HEALTHY BUILDING NETWORK

Optimizing Recycling:
Post-Consumer Polyethylene in Building Products

A Collaboration between StopWaste and the Healthy Building Network

with support from the San Francisco Department of the Environment

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This briefing paper and an associated series of research papers on optimizing specific recycled feedstocks can be found at healthybuilding.net/content/research-and-reports.

The Healthy Building Network (HealthyBuilding.net) is a nonprofit organization that works to reduce the use of hazardous chemicals in building products as a means of improving human health and the environment. HBN performs independent, foundational research and product evaluations required to provide building products specifiers with unbiased, up-to-date information about chemical hazards, practical product evaluations and comparisons, and recommendations about the healthfulness of widely-used building products.

StopWaste (StopWaste.org) is a public agency responsible for reducing waste in Alameda County. The agency helps local governments, businesses, schools and residents reduce waste through source reduction and recycling, market development, technical assistance and public education. StopWaste is governed jointly by three boards: the Alameda County Waste Management Authority, the Alameda County Source Reduction and Recycling Board, and the Energy Council.

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About the Optimizing Recycling Series

The Optimizing Recycling Series of reports is a collaboration between the Healthy Building Network (HBN), a non-profit organization whose mission is to protect health in the built environment, and StopWaste, a public agency responsible for reducing the waste stream in Alameda County, CA, with support from the San Francisco Department of the Environment. The reports examine the hazards, supply chains, and economic impacts of recycled feedstock streams found in building products.

The recycling industry and building product manufacturers have made significant strides toward the vision of a closed loop material system, whereby materials produced today become the raw materials for their products in the future. Contamination of feedstocks with chemicals of concern, however, can reduce feedstock value, impede growth of recycling rates and potentially endanger human and ecosystem health.

We describe the framework for our evaluation of polyethylene and other feedstocks in our collaboration's overview report, Optimizing Recycling: Criteria for Comparing and Improving Recycled Feedstocks in Building Products. It describes how best practices for monitoring and improving the purity of recycled feedstocks in building materials can improve feedstock value, protect human health and dramatically increase recycling rates in North America.

This report on post-consumer polyethylene examines ways to optimize recycled content feedstocks commonly used in building materials. The most common conditions of post-consumer feedstocks, as consumed in California, establish the baseline for assessments found in this report.

The views expressed in this evaluation are those of the authors and do not necessarily reflect the position or policy of StopWaste, or donors to HBN.

The reports are available on Healthy Building Network's website, http://healthybuilding.net/content/optimize-recycling.

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Executive Summary

- **Feedstock Health and Environmental Hazards**
- **Supply Chain Quality Control and Transparency**
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OVERALL: Polyethylene is a material widely used in packaging, food and beverage containers, and consumer products. High Density Polyethylene (HDPE), Low Density Polyethylene (LDPE), and Linear Low Density Polyethylene (LLDPE) are all readily recyclable in California. Polyethylene plastic scrap bottles and plastic bags usually have minimal contents of concern and are easily processed into feedstock for new products including building materials.

Contamination from cleaning fluids and other potentially toxic substances in plastic packaging is a concern, but the recycling industry is developing testing protocols and baseline specifications for its feedstocks in order to screen out residual contaminants.

Most polyethylene goes unrecycled in the United States, due to problems in supply chain controls, which leaves room for improvement as a driver of green jobs and local economic growth. The glut of unused scrap could be a significant untapped resource for domestic building product manufacturing, yet most polyethylene collected for recycling goes overseas. This is largely because post-consumer scrap collected from large recycling facilities is too contaminated and mixed with other plastics.

Biodegradation additives in plastic bags threaten the performance of products using recycling polyethylene. Cheap virgin polyethylene and other market forces are threatening the economic viability of using recycled polyethylene in building products.[1] Regulations and consumer-driven demand are needed to move this market towards optimization.

SUITABLE BUILDING APPLICATIONS: Recycled polyethylene that meets performance requirements and has been screened for toxic contaminants can be reprocessed into building products such as drainage pipes, plastic lumber, impact resistant walls, substrates, and table tops.

PATHWAYS FOR OPTIMIZATION:

1) Prevent contamination of future recycled feedstocks by simplifying plastic packaging design and avoiding problematic additives such as degradation ingredients.
2) Grow capacity to collect and sort post-consumer polyethylene.
3) Invest in technologies to remove contaminants from post-consumer polyethylene.
4) Institute product content requirements that replace virgin plastics with uncontaminated post-consumer polyethylene.

Introduction

Polyethylene (PE) is a thermoplastic, which means that it can be heated to a liquid state, cast into a desired shape, and left to harden as it cools. In theory, thermoplastics can be heated, cast in shape, used, discarded, collected, and recycled over and over again.[2] (In practice, there are limits.)[3]

The generally inconsistent mixture of resins used in plastic products and packaging poses a major challenge to polyethylene recycling. Efforts are underway to solve this problem, such as the *New Plastics Economy* initiative of the Ellen MacArthur Foundation that is bringing together key global stakeholders to re-think and re-design the future of plastics.

By a wide margin, polyethylene is the world's most common plastic. This report focuses on three types of polyethylene: High Density Polyethylene (HDPE), Low Density Polyethylene (LDPE), and Linear Low Density Polyethylene (LLDPE).[4] Collectively these plastics held a combined 35 percent share of all U.S. plastic resin sales in 2014, according to the American Chemistry Council.[5]

HDPE, LDPE and LLDPE have different degrees of flexibility, which makes them suitable for different applications.[6] About half of the HDPE and LLDPE, and most of the LDPE, winds up in packaging.[7]

Despite supply chain obstacles, the building and construction sector is a significant consumer of post-consumer recycled polyethylene from packaging. Overall, over a third of the polyethylene bottles and bags collected from the waste stream become new building materials. About 28 percent of recycled HDPE bottles wind up in new pipes, and another 7 percent in lumber and decking.[8] Plastic lumber manufacturers accounted for an estimated 44 percent of the films recovered from the post-consumer waste stream in 2014, the plastics industry estimates.[9] Companies are using post-consumer polyethylene in a wide variety of other building products, such as impact resistant walls,[10] partitions,[11] wall and ceiling panels, substrates,[12] and table tops.[13]

This report explores the condition of post-consumer polyethylene feedstocks as delivered to the building and construction industry, and the barriers to and opportunities for increasing its use. As part of the Optimizing Recycling initiative, this report evaluates post-consumer polyethylene feedstock against a set of four criteria. The criteria gauge

- Impacts on human health and the environment,
- Supply chain controls and transparency,
- The availability of "green jobs," and
- Opportunities to expand use of the feedstock.

Each criterion is judged on a three-part scale with green indicating "very good," yellow indicating "room for improvement", and red indicating "significant concerns." The review is focused on California's San Francisco and Alameda counties wherever possible, and on California more generally. The evaluations of health and environmental impact and supply chain controls are broadly applicable throughout the United States. Details regarding job availability and room to grow will vary based on region.

Behind the Ratings

FEEDSTOCK HEALTH AND ENVIRONMENTAL HAZARDS

The basic polymers HDPE, LDPE, and LLDPE are simple and have no known associated health hazards. While some polyethylene formulations contain problematic additives that have health hazards, we have found little evidence that these additives (such as metals that catalyze degradation) are commonly present at significant levels in feedstocks used to make recycled building products. Relative to other waste streams we have examined, post-consumer polyethylene scores a "Green - Very Good" for environmental and health hazards.

However, our analysis of environmental and health hazards identifies significant threats to the quality of recycled polyethylene from three types of additives, particularly degradation additives, reprocessing additives, and legacy contaminants absorbed into the plastic during use. These contaminants should be eliminated at the source or through screening technologies in order to increase the scale and value of polyethylene recycling.

Degradation Additives

Degradation additives are substances added to plastic packaging to accelerate the degradation of the plastic product. Originally added in response to public concern over plastic packaging litter, it is important to note that these additives do not reduce waste. They do not degrade the polyethylene itself, but rather break it up into smaller pieces, which remain as litter.

There are two types of degradation additives used in polyethylene packaging products:[14]

- Catalytic chemicals, also known as oxo-biodegradable or UV-degradable additives. When activated by physical manipulation, light, or heat, these catalysts fragment the plastic into smaller pieces;
- Non-catalytic additives, also known as hydro-degradable, organic (meaning they are carbon-based), or compostable additives. Once plastic is in the presence of microbes, the additives -- and only the additives -- will degrade.

The oxo-biodegradable additives industry uses metal salt catalysts, most commonly manganese, iron, cobalt, iron, manganese and nickel compounds.[15] Plastics manufacturers add these substances at significant proportions – between one and five percent – of the finished packaging.[16] A rival manufacturers association found cobalt levels as high as 1,450 ppm in a food waste bag treated with an oxo-biodegradable additive.[17] These additives may pose health hazards for reprocessing workers and future users. Cobalt is a California Proposition 65 carcinogen, and, in dust form, can cause asthma. Another concern: about half of the world's cobalt mining occurs in the southern Democratic Republic of Congo, where human rights and child labor abuses have been documented.[18]

Most non-catalytic organic additives appear more benign in terms of human health. Cellulose and gelatinized starch are the most common.[19] However, manufacturers also blend in proprietary desiccants and processing aids that may present health hazards.[20]

In addition to potential human health and environmental impacts, degradation additives might impact the durability of products made from post-consumer polyethylene. See Appendix A: Degradation Additives and Recycling for more information on common additives in polyethylene.

Reprocessing Additives

Incompatible plastics are routinely present in recycled polyethylene waste streams. Bands and sleeves on HDPE bottles, for example, are often made of polyvinyl chloride (PVC). The rise of single stream recycling further contaminates the feedstock. Single stream recycling may help boost recycling rates (the amount of waste diverted from landfills), but it also leads to increasingly mixed bales of recycled plastics coming from material recovery facilities (MRFs).

As the Society of the Plastics Industry recently noted, one of the main disadvantages of single stream recycling is that "end products are more contaminated."[21] An American Chemistry Council study found that in some MRFs, bales of pigmented HDPE contain up to 5.5 percent contaminants, mainly other plastics.[22]

Companies that produce resins from recycled polyethylene sometimes add new (virgin) chemicals to their batches to help blend polyethylene with different polymers (most often polypropylene). These additives improve the recycled plastics' strength and impact resistance,[23] and make their performance more competitive with virgin resins.[24]

Recycled plastic producers, including plastic lumber companies, use ***compatibilizers*** to blend polyethylene with other polymers.[25,26] In addition, ***stabilizers*** help to restore the strength of recycled polymers closer to that of virgin polyethylene. (Additives that provided strength to virgin polymers become degraded over a product's service life.)

Stabilizer mixtures often include hindered amine light stabilizers (HALS, typically added at around 0.1-0.5 percent by weight of the feedstock) and antioxidants (around 0.5 percent).[27] HALS and antioxidants are common components of virgin polyethylene resins, too, and are not known to have significant human health hazards.

Most often, maleic anhydride (MA) modifies these compatibilizers.[28] According to the US Environmental Protection Agency, "Chronic exposure to maleic anhydride has been observed to cause chronic bronchitis, asthma-like attacks, pulmonary edema, upper respiratory tract irritation, eye irritation, and dermatitis in workers."[29] MA-modified compatibilizers contain residual maleic anhydride at proportions as high as 1 percent.[30] There is no known threshold at which maleic anhydride does not cause respiratory sensitization. However, Dow Chemical says that once MA is in the presence of ambient moisture, it rapidly hydrolyzes to maleic acid, which is not a known asthmagen, and thus "the product as shipped is not expected to cause respiratory sensitization under recommended conditions of use."[31]

Other common compatibilizers are block copolymers, such as styrene-butadiene-styrene block copolymers used with HDPE film and LDPE blends.[32] Various doses yield different properties for different applications. In some cases, processes blend in block copolymers at proportions as high 20 percent for HDPE and 50 percent for LDPE.[33] These types of copolymers can contain residual impurities of concern including styrene monomer, which is a carcinogen.[34] However, the limited safety data available for block copolymers used in recycling polyethylene does not include information about these residuals.[35]

Mixed-metal organic catalysts, usually based on titanium or zirconium are less conventional recycled polyethylene compatibilizers.[36] Their use is limited. According to the Society of the Plastics Industry (SPI), "where there are varied recycle streams, the use of organometallic esters has to be investigated more thoroughly and its efficacy established."[37]

Legacy Contaminants

Plastic containers can host a variety of materials, from water and milk to detergent, pesticides, oil or antifreeze. When recycled, consumer products absorbed in the plastic container may be along for the ride.[38]

Processors have been concerned about these contaminants since the polyethylene recycling industry emerged in the 1990s. The plastics industry examined whether contaminants in post-consumer recycled plastics would survive reprocessing. Their studies found that typical processing practices – washing the post-consumer plastic, melting it, then extruding it into resin – did not remove contaminants with similar solubility attributes. Six of the eight processing practices tested yielded resins that exceeded Food and Drug Administration (FDA) regulatory thresholds for safety.[39]

To summarize: our analysis found potential environmental and health threats from various inputs, such as cobalt in degradation additives, residual carcinogens and respiratory sensitizers in compatibilizers, and contaminants absorbed in packaging. However, our research did not find evidence that significant amounts of high hazard substances are in feedstocks that typically get processed into recycled content building products. Relative to other waste streams we examined for the Optimizing Recycling series, post-consumer polyethylene scores a "Green – Very Good" for Environmental and Health Hazards.

SUPPLY CHAIN QUALITY CONTROL AND TRANSPARENCY

A decade ago, CalRecycle funded a survey on plastics recycling processors in California. Their survey's intention was to help improve the quality, profitability, and consistency of post-consumer resins, including polyethylene. Researchers found "inconsistent quality control of incoming plastic," "poor documentation," and "incomplete process control." Testing was a "quality area of concern." They recommended standardizing testing procedures for residual additives and contamination.[40]

Very recently, the industry has moved towards standardization. Until now, building product manufacturers have worked around these issues through a variety of practices to ensure the quality of their final product.

Typical Practices

Some recycled polyethylene building product manufacturers rely upon strict feedstock sourcing controls, do not test post-consumer resins for contaminants, and do not attempt to clean the incoming recycled feedstocks. Others accept more diverse post-consumer recycled feedstock streams and conduct more extensive testing, processing, washing, and other decontamination techniques.

Supply Chain Controls

Polyethylene recycling begins with the collection and baling of post-consumer material from various sources. Sources of feedstocks most commonly used in building products include large grocery and retail stores (LDPE shopping bags), warehouses (polyethylene films are often used to wrap products for shipping), and curbside and drop off recycling (HDPE bottles).

Purchasers of post-consumer recycled polyethylene feedstocks are far less likely to use plastic scrap coming from MRFs than better-controlled sources.[41] While strict source control helps to ensure that feedstocks contain minimal unknown substances, the general trend is in the other direction, towards increasingly contaminated bales of plastic scrap generated from MRFs. A new protocol from the Association for Plastics Recyclers allows just 2 percent total contaminants, and has zero tolerance for some contaminants.

Instead, recycled polyethylene building product manufacturers prefer recycled bottles and films from more reliable sources. These include shipping distribution centers, retailers, grocery stores and other retailers, and certified California Retail Value (CRV) recycling centers. Bags and film collected at grocery and retail stores are important sources for this industry, which maintains a database of drop-off centers and what each location will accept at http://www.plasticfilmrecycling.org/s01/s01dropoff.html.

A high-information supply chain helps to ensure the quality of materials that are ultimately used in building products. Many manufacturers rely upon long-term contractual arrangements with suppliers, in which the origins and quality of the feedstock are well-understood. Most building product manufacturers in the U.S. know where their recycled polyethylene feedstocks come from, and how much contamination (moisture, volatiles, etc.) is present.

This knowledge also can reduce operating costs by eliminating the need to clean the source material. Some manufacturers rely upon source control to ensure that recycled materials are dry (i.e., no MRF or curbside plastics), meet their specifications and have minimal amounts of contaminants. They take bales of bags, wrap, and bottles from known sources, do not wash them, and instead process them directly into building products.[42]

Strict sourcing is standard practice in the corrugated drainage pipe industry, in which recycled HDPE is an increasingly common material. Manufacturers need consistent scrap sources because pipes used in transportation projects must meet American Association of State Highway and Transportation Officials (AASHTO) or American Society of Testing & Materials (ASTM) performance standards.

Recycled drainage pipe market leader Prinsco uses up to 40 percent post-consumer HDPE in its ECOFLO®100 polyethylene pipe. It has testing labs at each of its 11 facilities to ensure quality standards, and claims that their manufacturing processes include "on-site quality control managers and extensive testing protocols to assure highest product quality and performance."[43]

Sorting and Cleaning

Some plastic lumber companies obtain recycled plastic from less expensive sources. These feedstocks may be more contaminated with different types of plastics, volatile substances, and moisture. To ensure that recycled plastic does not compromise performance, these companies typically test and sort incoming feedstocks. Plastic scrap may be sorted by hand or automatically, most commonly with near-infrared spectroscopy, which identifies different plastics based on patterns of infrared light.[44]

Fiberon's plant in North Carolina uses a mix of detergent bottles, grocery bags and other packaging to make recycled plastic decking. "Upon its arrival, the polyethylene must undergo a battery of tests, including thermal, moisture, and infrared analysis," says Fiberon. "These tests will confirm the molecular structure of the polymers as well as give our team insight into the history of that specific sample. Our inspectors look at the individual physical properties of the samples, check for possible degradation, and determine whether any contaminants are present that might have been incorporated during prior manufacturing processes. If the samples meet strict Fiberon quality requirements, they are staged in the warehouse, where they will undergo further inspection. If the samples fail, they are sent to alternate recycling operations with less stringent requirements."[45]

Some processors take additional steps beyond testing, including shredding, grinding, washing, and drying.[46] Armadillo Deck recycles contaminant-susceptible containers like detergent bottles. "Our recycling operation takes this plastic, grinds it, sterilizes it and treats it for further use in our lawn and garden products and composite decking materials," it explains.[47]

Ecoplast patented a process to use contaminated feedstock to produce recycled HDPE plastic pipes. This process begins with grinding recycled material into flakes, which is then exposed to heated gases. This heating removes any volatile organic compounds that would otherwise contaminate the processed feedstock.[48]

Best Practices

The U.S. Food and Drug Administration approves certain methods to ensure that polyethylene feedstocks do not introduce "unacceptable contaminant levels" into food grade products. Elements include:

- Strict source control, through techniques like those described above.[49]
- Secondary recycling processes to remove contaminants, such as solid state polycondensation.[50]
- No polymer additives in the recycling process.[51]

The best practices that FDA identifies for food grade products can also apply to building products. For example, the inventors of the Ecoplast technology used to make recycled HDPE pipes originally intended for this process to produce FDA-compliant recycled plastic. Currently, both pipe and lumber manufacturers appear to rely more upon strict source control than decontamination techniques.

Pipe manufacturers must comply with AASHTO and ASTM performance standards, so quality controls are most assured in this sector.

For plastic lumber, there is not yet this degree of multi-stakeholder standardization, but this year, the Association of Plastic Recyclers (APR) posted the industry's first testing protocols, benchmark specifications, and a grading system for bales of collected HDPE. It prohibits many contaminants and restricts others. There are no requirements for infrared testing or recommendations for decontamination techniques. It relies upon a combination of visually inspecting a truckload of baled plastic, and sorting through 225 pounds of sample material to determine whether a truckload of HDPE can meet its benchmark feedstock specifications.[52]

According to Steve Alexander, executive director for the APR, the industry association is also developing a testing protocol for polyethylene film.[53]

The building product industry's efforts to identify clean sources of recycled polyethylene, test and clean supplies that are more contaminated, and standardize testing procedures lead us to rate the supply chain controls for recycled polyethylene, as practiced in California, as "Green – Very Good."

GREEN JOBS & OTHER LOCAL IMPACTS

California's Department of Resources Recycling and Recovery (CalRecycle) estimates that recycling 1,000 tons of plastics in California creates 12.7 jobs. This includes 3.5 jobs for collection and processing, and 9.2 for manufacturing products using these collected materials. If the state meets its goal of reducing disposal of solid waste by 75 percent by 2020, plastics recycling and related manufacturing could generate over 25,000 new jobs.[54] "A higher volume of recyclables will also create manufacturing and recycling jobs and help contribute to California's competitiveness," notes Waste Management.[55]

Material contamination (as discussed above) and, perhaps even more significantly, materials exports threaten these projections.

CalRecycle cautions that "contamination of collected materials" and "export trends of recycled materials" may greatly impact future job growth.[56] Overseas markets inherit much of the value (and job creation) embedded in plastic scrap collected in California and the rest of the USA. Plastic scrap exports to Asia, for example, have soared since 2000. This trend continued through 2013, the most recent year for which data are available from the Society of the Plastics Industry. Of the plastic film collected for recycling in the US, only 42 percent was processed in the U.S. or Canada. Shippers exported the remaining 58 percent.[57] About 60 percent of polyethylene film scrap and 20 percent of HDPE bottles collected in the United States leave the country.[58] Ninety-five percent (95 percent) of the plastic scrap exported from the U.S. in 2012 went to China or Hong Kong.[59] Manufacturers in Asia use recycled polyethylene in place of virgin material "in order to lower production costs," according to PEMEX, the Mexican oil company.[60]

Should the practice of exporting recycled materials suddenly end, California does not currently have the capacity to absorb these materials into existing reprocessing facilities.[61]

There has been an interest in expanding domestic infrastructure to supply a growing market for post-consumer LLDPE films, according to a report prepared for the American Chemistry Council. However, the authors found that "until recently the strength of the export market made it difficult for domestic reclaimers to compete."[62]

While the potential for green jobs in California related to polyethylene recycling is considerable, the current prevalence of export markets, the growing contamination of feedstocks, and the limited capacity to process plastic waste in-state led us to evaluate this feedstock's Green Jobs potential as "Yellow – Room for Improvement".

ROOM TO GROW

A consultant to the Bureau of International Recycling (a global industry association) recently predicted that global demand for recycled plastics would nearly double in the next five years, from 45 million tons in 2015 to 85 million tons in 2020.[63] Antecedent evidence of such tremendous growth, unfortunately, is thin. Plastics recycling rates have remained quite low for a long time.

HDPE bottles are among the most frequently recycled plastics, but just one of every three bottles is recovered from the waste stream. The industry estimates that 28 percent of clear HDPE bottles and 34.9 percent of pigmented HDPE containers were recovered for recycling in 2013.[64]

Recycling of films is even lower. Overall, recovery rates for HDPE, LDPE and LLDPE films are around 10 percent of production rates. Plastic waste brokers export half of it, and the rest is processed in the U.S. and Canada.[65]

Steve Alexander, executive director of the Association of Plastic Recyclers, says the main thing holding back production is demand. "We believe there's a lot more untapped potential in building and construction," he said. "It's something people haven't thought about, it's beyond the normal paradigm."

The low capture rates suggest potential for growth. However, some building product manufacturers appear to be using more post-industrial, or even virgin, polyethylene than they did ten years ago.

Low Collection Rates

In 2005, the Healthy Building Network and Institute for Local Self-Reliance examined the market for lumber made from recycled plastic. The report rated 14 plastic lumber products as "most environmentally preferable" because they contained only polyethylene plastics and, according to the manufacturer at the time, at least 50 percent of the polyethylene was from post-consumer sources.[66]

At least eight of these 14 products remain on the market, but current literature reveals that most if not all have decreased post-consumer content in favor of pre-consumer (factory-generated) scrap or even virgin polyethylene.[67] Resco Plastics, manufacturer of MAXiTUF plastic lumber, explains, "Due to the current price increases for our raw material, Resco Plastics, Inc. is no longer able to guarantee its post consumer content."[68]

This reality betrays the significant macroeconomic and regulatory hurdles that stand in the way of substantial growth for the foreseeable future. In addition to the export, contamination, and infrastructure issues discussed earlier, other major hurdles include low collection rates, cheap energy, and the absence of regulatory mandates to boost the use of post-consumer recycled plastics in plastic products.

"The low collection rate of post-consumer HDPE in North America is a deterrent to its cost-effective use in consumer products," reports the Sustainable Packaging Coalition. The coalition attributes the generally low collection rate for plastics to the "lack of collection and reprocessing infrastructure, poor consumer participation in recycling, and a lack of domestic markets for the material."[70] The Association of Plastic Recyclers has long worried that there is "not enough plastic available. Plastics recycling has been supply-limited for over 95 percent of its existence."[71]

Cheap Energy

The low cost of energy from shale oil and natural gas is driving down production costs of all sorts of plastic resins made in the USA, and

December 31, 2015

APR The Association of Postconsumer Plastic Recyclers

January 10, 2016

APR The Association of Plastic Recyclers

One indication that there isn't much post-consumer plastic recycling going on is a recent name change. Last year, the leading plastics recycling industry association decided to drop the qualifier "post-consumer" from its name: the new name is simply, The Association of Plastic Recyclers. "It just more reflects what our members are already doing," said Steve Alexander. "They are not just restricted to post-consumer stuff. Good material is good material for our guys."[69]

leading many polyethylene manufacturers to dramatically increase production of prime (virgin) resins. "An avalanche of petrochemical and polymers capacity is coming in the US," chemical industry analysts observed in 2014. Nine petrochemical firms announced new or expanded polyethylene capacity. "In total, U.S. PE (polyethylene) capacity stands to jump by 7.1m tonnes, or 47 percent, to around 22.4 million tonnes/year if all the crackers and downstream plants, and stand-alone expansions take place." Most of the world's growth in polyethylene capacity is happening in the U.S. Gulf Coast, which is in the midst of a so-called "Shale Gas-Based Chemical Renaissance."[72]

The renaissance of virgin polyethylene production will test the economic viability of post-consumer recycled plastics, and underscores the need for policy commitments to recycled materials when the market fails.

Policies and Regulations

According to the plastics recycling industry, recycled content requirements can prevent polyethylene recycling from vanishing. These commitments can be regulatory, or driven by other stakeholders, including industry associations, shareholders, and consumers. "A lot of companies are expected to use post-consumer recycled content in their products," said APR's Steve Alexander.

For example, California plans to require that reusable plastic grocery bags contain a minimum of 20 percent post-consumer recycled material, a requirement that would double to 40 percent in the year 2020. These requirements are part of a reusable bag law up for vote on the state ballot this November.[74]

Plastics manufacturers acknowledge that they prefer voluntary measures. Alexander said there are "significant programs in place or about to be put in place to try and capture more consumer film" and predicted "spectacular growth."[75]

Regulators like CalRecycle believe that "a mandatory approach [is] necessary to achieve meaningful reduction of packaging disposed."[76] Higher recycling rates in other countries, where regulations and recycling targets are more aggressive than most of the United States, support CalRecycle's position. Six European countries "have already effectively eliminated the landfilling of municipal waste, reducing it from 90 percent to less than 5 percent in the past 20 years and reaching recycling rates of 85 percent in certain regions," according to the European Commission. The EC says "strong policy signals are needed to create longer-term predictability for investment and change so that materials, such as plastics, glass, metals, paper, wood, rubber and other recyclables, re-enter the economy as secondary raw materials at competitive prices."[77]

A growing number of local governments in California are requiring grocery stores to only offer reusable carryout bags at checkout, thus greatly reducing the consumption of lightweight plastic (polyethylene) bags. In 2013, Alameda County adopted a reusable bag ordinance. Results show that overall bag purchases by retail stores have declined by 85 percent.[73] In place of single-use bags, these laws typically promote the use of reusable bags that can be used over 125 times, including cloth, paper, and heavy-gauge polyethylene. Most recycling facilities accept heavy gauge LDPE bags that comply with this performance requirement. While single-use bag bans might reduce the supply of postconsumer polyethylene film, these laws also can boost demand for post-consumer polyethylene content in heavy-duty reusable bags.

- Bay Area Reusable Shopping Bag Ordinances

California sent one of those "strong policy signals" with the passage of California AB 341, which established a statewide goal to recycle, compost, or reduce at the source 75 percent of the state's solid waste by 2020.[78] So, too, is the state's planned reusable shopping bag law, which accomplishes both source reduction and the replacement of virgin material with post-consumer content.

Replacing Prime Production

The highest and best uses for post-consumer polyethylene are in applications where they are replacing virgin polyethylene, and thus fully close the loop. Plastic lumber company Trex recently started producing raw materials – recycled pellets – for use in other industries, including bag manufacturers. It is one of the first companies to sell recycled pellets as a direct competitor to and replacement for virgin polyethylene.

> **"If society paid the true price for virgin, fossil fuel-based plastic, then the true value of a circular economy would be clear."[80]**
>
> **- Trucost**

"In 2014, we entered new specialty material markets, leveraging two of Trex's core strengths – recycling and extrusion – and began manufacturing and selling polyethylene pellets made from recycled plastic into the plastic bag, film and sheet markets," reported Trex in its 2015 Annual Report. "**The pellets are designed to partially displace virgin and off-spec resin**, providing a lower cost alternative for original equipment manufacturers (OEMs)."[79]

> **The production of 1,000 pounds of virgin HDPE generates 1,478 pounds of carbon dioxide, according to the Sustainable Packaging Coalition. Virgin HDPE production has a global warming potential nine times higher than recycled HDPE, which generates 160 pounds of CO^2. Similarly, virgin LDPE generates 1,479 pounds of CO^2; recycled: 300 pounds.[81]**

This initiative shows the potential for post-consumer polyethylene to become more widely used in building products and other materials, and for this use to replace virgin resins. However, today's post-consumer polyethylene supply challenges and the coming flood of virgin resin, lead us to rate its "Room to Grow" as Yellow (Room for Improvement).

Conclusions

After evaluating the condition of feedstocks as delivered to building product manufacturers, the quality control systems that polyethylene recyclers have in place, the fates of the films and bottles that are collected for recycling, and the hurdles and opportunities to grow the market for its highest and best use, we have concluded:

- Biodegradation additives used in plastic packaging pose a grave threat to the value and usefulness of polyethylene feedstocks. These additives could degrade products like pipes and decking that are designed for very long service lives, thus lowering the reliability and value of this feedstock for many uses of recycled polyethylene.
- Other common additives in polyethylene feedstocks likely pose no human health concerns for recycling and manufacturing workers or building occupants.
- Some post-consumer polyethylene containers and packaging contain residual toxic substances like pesticides and motor oil. Most recyclers depend upon source control to avoid contaminated plastic wastes.
- Some recyclers use technologies like near-infrared spectrometry to sort incoming plastics and screen out contaminants. Others treat ground up recycled polyethylene by washing flakes and sterilizing them.
- The plastics recycling industry is just beginning to standardize its procedures for testing feedstocks for contaminants and establishing benchmark specifications.
- These efforts hold promise for improved supply chain control, but this industry lags other building sectors (such as flooring and other interior products) in disclosing content information to consumers.
- Maximizing the collection and reuse of post-consumer polyethylene could generate many jobs for Californians. CalRecycle projects that the state's mandate to reduce solid waste by 75 percent by 2020 could produce 25,000 new jobs, 18,000 of which would be in manufacturing.
- There is considerable room for this industry to grow and create green jobs. Current national recycling rates are about 33 percent for HDPE packaging and 10 percent for plastic films (including shopping bags).
- Most plastic waste collected in California is exported overseas, including 58 percent of plastic film and 20 percent of HDPE bottles. CalRecycle's projected job creation from recycling will only be realized if the plastic film and bottles remain in-state for processing and/or manufacturing.
- Mixed and low quality scrap materials are more likely to be exported than sorted and screened polyethylene scrap. The rise of single stream recycling via material recovery facilities is reducing the quality of polyethylene bales diverted from the waste stream due to excessive contamination. This reduces the likelihood that the collected plastic waste will replace virgin resins, or be used in building products made in California.
- Many plastic lumber manufacturers are using less post-consumer material than they did a decade ago, and are relying more upon post-industrial and even virgin polyethylene to make up the difference.
- This trend indicates a stagnating industry that faces considerable macroeconomic challenges. Primary polyethylene production in North America is on course to grow 50 percent thanks to a cheap energy-driven massive expansion in ethylene cracker capacity on the Gulf Coast. Simply put, recycled polyethylene is losing any margin it has to virgin polyethylene.
- Consumer demand for post-consumer content and regulatory mandates like the tentative California requirement that reusable bags contain post-consumer material appear to be the best hopes for increasing the use of high quality post-consumer polyethylene in building materials.

Most post-consumer polyethylene film recycled in the U.S. does not replace virgin polyethylene resin production. When manufacturers use post-consumer film, they usually produce products (such as wood/plastic composite lumber) that are quite different from the source material (like shopping bags).[82] Closing this loop will require recyclers to produce resins that are of sufficient quality that they can replace virgin production.

This linear, rather than circular, path (collection to new production to disposal, rather than back to collection and new production) reduces the environmental benefits of recycling. There are short-term benefits from diverting these wastes from other fates, like landfills or incinerators. And, hopefully, post-consumer polyethylene's presence in building products is replacing other materials that have greater impacts on human health and the environment (such as other plastics that include more problematic additives or legacy contaminants).[83]

Optimally, recycling reduces humanity's consumption of Earth's dwindling resources. Post-consumer content should be functionally and qualitatively equivalent to primary content, and satisfy manufacturer demand that only primary material previously served.

Recommendations

Stakeholders can take these steps to optimize the collection and use of post-consumer polyethylene content in building products made and sold in the Bay Area of California and beyond.

For the Plastics Manufacturing Industry:

- Label all substances that are present in the final product, including (and especially) degradation additives.
- Stop using degradation additives.
- Replace virgin polyethylene with post-consumer polyethylene wherever feasible.
- Establish industry-wide targets to cap and reduce overall primary polyethylene production.

For Biodegradability Additive Manufacturers:

- Stop marketing these additives for use in products that may become part of the post-consumer scrap market.
- Until production ceases, add a marker to the additives that helps recycling facilities identify plastics that contain biodegradability agents.

For Polyethylene Packaging Manufacturers:

The highest value polyethylene feedstocks are not pigmented, do not have direct printing on them, do not have rings or liners, and minimize the use of adhesives, according to the Sustainable Packaging Coalition.[84] The following recommendations can lead to greater circularity of the packaging materials industry:

- Design resins and products with recycling in mind.
- Seek renewably sourced and/or post-consumer recycled inputs for polyethylene that displace the need for finite fossil fuel inputs.
- Use only compatible plastics in caps, closures, and wraps.
- Refrain from direct printing and liners.
- Minimize the use of adhesives.
- Never add biodegradability additives.
- Replace virgin polyethylene with post-consumer polyethylene wherever feasible.

For Recyclers:

- Improve contaminant screening through infrared spectroscopy and other sorting technologies.
- Continue to establish industry wide standards for supply chain control, testing procedures, and allowable and prohibited contaminants.
- Improve contaminant removal processes, especially when using lower grade feedstocks.
- Clearly communicate the origins of recycled content and the contaminants potentially present in processed feedstock to downstream consumers and the general public.

For Building Product Manufacturers:

- Design with recycling in mind.
- Avoid creating compositions that can't be recycled at the end of life.

- Communicate recycled content clearly on labeling and other consumer communication.
- Make communications transparent by identifying the sources for any recycled content, the actual percentage of post-consumer content in an individual product, and all of the intentional ingredients, including non-reactive processing additives, on product labels and online systems such as the Health Product Declaration and the ILFI Declare database.
- Obtain third party verification of recycled content.
- Incorporate more post-consumer recycled polyethylene into building products, provided those feedstocks have been processed using to the best standards described above.

For Consumers:

- Do not purchase polyethylene bottles and bags that are labeled as degradable.
- At home, separate plastic film (like bags) from other recycled materials and take them to a local drop-off center, easily found through an online database (see http://www.plasticfilmrecycling.org/s01/s01dropoff.html).
- If purchasing plastic lumber, seek products with the highest amounts of post-consumer recycled polyethylene.
- When shopping, use bags that can be reused many times. California's planned single use bag law, for example, requires that bags must be designed for being used at least 125 times.[85]

For Government Agencies:

- Avoid single stream recycling. Retain bottle bills and similar incentive policies that segregate plastic wastes and increase the value of recycled content.
- Invest in recycling infrastructure, including loans and grants for private operators in order to better screen, test, sort and clean plastics.
- Establish minimum post-consumer content requirements for plastic lumber and non-potable piping products.
- Consider incentives for manufacturers that utilize local feedstocks, that are made within the local economic area, and that incorporate recycled content plastics into the products.

Appendix A: Degradation Additives & Recycling

The most critical concern related to degradation additives is the chance that they could jeopardize the performance of products made from post-consumer polyethylene.

Designing a product to fall apart is fundamentally at odds with recycling and resource conservation. "If the additives do their job, the plastic item will 'fall apart'. The question is when?" says the Association of Plastic Recyclers.[86]

Producers of organic degradation additives claim that their formulations degrade only "when it is surrounded by microbes present in a landfill environment" and "will only biodegrade at the end of the usable product life, if the plastic product is not recycled first." [87] But many building products that incorporate recycled polyethylene, like plastic decking and pipes, come into contact with water, and often host molds, which are microbes. Trex, one of the largest manufacturers of plastic lumber from recycled polyethylene films, says it "cannot support the introduction of oxo-biodegradable polyethylene materials into traditional recyclable polyethylene streams" unless long term durability testing finds no adverse effect on their products.[88]

We agree with the post-consumer plastics recycling industry, which includes many of the world's largest chemical companies. The industry argues there is no economic or environmental reason to use these additives in plastics at all, and has attempted to squash the market through education.[89] "Degradable additives potentially endanger post consumer plastic recycling since it remains unclear how these additives might affect the many next-life products made from recycled materials in terms of quality, performance, safety, and lifespan," notes the Association of Plastic Recyclers.[90]

Manufacturers of these additives continue to target grocers and retailers, according to the plastics industry. Recyclers are explaining to retailers why adding degradation agents to plastic bags is not a good idea. These outreach efforts, so far, appear to be working. "We're assuming it's a fairly small percentage of the post-consumer stream, maybe one to two percent," said Steve Alexander, executive director of the Association of Plastic Recyclers.[91] Plastic lumber producers say they have not seen any impact on their products yet.

In addition to potential impacts on recycling, some in the industry say the biodegradation industry undermines anti-litter campaigns, and engages in deceptive advertising.

The Society of the Plastics Industry (SPI), a trade association, noted earlier this year that efforts to prevent littering "could actually be damaged by giving users of plastic items the impression that those items might vanish harmlessly if discarded into the environment."[92]

The Federal Trade Commission (FTC) has challenged how manufacturers advertise both types of additives. A 2006 American Chemistry Council survey found that 60 percent of consumers believe that a package described as biodegradable will disappear in less than a year. "The key point is that only a portion of the additive will biodegrade and there is no data to show that the remaining 95 to 99 percent of the plastic package will also biodegrade," notes the BPI.[93]

The FTC has served notice to the entire industry not to feed this misconception. Last year, the commission determined that ECM BioFilms' claims that "plastics treated with ECM's additive would completely biodegrade in a landfill within nine months to five years" were false and unsubstantiated. In 2014, the FTC sent letters to 15 companies that market plastic waste bags as "oxodegradable." It warned the manufacturers that "these bags may be no more biodegradable than ordinary plastic waste bags when used as intended."[94]

California public law forbids the marketing terms "degradable" or "biodegradable." The law explains, "Given the complex nature of biodegradation and the fact that most plastic products will travel through multiple environments from the time of manufacture to the time of final disposition, and given the intrinsic constraints of marketing claims, including the space on the plastic product, there is no reasonable ability for plastic product manufacturers to provide an adequate disclaimer qualifying the use of these and like terms without relying on an established scientific standard specification for the action claimed." Violations are punishable by civil penalty.[95]

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