.e., not until about 2018 according to Senior Vice President of Nova Chemicals' PE business Chris Bezaire—the new capacity will likely depress prices of virgin resin (Schwarze, 2014a; Sherman, 2014). Currently, prices for virgin HDPE have increased several times since 2013 due to production outages for both polyethylene and ethylene and facilities operating near capacity (Esposito, 2014). Product manufacturers are able to financially justify the use of recycled resin when it is priced below that of virgin because rHDPE offers less consistent supply and lower quality.

2) Need for greater economies of scale: To reduce the costs of recycling, supply and quality of scrap HDPE need to be increased by raising recovery rates and improving infrastructure for collection, sorting, reclamation, and sale of recycled products. For collection, there are issues with regionalization, as supply is predominantly provided by densely populated areas but processed in areas with lower costs of living (ISRI, 2015). For sorting, it is becoming much more costly to operate due to the evolution of the waste stream from high levels of paper (for which older equipment was designed to handle) to more plastics and increasing diversity of materials (Robinson, 2014). Having larger amounts of HDPE recovered for recycling would make the industry more profitable in part through dilution of the contaminants (unwanted materials). For reclaimers, there are also seasonal mismatches in that the timing of incoming supply does not always match the timing of demand. For example, there was a shortage of natural HDPE scrap in 2014 due to the "winter effect" (i.e., snow storms that reduced bottle consumption and collection) (Ettefagh, 2014c).

3) Need for improved coordination: There are disconnects throughout the value chain from lack of awareness, misperceptions, and entrenched interests that inhibit change. Improved coordination, including top down strategic direction, and scaled innovation could greatly strengthen the rHDPE value chain. (See Appendix 2 for summary of key recommendations for improving engagement.)

   Feedback loops are missing within parts of the value chain and many players are talking past one another (Butler, 2014). Some recyclers and environment groups call for consumer product manufacturers to produce simpler packaging and increase use of recycled content, which would provide great benefits to the recycling industry and result in greater volumes of higher quality recycled resins. Meanwhile, challenges faced by responsible consumer packaged goods companies (CPGs) may be given less priority—such as issues with quality of recycled content and overall costs fluctuating so that rHDPE is more expensive than virgin at times (i.e., hard to justify internally) (Anonymous, 2014f).

   Information provided by organizations throughout the value chain (e.g., collectors, MRF operators, reclaimers, packaging producers) may be incomplete or even inaccurate. There is a large gap between what can theoretically be recycled and what is actually recycled—based on the best available technologies and their availability around the country. For example, some HDPE packaging is theoretically recyclable but is too small for sorting equipment at many MRFs. Until recently, one large CPG thought that all of its packaging could be recycled; it was surprised to learn that only a couple of its products' packaging was actually making it through MRFs into bales of scrap (Black, 2014). This results in companies unintentionally placing a lot of unrecyclable materials into commerce. For generators of waste, information dispensed about recycling can be misleading or inaccurate about local recovery capabilities. For example, sorting technologies (e.g., optical scanners) are improving but are not consistently available throughout the country, so messaging from one company or municipality about a material not being recyclable may inhibit people from putting material in recycle bins in places where it is accepted.

Another significant challenge for engagement is that partners can be at odds with each other. One wants aesthetically appealing products and the other wants recyclability (Taylor, 2014). Reclaimers want clean streams but many collectors, retailers, and product manufacturers do not want container deposit laws (also known as bottle bills), which result in cleaner streams. From the perspective of a collector, the law removes the most profitable material from curbside collection streams. For CPGs and retailers, the cost of recycling and safe disposal of their products becomes their responsibility. Another example is the perception that collectors are capturing huge profit margins, making the rest of the rHDPE industry struggle to stay in business. This seems to be only partially correct. While profit margins may be higher on HDPE than other recyclables (e.g., glass), recyclers' sorting costs are increasing, which reduces funds available to invest in new technologies and expand recovery services.

System-wide opportunities for engagement: Improved understanding of the whole value chain would lead to increased coordination (Anonymous, 2014b). Therefore, a major opportunity for engagement is to develop an industry-wide strategy, informed by better data. As You Sow offers the vision that "a government agency or multilateral stakeholder group with buy-in from the business and environmental communities needs to develop a blueprint—and a credible cost estimate—for boosting U.S. recycling rates to 75 percent or beyond." (MacKerron, 2015). According to Scott Mouw, North Carolina's State Recycling Director, the industry needs to "conduct a coordinated public and comprehensive analysis of the current material supply situation and infrastructure… [and] a coordinated analysis of the U.S. material recovery system versus those in Canada and Europe focused on the objective measures of cost, tonnage results, and the effects on overall material sustainability" (Mouw, 2011).

Disposal of Recyclable Content

State and local governments are responsible for waste collection and recycling services, but many do not have the incentive to recycle. Collection of MSW and recyclables, including HDPE scrap, is considered a public service in the United States. According to Mouw, "there is an alarming amount of naivety about how the supply is generated. The supply chain is controlled by hundreds or thousands of city councils" (Mouw, 2014). The 2012 Census of Governments reported that there are 38,910 general-purpose governments in the United States, which includes counties, municipalities, and townships (Hogue, 2013). It is unclear how many of these governments have direct responsibility for solid waste management in their communities, as there were also 51,146 special-purpose governments, which can overlap geographically with general-purpose governments and provide solid waste management services. In addition, all state governments have solid waste or recycling programs with roles ranging from permitting of recycling facilities to design of recycling programs, technical assistance, grants, and laws (Mouw, 2015).

State and local governments continue to face tight budgets as the economy recovers from the recent recession. There are competing priorities for their attention and tax revenue, such as education and road maintenance versus funds to expand recycling programs. In North Carolina, the public sector paid $95 million net of revenue earned to industry to collect recyclables in FY 2012-2013 (July 1, 2012 to June 30, 2013) (Mouw, 2014). The Closed Loop Fund estimates that across the United States, municipalities paid more than $500 billion for collection of recyclables in 2013 (Closed Loop Fund, 2015; Croke, 2014).

Residents, institutions, and commercial and industrial companies cover the costs through fees and taxes, which vary widely—e.g., a high performing curbside collection program can cost about $120 per ton (Mouw, 2015). Local governments who pay private haulers for collection services may receive a rebate for revenue earned from the sale of recyclables, which is used in a variety of ways. However, a city may only get $10-$20/ton rebate for its recyclables after paying much more to collect it, which provides little financial incentive to expand recycling efforts (Mouw, 2014). In addition, for some local governments the revenue that returns from haulers for recyclables is uncategorized, which means that it may not be attributed to recycling efforts (Ettefagh, 2014b).

Some industry experts believe that the most impactful changes in recycling rates will only come with substantive public policy initiatives. According to plastics recycling expert Patty Moore, "recycling is a national priority in every part of the world that has high recycling rates. As a start, recycling should be mandatory and harmonized across jurisdictions" (ISRI, 2015). State governments currently set policies to drive recycling and provide recycling assistance to local governments. However, there is fragmentation of policies because measures are not implemented widely or uniformly. In the United States, four states have enacted bans on landfill disposal of consumer packaging; five states have policies mandating or encouraging pay-as-you-throw (PAYT) programs; 13 states have recycling service provisions; 13 states have performance targets for waste generation, waste prevention, or recovery; and 10 states have bottle bills (Carton Council, 2014).

The CA Rigid Plastic Packaging Container (RPPC) Law, while covering a single state, has had a noticeable influence on the HDPE value chain and may be responsible for keeping HDPE reclaimers in business (Butler, 2014; Mouw, 2014). The law, initially implemented in 1995 and administered by CalRecycle, aims to "reduce the amount of plastic waste disposed in California landfills and to increase the use of recycled postconsumer plastic" (CalRecycle, 2013a). Compliance options for product manufacturers include using a minimum 25 percent post-consumer resin in containers or 10 percent source reduction (CalRecycle, 2013b).[7] The impact of this law suggests that policies are most effective if they are able to adapt, harness the power of markets, and move towards circular systems (Shireman, 2014).

Types of Policy Mechanisms to Spur Recycling

- Recycling service provisions: requirement that a municipality provide services to a population above a certain size or to a specific type of generator (e.g., commercial properties)
- Recycling participation: requirement to participate in programs (e.g., source separation)
- Recycling target: local or state-level performance goals for waste reduction and collection for recycling
- Disposal bans: prohibits disposal of consumer packaging in landfills
- Pay-as-You-Throw programs: assigns fees for waste disposal based on volume or weight
- EPR laws: requires product manufacturers to finance the recycling or safe disposal of their products after use; some argue for EPR laws for hard to recycle items (e.g., mattresses)

Sources: Carton Council (2014); Nash and Bosso (2013)

Consumers' confusion and apathy about recycling has led to low participation rates in recycling programs. While three-quarters of adults report that they recycle household items everyday, about 60 percent of respondents to at 2014 poll said that they do not understand what types of plastics can be recycled

[7] According to 14CCR Section 17945.3, source reduction can be achieved through reduced container weight, product concentration, a combination of reduced container weight and product concentration, or comparison to similar products' containers (CalRecycle, 2013b).

(Ipsos Marketing and Call2Recycle, 2012; ISRI, 2014). Regional differences in policies and infrastructure and inconsistent terminology used by recycling programs have resulted in confusion or, at worst, apathy as consumers have tried to recycle but learned that a material is not collected in their area and given up. The result of the confusion is shown through the fact that an estimated 94 percent of Americans have access to recycling for HDPE bottles, jugs, and jars with caps (and 65 percent have access for HDPE rigid cups, tubs, and containers), while only 10.3 percent of post-consumer HPDE material is collected (Moore Recycling Associates Inc., 2013; U.S. EPA, 2014).

Since about two to three percent of landfilled waste is HDPE (approximately 85 pounds of HDPE per household per year), to meaningfully increase supply, the value chain would need to encourage millions more to participate in recycling (Mouw, 2014; U.S. Census Bureau, 2015; U.S. EPA, 2014). In the current situation, it could be detrimental for CPGs to promote recycling to consumers who do not have access to collection or drop-off services.

Opportunities for engagement: Local and state governments can work with industry to agree on sets of materials that can be collected throughout a region (ISRI, 2015). Additionally, local governments can reduce consumers' confusion by adopting for recycling programs the common terminology offered by the RecycleYourPlastics.org Terms and Tools app (provided by the Plastics Division of the American Chemistry Council (ACC)) (Ettefagh, 2014b). Finally, there is continued opportunity and need for consumer education offered by actors throughout the value chain to inform consumers and encourage recycling. For example, it appears to be unknown to consumers that residue in HDPE bottles that contained cleaning products, such as shampoo and detergent, is beneficial for reclaimers as it reduces the need for soaps in washing scrap. Because many consumers believe that all packaging needs to be fully rinsed to recycle, bottles end up in the trash.

Hauling and Materials Recovery

Material recovery facility (MRF) operators aggregate materials collected from a wide variety of locations and broker sales of various types of plastics, such as HDPE, as bales. Some local governments own and operate fleets of collection trucks and recovery facilities for sorting recyclable materials, which include paper, metals, plastics, and glass. However, the majority of sorting services has been privatized. It is estimated that there are 596 multi-material MRFs operating in the United States (2014), of which for-profit companies own 70 percent (Berenyi, 2014). Mechanization of MRFs is also growing; 280 of the MRFs serve single stream recycling, which requires more advanced sorting technologies than for pre-sorted streams. 150 MRFs have optical sorting systems or plans to install them (Berenyi, 2014).

The largest for-profit companies that provide collection and material recovery services are WM Recycle America, Republic Services, and Waste Connections, which all own landfills and haul solid waste in addition to collecting and sorting recyclables (see Table 1). In addition, ReCommunity claims to be the largest "pure-play" recycling and recovery company (ReCommunity, 2015).

Table 1. Largest U.S. MRF Operators

Organization Name	Description	Influence on the Value Chain
WM Recycle America LLC Houston, TX	Operating subsidiary of the publicly owned solid waste services and material recovery company Waste Management, Inc., which reported $1.37B in revenues from recycling (of WM's $13.99B revenues, 2014); operates 120 MRFs	Largest recover of recyclable material in the United States; Influences collection prices industry-wide; processes 711M lbs of plastics per year; joined CVP's Recycling Partnership in 2015

Republic Services, Inc. Phoenix, AZ	Publicly owned solid waste management company with $352M in revenues from recycling services (4% of total revenues of $8.79B, 2014); owns and operates 60 MRFs	Operates through 332 collection companies in 38 states in the United States and Puerto Rico; most recyclable materials are collected from residential customers
Waste Connections, Inc. The Woodlands, TX	Publicly owned, integrated MSW services company that reported $58.2M in revenues for recycling (of $2.3B total, 2014); owns or operates 36 recycling facilities	Targets secondary and rural markets, avoiding competitive, large urban markets
ReCommunity Recycling LLC Charlotte, NC	Privately-held materials recovery services company; operates 32 recycling facilities	

Note: recycling revenues may not be comparable; some include collection revenues while others only sales of recycling commodities.

Source: Plastics News (2014), company financial reports and press releases.

Due to the additive nature of the industry, material must be transported between each segment in the chain. Because plastic scrap and PCR pellets are traded as commodities, as with virgin HDPE resin, they command relatively low prices per pound. In addition, processing costs and transportation can be quite high. These factors limit the distance from which material can cost-effectively be collected and transported. Recycling rates tend to be positively correlated with tipping fees, or the cost of disposing (tipping a truck) of a ton of solid waste in a landfill, as it becomes economically more attractive as the cost of disposal rises. For recyclable materials, the true cost could be considered as the total miles minus the cost that would have otherwise been incurred to take the material to the landfill (Ettefagh, 2014b).

MRF operators may currently be using profitable scrap streams, like HDPE, to subsidize less profitable ones, like glass. Recyclables could cost around $0.06 per pound to collect (based on collection fee of $120/ton), while bales of HDPE scrap could sell for $0.30 (for mixed color) to $0.40 (for natural, uncolored) per pound (Ettefagh, 2014a). The disparity is related to the wide range in profitability of the all materials collected. Processing glass can result in a net cost for MRF operators, so some communities have considered ceasing glass collection or have already done so. Recently, MRFs have been struggling to be profitable due to volatile commodity prices and increasing levels of "contamination" (i.e., unwanted materials) in incoming streams. The nation's largest waste hauler and MRF operator, WM Recycle America, is taking an aggressive stance on changing customer contracts (e.g., with municipalities) to cover all processing costs (Steiner, 2015). Future contracts will stipulate fees for contamination levels above 10 percent on incoming loads, include clauses to cover loss of revenue from slowdowns of exports at ports, and tie customer rebates (i.e., proceeds from recyclables sold) to actual revenues earned versus an indexed price (Trevathan, 2015). Such specifications may be new for haulers but are practiced in the next step of the value chain. For example, KW's purchasing specification sheet for HDPE scrap indicates that loads with high levels of contamination can be rejected with the return costs incurred by the material supplier (KW Plastics Recycling Division, 2012).

The costs of sorting plastics into high-quality bales (i.e., bales with a high proportion of the desired plastic) have been on the rise. Material streams are getting more complex due to demand and recycling programs' acceptance of more mixed rigid plastics, such as plastic tubs and lids. This requires more MRF processing of many different types of plastics, which increases the need for innovation and new technologies as much sorting equipment was designed to handle plastic bottles and not other shapes

(Green Spectrum Consulting, 2015; ISRI, 2015). The business case is growing for establishment of plastics recovery facilities (PRFs) to conduct secondary sorts for bales of mixed plastics that garner lower selling prices (Ettefagh, 2014c).

Lower value materials, such as flexible packaging, are also increasingly entering the recyclables collection stream due to changing customer preferences (Bedarf, 2014; MarketLine, 2014). Flexible packaging includes pouches that are multilayer, multi-material (resins and aluminum), with barrier layers for protection and tie layers to chemically bond materials. The flexible packaging market is growing—due to its lighter weight (compared to metal and even rigid plastics) and strength (resulting in reduced breakages)—but there are no domestic recycling options for the material yet. In Europe, only InterGroup International accepts flexible film packaging, and it only extracts the aluminum and heat by incinerating the other layers (Roth, 2014).

The rHDPE industry competes with conversion technologies, such as waste-to-energy (WTE), in locations where recycling costs are high. Thermal waste conversion results in energy (e.g., heat), fuel (e.g., methane), or chemical products (e.g., ammonia). According to the U.S. EPA's non-hazardous waste management hierarchy, energy recovery is an environmentally sound option for material that is not cost-effective to recycle or compost (U.S. EPA, 2013). However, WTE and refused derived fuels (RDF) plants are costly to build and require high volumes of input materials to be profitable. Co-locating a conversion facility with a MRF requires having enough volumes for both.

Dow is working on a plastics-to-fuel project with the Flexible Packaging Association, Republic Services, Agilyx, Reynolds Consumer Products, and the city of Citrus Heights, California, to divert from landfill items undesirable to recyclers, such as flexible packaging and plastic utensils (Recycling Today, 2015). In the project's pilot, the city distributed purple "energy bags" to participating residents for items to be converted to synthetic crude oil using Agilyx's patented pyrolysis technology (The Dow Chemical Company, 2015). Through the pilot, approximately three tons of material were converted into 512 gallons of synthetic fuel oil (The Dow Chemical Company & Flexible Packaging Association, 2015).

Mixed waste facilities and so-called "dirty MRFs" are also trying to solve the "first mile problem" of how to get more assets out of the trash can and into processing facilities (Biddle, 2014). At such facilities, all waste is sorted into recyclables, compostables, and materials that can be used to generate energy with very little material remaining to be landfilled. Mixed waste facilities can result in much higher recovery rates but, depending on the type of facility, can also increase contamination in bales and result in greater amounts of recyclable materials incinerated to justify costly technology investments.

Opportunities for engagement: To incentivize participation in recycling programs (e.g., curbside collection), collectors can experiment with market-based mechanisms to assign a value to desired materials. On the sell side, MRF operators can work with secondary sorters to create new types of bales for re-sort at PRFs or for alternative disposal, such as WTE (Lindberg, 2014). MRF operators and the packaging industry can work together to improve product design for recyclability. The entire value chain can increase its understanding of capture rates of HDPE at MRFs around the country. Finally, industry associations and MRF operators can work with local governments to encourage recycling of high-value materials like HDPE and conversion of lower value materials.

Reclaiming and Reprocessing

Reclaimers purchase scrap and process it into secondary material inputs, such as plastic pellets, for product and packaging manufacturers. There are 26 reclaimers that process HDPE in the United States. The eight largest bottle reclaimers produced more than 80 percent of the rHDPE in the United States in 2013. Among the largest HDPE reclaimers are KW Plastics, Envision Plastics, B&B Plastics, Custom Polymers, and Clean Tech (see

Table 2). Reclaimers have a wide variety of customers, including export traders, packaging producers, product manufacturers, and even internal operations for vertically integrated companies.

Processes at reclaiming facilities can include additional sorting, such as hand-sorting and float-testing[8] to ensure that only HDPE plastics ever reach the later production stages, grinding into smaller pieces, washing and label removal, melting, extruding, and pelletizing.

rHDPE pellets produced by Envision Plastics, October 2014.

Table 2. Largest U.S. Reclaimers

Company	Description	Plastics reprocessed	Influence on Value Chain
KW Plastics Recycling Troy, AL	Privately owned company with revenues of $2.9B; washes and reprocesses HDPE (rigid) and PP (rigid and flexible) scrap; world's largest plastics recycler	570M lbs	Serves the blow-molding, automotive, agricultural, and pipe industries; KW Container produces 100% recycled plastic containers for the paint and coatings industry
Envision Plastics Industries LLC Reidsville, NC	Operating subsidiary of Consolidated Container with sales of $110M (2011); processes post-consumer HDPE scrap	144M lbs (all HDPE)	Provides rHDPE resins for food and beverage, personal care, healthcare, and other industries including EcoPrime™, the first FDA-approved HDPE resin, and PRISMA™ color-sorted resins
B&B Plastics Inc. Rialto, CA	Privately-owned company; processes post-industrial plastics	421M lbs	Provides recycling services (grinding, shredding, pelletizing, baling, bagging, and metal separating) for plastic manufacturers
Custom Polymers Inc. Charlotte, NC	Privately-owned company with revenues of $40.5M (2011); processes post-industrial and post-consumer plastics	239M lbs	Provides grinding, washing, pelletizing, compounding, densifying, metal separation, sorting, repackaging, and distribution services in the United States and abroad

[8] Using a sink/float tank, PE and PP, which are less dense than water, can be separated from PET and PVC, which sink (Holmes, 2013).

Clean Tech Incorporated Dundee, MI	Wholly-owned subsidiary of Plastipak Holdings, Inc.; processes post-consumer PET and HDPE bottles	Wash capacity of 200M lbs (2011)	Receives bales from 350 recycling centers; provides material directly to its affiliate Plastipak Packaging Inc. and others

Source: Plastics News (2014); revenue data provided by PrivCo and online company sources.

Prices for HDPE scrap are influenced by reclaimers' buying power, prices for virgin HDPE, traders of scrap for export to China, and the general economy. Prices are set through the buy/sell transactions between traders (e.g., MRF operators) and reclaimers, which results in disjointed information flow to parties external to the transactions (Mouw, 2014; Taylor, 2014).[9] The price of HDPE scrap is often lower than primary plastic resins but at times criss-cross, with HDPE scrap being higher than virgin inputs. Reclaimers face customers that expect recycled resins to offer "significant, unrealistic cost savings," which can leave reclaimers with relatively small margins (ISRI, 2015). According to one company, a reclaimer is lucky to make $0.03 per pound for its rHDPE pellets.

During 2014, virgin HDPE resin sold in the range of $0.70 per pound (for HDPE frac melt dairy pellets) while natural HDPE scrap sold in the range of $0.40 per pound (Resource Recycling, 2015a). The delta in price between natural and colored HDPE scrap tends to be around 20 percent (Ettefagh, 2014c). Recycled plastics are unique in that prices do not directly follow those for virgin resin but are strongly influenced by them (as seen in Figure 9 where prices for crude oil serve as a reference for trends in virgin HDPE prices). After reaching record highs in 2014 (at $0.47 per pound for natural scrap in May), HDPE scrap prices have weakened in 2015 and were around $0.25 per pound for natural scrap in February (Resource Recycling, 2015a).

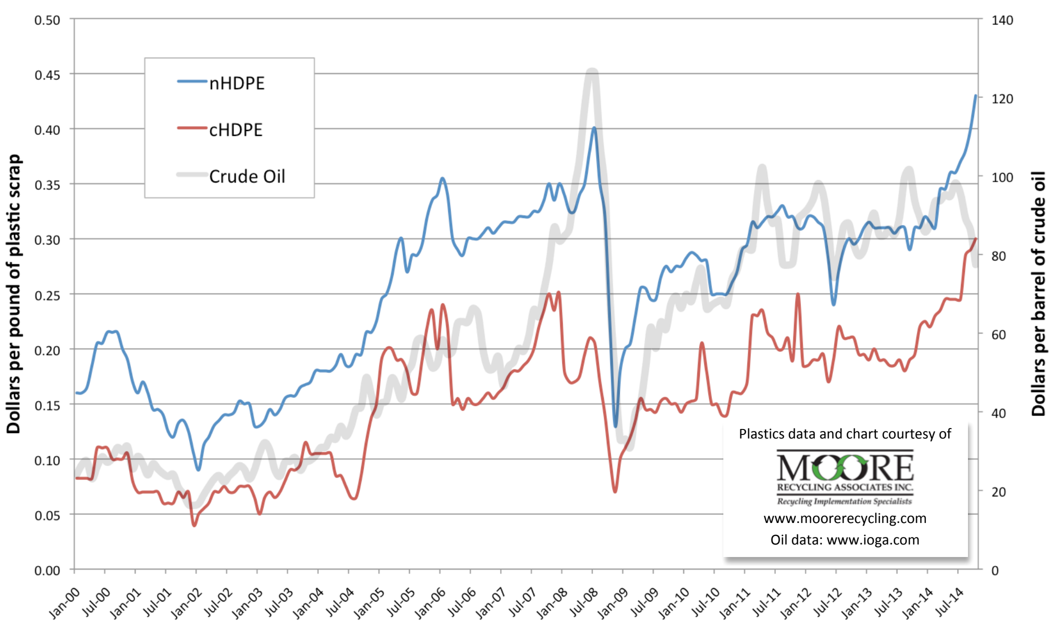

Figure 9. U.S. Prices for Natural HDPE (nHDPE) and Colored HDPE (cHDPE) Scrap, 2000-2014

Source: Moore Recycling Associates (2014).

[9] Some pricing data can be found on RecyclingMarkets.net, which offers commodity pricing data for recovered materials (Anonymous, 2014c).

Prices are not consistent across the United States; prices for scrap exports from the West and East coasts vary based on supply. In addition, the rHDPE industry has faced severe price volatility for several years. Price fluctuations for HDPE scrap impact profit margins, which combined with contamination or other cost increases, can impact reclaimers' ability to invest in the future. Reclaimers may face more difficulty in a couple of years when several ethylene crackers that are being built start production.

There is a trend of vertical integration within reclaimers (Anonymous, 2014c). For example, several packaging companies have acquired reclaimers, signaling to the market a commitment to recycled inputs (Mouw, 2014). Sonoco Recycling, subsidiary of Sonoco Packaging, acquired a large MRF from American Recycling of South Carolina in 2011 bringing Sonoco Recycling's total to five MRFs. In mid-2014, Consolidated Container Company, which is owned by private equity firm Bain Capital, acquired Envision Plastics, the second largest producer of rHDPE resins in the United States (Business Wire, 2014; Ettefagh, 2014c). Other product manufacturers using rHDPE have chosen vertically integrated structures to reduce the number of entities capturing margins. For example, Trex, a manufacturer of wood-alternative decking and rail, is vertically integrated, from bale to end product (Butler, 2014).

Snapshot: Envision Plastics

Envision Plastics is a privately held company that formed in 2001. The company owns and operates two rHDPE production facilities—in Reidsville, NC and Chino, CA—with a total capacity of 144 million pounds of resin per year (Verespej, 2011). Envision produces recycled resins in flake and pellet form, as natural and color-sorted, and as premium food-grade or utility grade.

Envision Plastics NC facility, October 2014.

The cost of transporting resin from Envision's plants to molders is extremely high. The trucking industry is operating almost at capacity, and there are very few new players (or even new drivers) entering the industry. With 30,000 driver vacancies (predicted to go as high as 200,000 in the next decade due to an aging driver base) across the country, transportation is becoming a major bottleneck for all industries including Envision and its supply chain (Rott, 2014).

On the downstream side, Envision sells its completed products to packaging molders, who create custom packaging sold to consumer product manufacturers. For example, Envision's rHDPE resins are used in many commonly known household goods such as Downy and Tide detergent bottles (P&G), Aveda hair product bottles and Clinique containers (Estee Lauder), and Biolage shampoo bottles (L'Oreal) (Ettefagh, 2014a). In addition to P&G, Estee Lauder, and L'Oreal, Envision also works with consumer product companies such as Method, Seventh Generation, Kellogg's, Dannon, Kashi, and Unilever, who then fill the packages with their product (Envision Plastics, 2014b).

Envision provides two unique value adds in transforming bales of plastic received into high-quality, rHDPE pellets. First, the company developed a proprietary technology and became the first in the world to produce food-grade PCR HDPE resins. The U.S. Food and Drug Administration approved (via a letter of non-objection) Envision's production process and quality testing of its food-grade EcoPrime™ recycled resins. The additional processing removes impurities, such as volatile organic compounds (VOCs) that cause the plastic to smell, which results in higher quality EcoPrime™ resins that sell for a higher price. Second, Envision has patented its PRISMA™ color sorting process, which can identify and sort 40 million different shades (Envision Plastics, 2014a). Color sorting results in significant cost savings for its customers by reducing the amount of pigment needed in molders' processes to reach final color specifications, such as the Tide red, Gain green, and Downy blue for P&G bottles.

Envision achieves production of high quality resin through several steps. First, it sorts scrap HDPE via hand to: (1) remove any non-HDPE pieces (e.g., aluminum cans, easily identifiable PET containers, etc.) and (2) remove colored bottles from natural (non-colored) bottles, which command premium prices. The remaining streams—colored versus natural—are then chopped into 1 cm by 1 cm flakes, washed with detergent water, and sent through a sink/float tank. Bottle labels, which are not HDPE and therefore contaminants, are removed through aspiration.[10]

The cleaned HDPE flakes are sorted by color using the proprietary, high-speed, PRISMA™ system that sorts at a rate of more than 1 million flakes per minute (Verespej, 2011). The color-sorted flakes can then be blended to produce rHDPE pellets of desired final colors, and/or Envision can add colorants to meet customer specifications. The resulting colored pellets are sold under the PRISMA™ product line. Natural rHDPE pellets—washed as flake and extruded on a separate line—may either be sold or processed further into EcoPrime™ resin. Depending on the specifications of its customers and the quality of the scrap inputs, Envision may add oxidizers to its products to extend the life of the rHDPE.

One of the company's most critical issues is material procurement. Envision procures bales of HDPE bottles from all over the United States and Canada, which provides it a wider reach than regional processors. To mitigate seasonality in supply (i.e., minimize the risk of especially bad weather in a particular region), Envision engages in a sort of risk pooling by sourcing from a variety of geographies. Envision also provides bale specifications for suppliers on its website and works with several of the largest material recovery companies. It has long-term supplier contracts in place, which helps mitigate material procurement fluctuations and provides a stable financing environment over time. Due to high demand for its product, the Envision facility in North Carolina works at full capacity—24 hours a day, 7 days a week.

Finally, Envision works directly with downstream CPGs, before shipping its resin to packaging molders. For example, Envision worked with Method Products to develop a recycling process for ocean plastics (plastics washed up onto Hawaiian shorelines) for use in Method soap bottles (Method Products, 2014).

Source: Method Products (2014).

Opportunity for engagement: Reclaimers and MRF operators can work with converters and product manufacturers to develop an accurate price index to enable more widespread long-term agreements; this may stimulate investments in infrastructure to improve product quality (ISRI, 2015). It may also be

[10] Process specific details not specifically cited come from a plant tour (Reidsville, NC facility) on 3 October 2014.

beneficial to connect more segments of rHDPE and virgin HDPE value chains. Product manufacturers work with both virgin and PCR providers, and collectors and MRF operators work with reclaimers, but there are weak links between virgin HDPE producers and others in the rHDPE value chain.

Trade of HDPE Scrap

15.6 percent of HDPE bottle scrap (163 million pounds) was exported in 2013, predominantly to reclaimers in China (ACC and APR, 2014). (See Figure 10.) Waste PE can take several forms for export: baled bottles, baled mixed plastics (e.g., tubs and lids), ground flake, and films and bags. In 2012, total world exports of waste PE were valued at $2.05 billion (UN Comtrade Database, 2014).[11] These exports include preconsumer industrial and post-consumer HDPE, LDPE, and LLDPE scrap collected for recycling (MacBride, 2012). Most of the waste HDPE imported to China is non-bottle rigid scrap (Moore, 2014). Waste PE exports represented just three percent of total world exports of PE, which were $67.5 billion in 2012 (UN Comtrade Database, 2014).[12] The top five largest exporters of waste PE were Germany, the United States, Japan, the United Kingdom, and Hong Kong, with the majority of shipments going to China (UN Comtrade Database, 2014) (see Appendix 3: Global Trade of Waste PE).

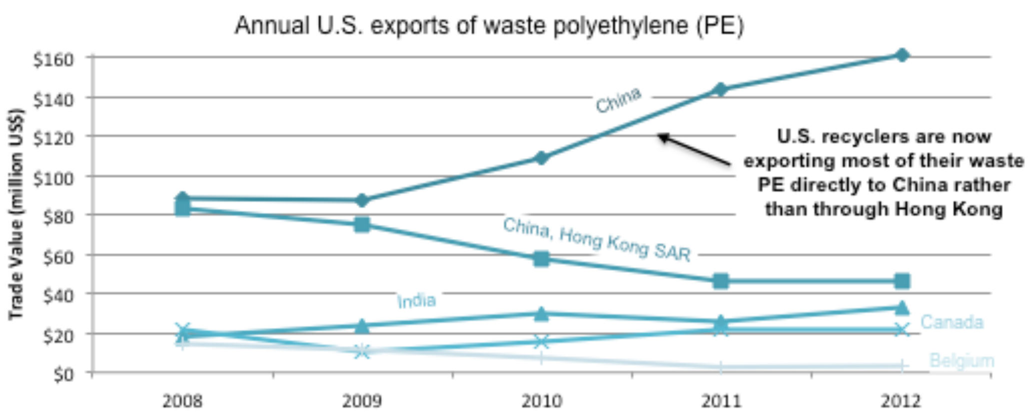

Figure 10. Annual U.S. exports of waste PE

Source: UN Comtrade Database (2014).

It is cost-effective to ship waste PE to China from the United States (and Europe) because of the trade deficits in Western countries. Otherwise empty shipping containers returning to China are available to scrap traders at a discount (Velis, 2014, p. 21). For example, in the United States in 2012, "shipping a container from Los Angeles to China cost around $600, while sending the same container to Chicago via rail cost four times as much" (Royte, 2013). The United States was the largest trade partner to China for waste PE and second largest partner for all scrap plastic (UN Comtrade Database, 2014). After soy beans, the largest export from the United States to China in 2012 was scrap—i.e., metal, paper, and plastic scrap. It is estimated that 20 percent to 50 percent of the waste PE exports from the United States to China were HDPE scrap (Anonymous, 2014d).

From approximately 2001—when China entered the World Trade Organization and imports of scrap plastics increased greatly—until late 2012, shipments of waste PE and other scrap materials were illegally

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[11] Waste PE is under the SITC code 5791: "Waste, parings and scrap polymers of ethylene." This paper analyzes trade of waste PE as data for waste HDPE is not available other than for HDPE bottles. There are differences in the markets for the various types of PE, so distinctions are made when known.

[12] Exports of PE are under SITC code 571: "Polymers of ethylene"

entering China increasingly contaminated with solid waste (Jia, 2013).[13] China became a "pollution haven" for countries like the United States. Many imports were illegal due to restrictions originally enacted in 1996 that specified only clean flake or processed plastics could be imported (Ministry of Environmental Protection of the People's Republic of China, 2009). In the United States, plastics reclaimers of all sizes were selling their highest quality bales to U.S. processors and exporting much of their unprocessed, mixed plastic bales of scrap plastic to Chinese processors. This was in part due to the preference of Chinese processors for U.S. scrap over even lower-quality domestic supply in China. In addition, Chinese recyclers faced low operating costs due to low wages and disposal costs for waste residues by evading environmental and safety protection laws (Velis, 2014).

Global trade of plastic scrap has been extremely volatile and has been causing financial difficulties for MRF operators and exporters. In response to the illegal imports, the Chinese government launched a campaign known as Operation Green Fence in October 2012 to strictly enforce existing environmental standards (Toloken, 2012). China's Department of the Environment, the General Administration of Customs, and the State Quality Inspection Administration started working together to inspect and restrict shipping containers in both Chinese and foreign ports with more than "1.5 percent of allowable contaminant for each bale of imported recyclables (including materials such as metal, plastics, textiles, rubber and recovered paper)" from entering China (Holmes, 2014; Jia, 2013). The effect was an 11.2 percent drop in Chinese imports (by mass) of scrap plastic from 2012 to 2013—from 8.88 million metric tons to 7.89 million metric tons (Recycling Today, 2014). The effect in the United States was an 18 percent drop in plastic scrap exports to China from 2012 to 2013 (Nelson, 2014). As a result of Operation Green Fence, many small, unlicensed U.S. recyclers went out of business (Holmes, 2014).

Many U.S. plastics reclaimers had expected Operation Green Fence to be temporary and inspections to cease in 2013. However, there is now agreement among U.S. recyclers that there will be no post-Green Fence and that the impact on the U.S. waste plastics industry is lasting. China is now shifting to purchases from larger recyclers with Chinese inspection licenses. Foreign reclaimers have been forced to increase the quality of their materials for export but as a result receive higher prices. Some Chinese recyclers are now reporting plans to establish U.S. facilities in three to five years for processing material for shipment to China (Holmes, 2014). In fact, Shanghai Pret Composites Co. Ltd. acquired WPR Holdings LLC and its subsidiary Wellman Plastics Recycling LLC in January 2015 (Sun, 2015).

Converting and Manufacturing

Packaging producers blend virgin and rHDPE pellets and convert the resin into a variety of shapes. Product manufacturing using rHDPE inputs includes blow molding, injection molding, film blowing, and pipe profile tubing (Neidel & Jakobsen, 2013). This value chain segment may also include compounding, or mixing of plastics to reach desired properties, such as blending rHDPE with other recycled resins and colorants. Bottles can be made with a single or multiple layers of HDPE, for example layering rHDPE between virgin (APR, 2014). Layers of nylon or a copolymer of ethylene and vinyl alcohol (i.e., EVOH) can also be used as oxygen barriers. Calcium carbonate is sometimes added to HDPE to reduce material costs (resin is more costly) and cycle times (calcium carbonate has a higher thermal conductivity) (Ampacet Corporation, 2015). However, the addition of calcium carbonate can increase the material density of HDPE scrap, resulting in flakes not being recovered during sink/float testing when the scrap resin is comprised of more than about 8 percent calcium carbonate (Mouw, 2014; Ruiz, 2013).

[13] U.S. exports to China reduced temporarily in 2005 after Hurricane Katrina damaged primary PE production in the United States, which increased local demand for waste PE (Moore, 2014).

The largest HDPE converters are: Amcor Rigid Plastics, Graham Packaging Co., Plastipak Packaging, Alpla, Advanced Drainage Systems, Genpak, and Berry Plastics Corp (see Table 3).[14]

Table 3. Largest U.S. HDPE Converters

Organization Name	Description	Influence on Value Chain
Amcor Rigid Plastics USA Inc. Ann Arbor, MI	Privately-held company with $2.65B in blow molding sales (2013); subsidiary of Australia-based Amcor Limited; uses recycled HDPE and PET content in products	Provides containers for beverage, food, pharmaceutical, spirits, wine and beer, and personal and home care markets; sponsor of CVP's Recycling Partnership
Graham Packaging Co. LP York, PA	Privately-held company with $2.63B in blow molding sales (2013); designer and manufacturer of PET and HDPE bottles; has a HDPE bottle recycling facility and uses post consumer recycled plastic in many products	Provides plastic containers for the beverage, household, personal care, and automotive lubricants industries
Plastipak Packaging Inc. Plymouth, MI	Wholly-owned subsidiary of private company Plastipak Holdings, Inc. with $1.65B in blow molding sales (2013); large user of PET and HDPE resin; about one-quarter of the plastic resin in packaging and preforms business is PCR (portion of HDPE unknown)	Provides containers for beverage, food, cleaning products, industrial and automotive, personal care, and spirit and beer industries
Alpla Inc. McDonough, GA	Operating subsidiary of publicly held ALPLA Werke Alwin Lehner GmbH & Co KG in Austria with $49.5M in revenue; extrusion blow molds containers, including HDPE	Largest producer of packaging in Europe; serves cosmetics, food, household and laundry care, and oils and lubricants industries with variety of plastic containers
Advanced Drainage Systems Inc. Hilliard, OH	Publicly owned company with $1.07B in pipe, profile, and tubing sales; vertically integrated into plastics recycling through subsidiary Green Line Polymers	Provides HDPE corrugated pipes to commercial, residential, agricultural, and industrial sectors
Genpak LLC Glens Falls, NY	Operating subsidiary of privately owned Great Pacific Enterprises, Inc. with $470M in thermoforming sales; recycling plant in Minnesota annually processes 15M lbs. of post-industrial and post-consumer PE scrap for Bags Again and Superbag® Renew products	Serves retail, food processing, and food service industries with single use food packaging products made from a variety of plastics
Berry Plastics Corp. Evansville, IN	Operating subsidiary of publicly owned Berry Plastics Group, Inc. with $1.5B in injection molding sales, $1B in film and sheet sales, and $436M in	Provides packaging, tapes and adhesives, and other plastic products to personal care, household, food, beverage, food

[14] While all the companies use rHDPE, it is unknown from publicly available information which company uses the most rHDPE in its products.

	thermoforming sales; produces PE film products, including HDPE trash can liners with pre- and post-consumer recycled content	service, health care, and industrial and transportation markets

Source: Plastics News (2014), blow molding sales data provided by PrivCo.

Total costs of production from collection through product manufacturing can be higher for recycled resins depending on local market factors and end-use applications. Packaging producers that primarily produce with virgin resins face additional costs—capital costs, set up costs, lower economies of scale—that result in cost parity between or even a premium for rHDPE over virgin HDPE content. For example, rather than pellets arriving by rail in hopper cars each carrying 185,000 pounds, rHDPE pellets tend to arrive in Gaylord boxes of 1,000 or 1,500 pounds each, which requires special handling. Packaging producers may have to pass on additional processing costs for using rHDPE to customers. In addition, the rHDPE could have slower cycle times or require additional maintenance on molds, which can add cost to packaging production (Anonymous, 2014b). In such cases, the buyers (e.g., product manufacturers) pay a premium for recycled resin over primary resin inputs (Schwarze, 2014a). Lower pricing for PET in general has led to interest in shifts from HDPE to PET. This has in turn affected demand for both virgin and recycled HDPE (Schwarze, 2014a).

Opportunities for engagement: There is an opportunity for more product manufacturers to work directly with reclaimers on resin specifications, such as color and melt flow.

Designing and Producing Consumer Packaged Goods

Product manufacturers that incorporate rHDPE into their products or packaging have a variety of motivations for using rHDPE, including reducing environmental impacts, cost reduction and revenue generation, brand benefits through fit with mission, and even just avoiding negative publicity (Schwarze, 2014a; UNEP, 2014).[15] CPGs contribute to their sustainability missions and brand image by incorporating rHDPE into packaging (see

[15] For example, the Make It, Take It campaign is publicly pressuring Kraft Foods to replace Capri Sun juice pouches with a recyclable alternative.

Table 4 for examples of leading companies' practices and goals around the use of rHDPE and other plastics). Failing to invest in product stewardship can result in consumer and policy backlash (Schwarze, 2014b). The main motivation for caring about recyclability at one large CPG interviewed is internal corporate responsibility goals rather than consumer demand for it (Anonymous, 2014e).

Other companies are becoming more involved with the recycling value chain for the long-term impact on prices for product input materials. According to the McKinsey Global Institute, declines in prices of natural resources (e.g., energy, food, water, and materials) achieved during the 20th century were erased in the first decade of the 21st century. In addition, "many are asking whether an era of sustained high resource prices and increased economic, social, and environmental risk is likely to emerge" (McKinsey Global Institute, 2011). Unilever is actively aiming to strengthen the entire plastics recycling industry by increasing the amount of recycled content in its packaging to "maximum possible levels …to act as a catalyst to increase recycling rates" and drive up volumes of post-consumer material collected (Unilever, 2015). The CPG is also working with reclaimers on closed loop systems to generate continual supplies of high-quality PCR.

Table 4. Practices and Goals of Leading Users of rHDPE for Consumer Packaged Goods

Company	Use of rHDPE	Company-wide 2020 recycling goals
Unilever	In 2013, 3,204 tonnes of post-consumer recycled materials were incorporated into rigid plastic packaging	Increase recycling and recovery rates by 15% (in top 14 countries) by working in partnership with industry, governments, and NGOs, which could mean doubling or tripling existing recycling rates in some markets
Seventh Generation	100% PCR HDPE in many bottles packaging product: 70 oz. auto dish gel, 26 oz. disinfectant, 32 oz. toilet bow cleaner, 50 oz. dish liquid, 50 oz. laundry detergent	Produce zero waste: (1) all products and packaging are biobased or recycled and (2) all products and packaging are biodegradable or recyclable
Method	HDPE bottles range from 25% PCR in toilet cleaners to 50% PCR in 8x laundry detergent*	Ultimate goal is closed loop packaging
Procter & Gamble	Developed sustainably sourced sugarcane-derived HDPE plastic used in Pantene and Max Factor packaging; limited information on plastic packaging portfolio but rHDPE used in some packaging	"Double the use of recycled resin in plastic packaging" "Ensure 90% of product packaging is recyclable or that programs are in place to create the ability to recycle it"**
Colgate-Palmolive	Limited information on plastic packaging portfolio	Make product packaging 100% recyclable for its Home, Pet, and Personal Care divisions (3 of 4 product divisions, excluding oral care) Increase recycled content in packaging from 40% to 50% Develop a recyclable toothpaste tube

Notes: *The majority of Method's product packaging, such as for cleaning and hand wash bottles, are made from 100% recycled PET. **P&G's 2020 goals contribute to its long-term vision of having "zero consumer and manufacturing waste go to landfills."

Sources: As You Sow (2014); Method Products (2015); Procter & Gamble (2015); Seventh Generation (2014); Unilever (2015); Unilever US (2014); Walmart (2014)

Many large CPGs have calculated that the optimum portion of rHDPE in bottles (e.g., for personal care items) based on quality and price is about 25 percent (Anonymous, 2014e). Overall, demand for rHDPE is greater than supply, but for some companies, the difference in price between rHDPE and virgin does not make up for supply volatility and quality issues that are absent with virgin resins (Anonymous, 2014f; Croke, 2014). Recycled HDPE can theoretically achieve the same quality level as virgin HDPE (Ettefagh, 2014b; Fendley, 2014). However, aggregating HDPE from multiple sources results in quality downgrading. Some brand owners have refrained from using recycled content, especially in food and beverage markets, due to lack of confirmation that food-grade rHDPE is consistently clean enough, concerns about product breakage (e.g., Hefty bags), and color inconsistencies in rHDPE (Black, 2014; Schwarze, 2014a). At times, poorer physical characteristics of recycled content require that resin be added to a package, which increases its weight and cost (Anonymous, 2014b). Many CPGs refrain from publicly stating use of PCR or certain percentages to allow for the flexibility to adjust the proportion of rHDPE in its packaging at any time (Anonymous, 2014f).

Product manufacturers want high quality rHDPE resin at costs below that for using virgin HDPE. Companies committed to using recycled content may end up paying a bit more. For example, Seventh Generation, provider of healthy and safe household and personal care products, is fulfilling its commitment to nurture nature by using bottles with an average of more than 85 percent PCR—100 percent rHDPE in smaller bottles and 80 percent rHDPE in larger ones (100 and 150 mL bottles for laundry detergent) (Seventh Generation, 2014).

Product designers may also have to choose between recycled content and recyclability. Black PCR is relatively attractive in price compared to virgin, but optical sorters in MRFs cannot currently detect it from the black conveyer belt it lies on. In other instances, rHDPE cannot achieve the characteristics desired of a package—such as a specified level of environmental stress crack resistance, certain contours through blow molding, and color consistency—that are afforded with virgin resin. For example, Tide detergent bottles use a layer of color-matched rHDPE sandwiched in between virgin layers to ensure that bottles' signature color is unblemished on store shelves (Ettefagh, 2014b).

Some CPGs are excited and intensely knowledgeable about the rHDPE value chain; others are still learning. According to one expert, "savvy companies are connected" (Ettefagh, 2014b). However, others are unaware of design elements to increase recyclability or have become irritated—such as by continued pressure to consider recyclability or after having tried to incorporate recyclability considerations only to learn that they received misinformation or insufficient information. Well-intentioned companies who change their products or packaging have to consider a multitude of factors to ensure recyclability of their products and prevent negative publicity.

UNEP's *Value Plastics* Report – Recommendations for Companies

- "Raise awareness of the risks and opportunities of plastic at executive board level.
- Measure plastic use in products, packaging, operations and supply chains and publish the results in annual reports and, for example, through the [Plastic Disclosure Project].
- Commit to reducing the environmental impact of plastic and set targets with deadlines to ensure this goal is achieved.
- Innovate products and processes to increase resource efficiency and recycling of plastic.
- Collaborate with governments to develop legislation to facilitate sustainable management of plastic, such as through extended producer responsibility and waste management infrastructure, especially in developing countries.
- Support data collection and further research into the impacts of plastic, especially in the marine environment, in partnership with academic institutions and conservation groups."

Source: UNEP (2014).

Package designers consider environmental benefits from changes in in all stages of products' lives. Many consumers think that sustainable packaging is all about recycling—recyclability and using recycled content—while many packaging designers think that it is all about lower CO_2 emissions (MacKerron, 2015). For example, many CPGs have reduced product packaging (e.g., lightweighting) to cut emissions impacts. According to Walmart, who reduced packaging on store shelves by five percent from 2008 (baseline year) to 2013, reducing packaging results in significant reductions of fuel use in distributing products, in water use, and in the amount of packaging material discarded (Thomas, 2013). Life cycle assessment (LCA) is the primary tool for assessing impacts of a product over its entire lifetime and is designed to evaluate impacts on CO_2 emissions by changing material types—such as with packaging. For example, it is valuable in identifying hotspots of resource use. However, LCA may not effectively assess the impacts of recycling in comparison to other changes as they rely on data sets with limited information about the impacts of landfill disposal and recycling. Product designers should be aware of these limitations and encourage the industry to strengthen LCA data sets.

Opportunity for engagement: Product designers and manufacturers can reduce the diversity of plastics by standardizing product segments (Ettefagh, 2014b). For example, in the dairy aisle of supermarkets, there is a range of containers made from HDPE that have different melt flows. The value chain, in collaboration with CPGs, can also be more proactive about preventing migration of used packaging into waterways.

Retailing Products and Packaging with rHDPE

Walmart is actively trying to encourage the health of the recycling industry. As part of its global sustainability efforts, Walmart is working with major suppliers to increase recycled content in the products it sells by an estimated 3 billion pounds by 2020 (Johnson, 2014). While the portion of this content that will be plastic is unclear, the goal sends a strong signal to suppliers. To support its goal, the retailer is incorporating elements of its Packaging Scorecard into its Sustainability Index for suppliers—to "build packaging into [Walmart's] holistic view of sustainability performance for all categories" (Walmart, 2014). It also worked with the Association of Postconsumer Plastic Recyclers (APR) to create design for recyclability guidelines for suppliers of plastic packaging. Finally, Walmart, Goldman Sachs, and several large CPGs contributed to a $100 million Closed Loop Fund that will provide zero interest loans to U.S. municipalities for upgrading recycling infrastructure to improve sorting and enable higher-quality bales to be generated (Closed Loop Fund, 2014; Walmart, 2014). Only recently have corporate players been putting money into infrastructure—through the Closed Loop Fund and the Recycling Partnership, which is providing roll carts to households and technical assistance to recycling coordinators (Mouw, 2014).

Opportunity for engagement: Retailers can continue to put pressure on suppliers to provide products that are designed for recycling and contain recycled content (ISRI, 2015). (See Appendix 4 for a summary of all opportunities for increasing engagement in the rHDPE value chain.)

Efforts Underway for Improving Engagement

Trade associations and other non-profit organizations are providing essential tools and analysis to strengthen the entire plastics recycling industry. The main associations in the HDPE recycling value chain are APR and the American Chemistry Council (ACC) (Mouw, 2014). The Institute of Scrap Recycling Industries (ISRI) also represents companies in the value chain and has a strong influence through political lobbying (Ettefagh, 2014b). (Descriptions of the most influential associations and non-profits affecting the rHDPE value chain are provided in Table 5.)

APR is a national trade association that represents "90 percent of post-consumer plastic processing capacity in North America" (APR, 2015). Among many other efforts, APR developed design for recyclability (DfR) guidelines for specific resin types, including HDPE, in 1994 and has been updating them regularly (APR, 2012). It hosts a directory of materials that APR members purchase and sell. Its Rigid Plastics Recycling Program created specifications for model bales of HDPE bottles and non-bottle materials for sellers to use in transactions, which increases transparency in purchases (ISRI, 2015).[16] The association also has a tool, that is rarely used but known, to notify its converters and brand owners when they have created packaging "not according to guidance"—referred to as a NAG letter (Schwarze,

[16] For example, the specification for "Pigmented HDPE bottles" limits the weight of certain non-bottle, non-HDPE material in the bale to a total of 10 percent, while prohibiting other contaminants (APR, 2013).

2014a). Despite marketing efforts and teaming up with Walmart to promote its DfR guidelines, there may still be lack of awareness of APR resources. In response, APR is increasing direct engagement with product designers through webinars and onsite visits and has also formed a training program for packaging engineers to increase awareness of its guidelines (Bedard, 2014; Johnson, 2015a).

Table 5. Influential Associations and Non-Profits

Organization Name	Description	Influence on the Value Chain
Association of Postconsumer Plastic Recyclers (APR) Washington, DC	National trade association, formed in 1992, representing 90% of post-consumer plastic processing capacity in North America; Rigid Plastics Recycling Committee has 36 stakeholders (i.e., generators, collectors, reclaimers, brands, resin producers, public policy makers)	Provides PE model bale specs; regularly updates design guide for plastics recyclability covering HDPE bottles; hosts directory of materials that members purchase and sell
American Chemistry Council (ACC) Plastics Division Washington, DC	Division of national trade association representing chemical companies; members include 13 U.S plastic resins manufacturers and a vinyl industry trade association	Provides communities with resources to increase post-consumer plastic collection, such as through funding RecycleYourPlastics.org.
Sustainable Packaging Coalition (SPC) of GreenBlue Charlottesville, VA	Project of the environmental nonprofit, GreenBlue, which is "dedicated to the sustainable use of materials in society;" industry working group	Initiated the How2Recycle label, a "voluntary, standardized labeling system that clearly communicates recycling instructions to the public"
SPI: The Plastics Industry Trade Association Washington, DC	U.S. plastics industry trade association representing resin suppliers, equipment makers, processors, and brand owners; founded in 1937	Owns and produces the international NPE trade show; Recycling Committee gathers information on recycled plastics, such as projected demand, and provides resources on the Chinese export market
Curbside Value Partnership (CVP) Falls Church, VA	Non-profit that focuses on improving residential recycling in the United States; members of Recycling Partnership initiative, launched in 2014, include Alcoa, ACC, Carton Council, Coca-Cola, Sonoco, WM, and others	Recycling Partnership working with 4 communities to provide roll carts to households and technical assistance to recycling coordinators
Institute of Scrap Recyclers Industry (ISRI) Washington, DC	Trade association representing more than 1,600 companies; members include manufacturers and processors, brokers, and industrial consumers of scrap commodities (i.e., metals, paper, electronics, rubber, plastics, glass, and textiles)	Provides guidelines for baled plastic scrap
Closed Loop Fund New York, NY	Fund launched in 2014; Walmart, Coca-Cola, Keurig Green Mountain, Johnson & Johnson, PepsiCo,	Applications are being accepted for funding; aims to provide $100M in "0% interest loans to

	Procter & Gamble, Unilever, Goldman Sachs joined	municipalities and below market interest loans to private companies to develop local and recycling infrastructure" in 5 years
National Waste & Recycling Association (NWRA) Washington, DC	Trade association representing U.S. waste and recycling industries by providing "leadership, advocacy, research, education, and safety expertise;" founded in 1962	Conducts annual WasteExpo to bring recycling experts together
Keep America Beautiful Stamford, CT	Formed in 1953; uses education and behavior change programs through public-private partnerships to "reduce waste, increase recycling, protect the natural areas of our communities, and ensure beauty is the lasting signature"	Programs include America Recycles Day, the "I Want To Be Recycled" campaign in partnership with the Ad Council, the Recycle Bowl national competition among K-12 schools, and others
China Scrap Plastics Association (CSPA) Hong Kong	Represents 400 members from the plastics recycling industry in China; mission to "create a favorable business and legislative environment for plastics recycling and to tackle key issues in the development of the industry"	News on plastics recycling in China provided to SPI members; conducts annual conference, ChinaReplas, that connects the Chinese and U.S. recycling industries
Society of Plastics Engineers' (SPE) Plastics Environmental Division (PED) Newtown, CT	Division of plastics professional society with mission to "provide and promote environmental stewardship of plastics materials;" serves as a liaison to the plastics industry, the public, educational institutions, environmental groups, and government agencies	Hosts Global Plastics Environmental Conference annually to bring together experts

Sources: ACC (2015); Bedard (2014); CSPA (2015); CVP (2014); GreenBlue (2015); NWRA (2015); Resource Recycling (2015b); SPC (2015); SPE Plastics Environmental Division (2015); SPI (2015).

Efforts underway to increase engagement and understanding of the value chain include improved product labeling and public awareness campaigns. The Sustainable Packaging Coalition (SPC), an initiative of the U.S. non-profit GreenBlue, is creating a connection between product designers and consumers with its How2Recycle label (Butler, 2014). The How2Recycle label informs consumers on the type of material in a product or packaging and instructs them on proper disposal to reduce the level of contamination in waste streams recovered for recycling (Sustainable Packaging Coalition, 2014). SPC is promoting the label to CPGs to expand its use. Further, SPC is collaborating with the ACC's Flexible Film Recycling Group (FFRG) to sponsor the use of the How2Recycle "Store Drop-off" label for HDPE and LDPE bags and films and working with packaging producers, such as Ampac, to develop flexible pouches made from all HDPE that can be recycled (Bedarf, 2014; Lahvic, 2013).

Source: GreenBlue (2015).

Keep America Beautiful is partnering with the Ad Council, Unilever, and others on its "I Want to Be Recycled" campaign to raise awareness among consumers of where recycled content can end up—such as a used shampoo bottle becoming a hairbrush (Keep America Beautiful, 2015). In addition, Johnson & Johnson is directly engaging its customers through its CareToRecycle campaign on Tumblr to encourage recycling of items in the bathroom (Environmental Leader, 2013).

Trade associations and other non-profit organizations have an opportunity to expand their endorsements to spread awareness of effective efforts developed and managed by other organizations to their constituencies.

Several efforts underway to improve plastics recycling in Europe could serve as models for U.S. efforts. Project MainStream, a collaboration of the World Economic Forum and the Ellen MacArthur Foundation, is developing a global plastics packaging roadmap. The multi-stakeholder project involves a pilot group of cities and consumer goods companies aiming to enable a 20-year transition to effective packaging solutions based predominantly on re-use and recycling of plastic (Ellen MacArthur Foundation, 2015). The European Commission's Eco-Innovation Programme is funding a project called EUCertPlast, introduced in July 2012, to create a European certification for post-consumer plastic recyclers to confirm the quality recycled plastics (EuCertPlast, 2014).

Further Research

Several topics are recommended for further research, including other aspects of the rHDPE value chain, the applicability of the opportunities for engagement in this report to other recycling value chains, and communication methods to facilitate engagement.

This research did not address sorting and processing equipment providers, the state of technological innovation, post-industrial plastics recyclers, or the impact of policy within each value chain segment. Research on such topics might uncover further opportunities for increasing engagement.

The applicability of the recommendations in this report to value chains for other plastic types, such as LDPE and PP, could also be considered. Further research could investigate the certain characteristics or conditions of recycling value chains for other commodities that enable increased coordination, such as location of reclaimers to manufacturers, the dynamics of value creation and capture, and the cost of imposed on a value chain of increasing diversity of material streams.

Finally, further research could investigate various communication methods to facilitate engagement, such as the potential to use networks to track the flow of HDPE scrap and share data. According to Duchin & Levine:

> "At the present time there are growing concerns about the loss of access to critical natural resources because of the combined effects of growth in demand, geological scarcity, and the related challenge of increasing extraction costs, as well as geopolitical motives for limiting output and exports. For this reason it is becoming vital to substantially *expand data compilation about resource endowments and develop methods for tracking the origins and destinations of strategic resources throughout the supply chain [emphasis added]*, both for countries supplying resources and for those dependent upon them" (Duchin & Levine, 2012).

For example, firms could work together to sensor material flows through automated systems and develop a material flow map for the value chain. Efforts in the agricultural sector—to differentiate genetically modified from non-genetically modified grains—could prove useful for differentiating HDPE from other types of resin.

Conclusion

This report explained how, despite generally high demand for rHDPE, there are disconnects between many recyclers, product manufacturers, and other actors that result in suboptimal design for recyclability and insufficient supply of quality materials for recycling. This resulted in an estimated $2.85 billion of HDPE packaging being discarded in U.S. landfills in 2010 and thousands of tons of wasted material entering waterways each year. To address these challenges, the report described the key market dynamics in the value chain for recycling rigid HDPE scrap—i.e., recycling a used shampoo bottle into new products. It also identified opportunities to increase engagement within each segment of the value chain, such as municipalities adopting common terminology for their recycling programs, collectors and MRFs applying a market-based mechanism to assign a value to desirable materials so that they show up in curbside bins, product manufacturers working directly with reclaimers on resin specifications, retailers reducing diversity of plastics in stores by encouraging CPGs to standardize packaging by product segments (e.g., all HDPE in the dairy aisle), and industry groups conducting coordinated analyses to inform the development of an industry-wide strategy. With these measures, it is hoped that CPGs and retailers, equipped with an improved understanding of the value chain, will continue to encourage consumers to participate in recycling programs, which will lead to a financially healthier value chain, more rHDPE in products and packaging, and less waste plastic in the environment.

Acknowledgements

I would like to thank the following people for their contributions to this research:

- My faculty advisor, Dr. Dan Vermeer, of the Duke Center for Energy, Development, and the Global Environment, or his indispensible guidance and encouragement;
- Herman Hsuan, of WM Sustainability Services, for his encouragement and financial support of my attendance at the 2014 Resource Recycling Conference;
- Research advisors Gary Tyson, of WasteZero, and Lukas Brun, of the Duke Center on Globalization, Governance, and Competitiveness, for their guidance on my research method;
- Dr. Gary Gereffi, of Duke Center on Globalization, Governance, and Competitiveness, for his Fall 2014 course on globalization where I learned the value and mechanics of value chain analysis;
- The many experts interviewed who offered their time and enthusiasm for the project.

Appendices

Appendix 1: Interviews

Value Chain Segment	Name, Title, Organization	Years in Industry*	Interview Date and Location
Consulting	Larry Black, Senior Advisor & Business Development, Waste Management McDonough Innovation Collaboration	7	10/20/14 by phone
State recycling program	Scott Mouw, State Recycling Director, NC Department of Environment and Natural Resources (NC DENR)	22	10/20/14 in Raleigh, NC
State recycling program	Rob Taylor, Local Government Team Leader, NC Division of Environmental Assistance & Customer Service, NC DENR	17	10/20/14 in Raleigh, NC
Reprocessing	Tamsin Ettefagh, Vice President - Sales, Envision Plastics	22	10/22/14 by phone
Consulting	Nina Butler, Managing Director, Moore Recycling Associates	15	10/27/14 in Chapel Hill, NC
Retailer	Anonymous sustainability professional	6	11/10/14 by phone
Consulting	Patty Moore, President and CEO, Moore Recycling Associates	32	11/10/14 by phone
Non-profit organization	Bridget Croke, Investor Partnerships and Communications, Closed Loop Fund	10	11/12/14 by phone
Collector and MRF operator	Anonymous recycling services professional		11/25/14 by phone
CPG	Anonymous sustainability marketing professional		12/1/14 by phone
Packaging producer	Charlie Schwarze, Global Sustainability Manager, Amcor Rigid Plastics, Amcor Ltd.	3	12/2/14 by phone
CPG	Anonymous packaging sustainability professional	13	12/11/14 by phone
Consulting	Howie Fendley, Director of Business Development, McDonough Braungart Design Chemistry (MBDC)	13	12/17/14 in Charlottesville, VA
Non-profit organization	Anne Bedarf, Senior Manager, GreenBlue's Sustainable Packaging Coalition	7	12/17/14 in Charlottesville, VA

* Approximate years of experience working in plastics, packaging, and/or recycling.

Project Overview

Objective:	Identify opportunities for increasing recycled content, specifically rHDPE, in consumer products.
Method:	Conduct a global value chain (GVC) analysis of the end of life of a consumer product made of HDPE (#2 plastic resin, e.g., shampoo bottle)—in aggregate—used in the United States.
Deliverable:	Thesis report, including map of value chain a consumer product with rHDPE, characterization of value chain transactions, and analysis of key opportunities and

	challenges for HDPE recycling—as compared to PET recycling.

Emerging Hypotheses:

1. Despite high demand for recycled content, there is a disconnect between many recyclers and product manufacturers that results in suboptimal design for recyclability and insufficient supply of post-consumer and post-industrial materials for recycling.
2. Product manufacturers would be more engaged with the rHDPE industry if they had more insight into the upstream value chain.

Example Interview Guide for Upstream Actors

Industry Structure

- What are the value adds of your products (e.g., advanced/proprietary processing)?
- What are your input materials (e.g., HDPE flakes from post-consumer bottles)?
- Are your suppliers of HDPE primarily located in your region or abroad? Which country?
- Who buys your products/materials (e.g., customer name, industry, or product type)? If exported, where does it travel before final use?
- Where is the most value created in the rHDPE value chain? Most value captured (i.e., highest margins earned)? Why?

Partnerships & Information Sharing

- What are your best sources for information on rHDPE in your market (e.g., pricing data, volume/sales)?
- How does information (esp. about HDPE) flow in your company? Your industry?
- Which associations have the most influence on your company and why?
- Has your company partnered with a final product manufacturer? If that hasn't been considered, why not? If you have, was the partnership successful? Why or why not?

Challenges, Opportunities, and Trends

- What are the main challenges faced by the HDPE recycling industry? For bridging the gap with CPGs and working collectively?
- What are the key opportunities, in absence of new policies and regulations, for your company for increasing engagement with recyclers—to ultimately increasing the quantity and quality of rHDPE?
- How have supply and demand for rHDPE changed over the past 10 years?
- How have business models in your industry changed in the last 10 years?

Final Product Manufacturing

- How do you characterize the benefit of your material over that produced from raw/petroleum inputs?
- What information about the rHDPE industry has been helpful for final product manufacturers (you/your clients) to know?
- How much rHDPE content is in your/your clients' consumer products? Why that portion?

Interview Guide for Downstream Actors

Use of Recycled HDPE

- What types of products/materials with recycled HDPE (rHDPE) does your company sell? How does this vary in the U.S. versus your foreign operations?
- Are there properties of HDPE that make it a preferred or less preferred material than other resins? Why?
- What are some of the sustainability trade-offs of focusing on end-of-life (i.e., using rHDPE) versus on other environmental attributes?

- How much rHDPE content is in your consumer products? Why that portion?
- What are the motivations to increase the amount of recycled content in your products?

Partnerships & Information Sharing

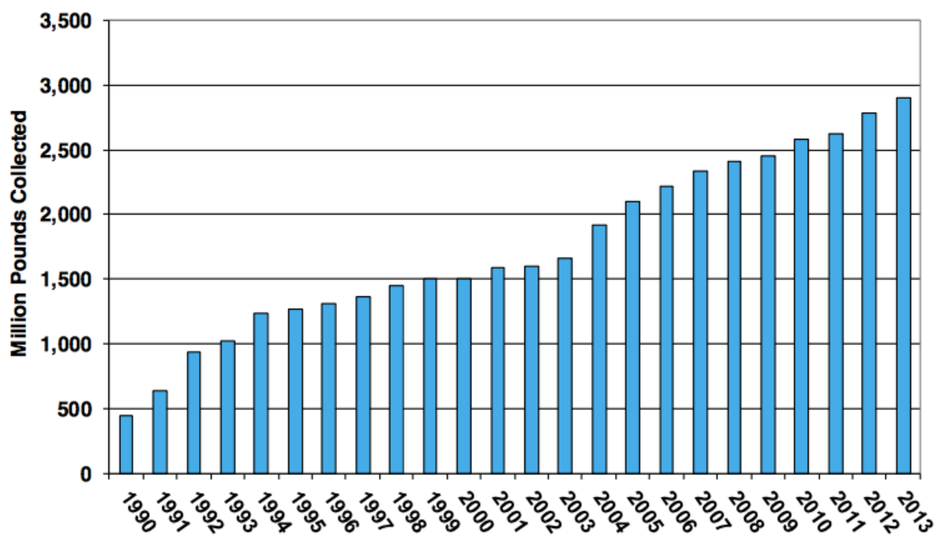
- Who are the key actors (companies) in the recycled HDPE industry?
- What are your best sources for information on rHDPE in your market (e.g., pricing data, volume/sales)?
- How does information (esp. about HDPE) flow in your company? Your industry?
- Which associations have the most influence on your company and why?
- What information about the rHDPE industry has been helpful for final product manufacturers and retailers to know?

Challenges, Opportunities, and Trends

- What are the main challenges faced by the HDPE recycling industry? For bridging the gap with CPGs and working collectively?
- What are the key opportunities, in absence of new policies and regulations, for your company for increasing engagement with recyclers—to ultimately increasing the quantity and quality of rHDPE?

Appendix 2: HDPE Bottle Recycling Facts & Figures

Figure 1
Growth in Post-Consumer Plastic Bottle Recycling



SOURCE: NAPCOR, all years, for PET. For other bottle resins, R.W. Beck, Inc., 1990-2006; Moore Recycling Associates, Inc., 2007-2014

Source: ACC and APR (2014)

Table 6. Post-consumer Plastic Bottle Recycling Collection Results

Post-Consumer Plastics Bottles Recycled in
Calendar Year 2013 Compared to Calendar Year 2012 Results [1,2,3,4,5,6,7]
(in millions of pounds per year)

	Calendar Year 2012			Calendar Year 2013		
Plastic Bottle Type	Plastic Recycled [2]	Resin Sales [3,4]	Recycling Rate	Plastic Recycled [2]	Resin Sales [3,4]	Recycling Rate
PET [4]	1717.9	5585.6	30.8%	1798.0	5764	31.2%
HDPE Natural	445.6	1560	28.6%	440.4	1571	28.0%
HDPE Pigmented	573.6	1669	34.4%	605.0	1733	34.9%
Total HDPE Bottles	1019.2	3229	31.6%	1045.4	3304	31.6%
PVC [5]	1.0	75	1.3%	0.4	76	0.5%
LDPE [5]	0.7	77	0.9%	0.3	78	0.4%
PP [6]	47.0	174	27.0%	62.0	195	31.8%
Other [7]	4.3			3.8		
TOTAL BOTTLES	2786	9140	30.5%	2906	9417	30.9%

[1] These data provide a snapshot of plastic bottle recycling collection trends from a national perspective. The data are particularly useful in identifying national trends and highlighting changes that have occurred from year to year, and may be a useful tool for planning purposes. While national data may be useful as a comparison with local waste characterization and recycling data, significant differences will exist from locality to locality, and from state to state. If communities or states are making decisions where precise knowledge of the amount, composition and disposition of MSW is crucial, e.g., where a solid waste management facility is being designed, or for local or state regulatory enforcement, etc., then local characterization of the quantities of individual components generated, recycled and disposed is essential.
[2] Data are based on surveys performed by Moore Recycling Associates, Inc. and include bale composition data provided by Moore Recycling Associates, Inc. and others.
[3] Based on data provided by the American Chemistry Council's Plastics Industry Producers Statistics Group. HDPE resin sales include both the virgin and recycled plastic pounds used to produce new bottles. Imports from non-ACC members are not included.
[4] Source: Report of Post Consumer PET Container Recycling Activity in 2013, National Association of PET Container Resources, Sonoma, California
[5] The majority of PVC and LDPE recycled were as part of commingled bottle and container bales.
[6] About 82% of PP bottles were deliberately recycled as PP bottles.

Source: ACC and APR (2014)

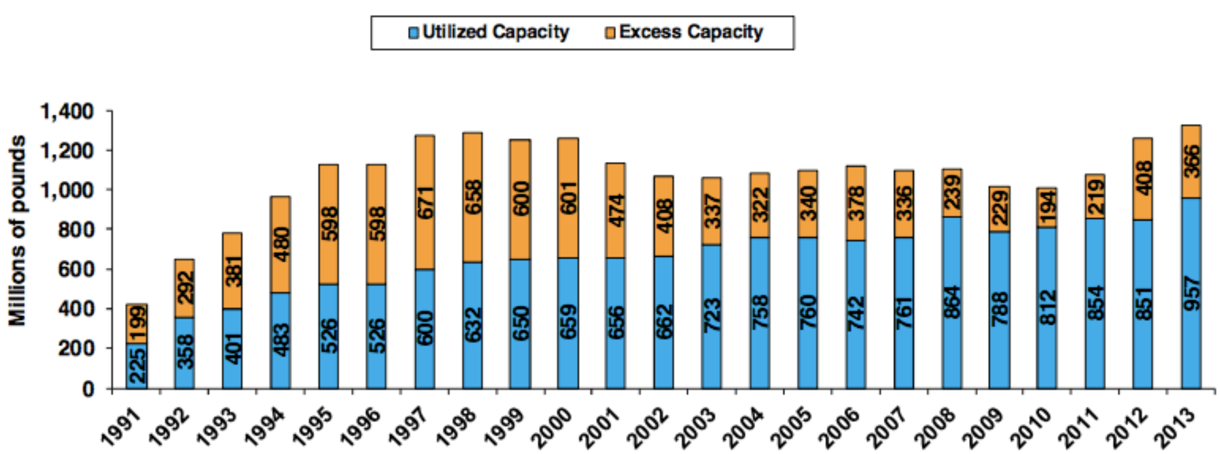


Figure 11. HDPE Bottle Wash Capacity in the United States

Note: The figures shown above are estimates and should not be used for business planning purposes. Utilized capacity includes post-consumer material quantities processed domestically only. Capacity is based on 24 hours per day and 365 days per year.

Source: ACC and APR (2014)

Appendix 3: Global Trade of Waste PE

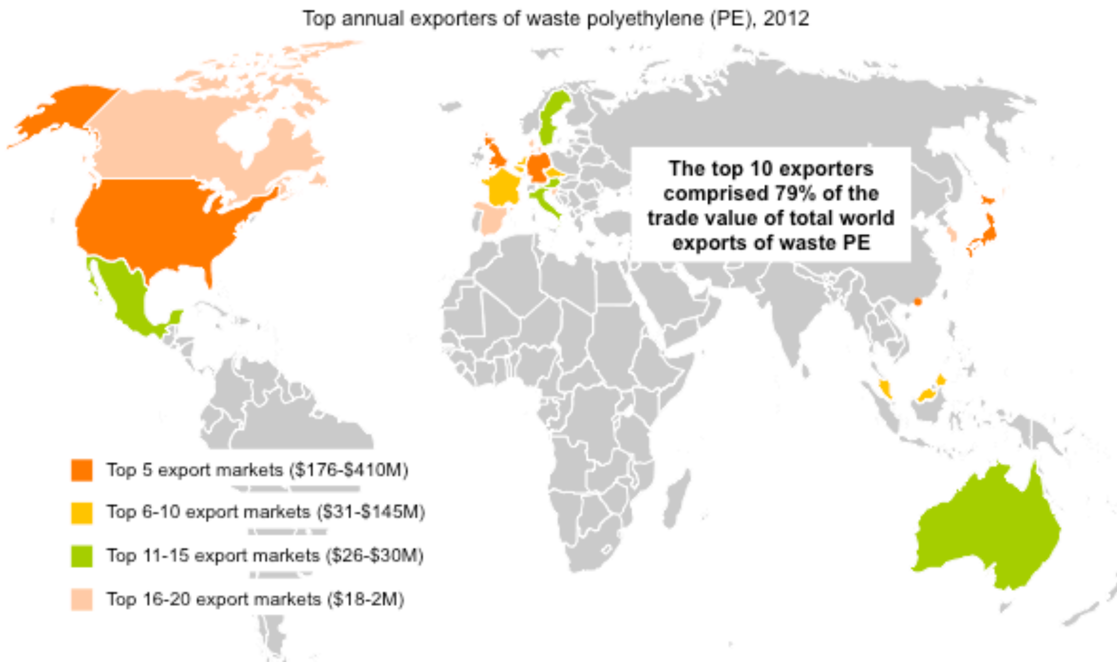


Figure 12. Top exporters of waste polyethylene globally, 2012

Source: UN Comtrade Database, 2014.

Appendix 4: Summary of Opportunities for Increasing Engagement in the rHDPE Value Chain

Value Chain Segment(s)	Opportunities
System-wide	Consultants, researchers at non-profit organizations and academic institutions, and other industry experts can develop an industry-wide strategy, informed by better data (e.g., material flow map, industry-wide infrastructure data)—to increase understanding of capture rates of HDPE at MRFs around the country
System-wide	All actors can educate consumers and each other to inform and encourage recycling behaviors
System-wide	All actors, in collaboration with CPGs, can an be more proactive about preventing migration of used packaging into waterways
Disposal of Recyclable Content	Local and state governments can work with industry to agree on sets of materials that can be collected throughout a region
Disposal of Recyclable Content	Local governments can adopt the common terminology offered by the RecycleYourPlastics.org Terms and Tools app, provided by the Plastics Division of the American Chemistry Council (ACC)
Hauling & Materials Recovery	Collectors can experiment with market-based mechanisms to assign a value to desired material to incentivize participation in recycling programs (e.g., curbside collection)
Hauling & Materials Recovery	MRF operators can work with secondary sorters to create new types of bales for re-sort at PRFs or for alternative disposal, such as WTE

Hauling & Materials Recovery Converting & Manufacturing	MRF operators and the packaging industry can work together to improve product design for recyclability
Hauling & Materials Recovery Non-profit Organizations	Industry associations and MRF operators can work with local governments to encourage recycling of high-value materials like HDPE and conversion of lower value materials
Hauling & Materials Recovery Reclaiming & Reprocessing Converting & Manufacturing	Converters and product manufacturers can work with reclaimers and MRF operators to develop an accurate price index that enables more long-term agreements between reclaimers and suppliers—to stimulate investments in infrastructure to improve product quality
Reclaiming & Reprocessing CPGs Design & Production	More product manufacturers can work directly with reclaimers on resin specifications, such as color and melt flow
CPGs Design & Production	Product designers and manufacturers can standardize product segments—e.g., set specifications for using HDPE in dairy product packaging—to reduce the diversity of plastics
Retailing	Retailers can continue to put pressure on suppliers to provide products that are designed for recycling and contain recycled content
Non-profit Organizations	Organizations can expand their endorsements of effective efforts developed and managed by other organizations to spread awareness to their constituencies

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