HEALTHY BUILDING NETWORK

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A Department of the City and County of San Francisco

Optimizing Recycling:
Criteria for Comparing and Improving Recycled Feedstocks in Building Products


A Collaboration between StopWaste and the Healthy Building Network with support from the San Francisco Department of the Environment

2015

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.

San Francisco Department of the Environment (sfenvironment.org) is an agency of the City and County of San Francisco. SF Environment creates visionary policies and innovative programs that promote social equity, protect human health, and lead the way toward a sustainable future. SF Environment puts its mission into action by mobilizing communities and providing the resources needed to safeguard our homes, our city, and ultimately our planet.

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ABSTRACT

Global industry has made progress toward a world in which more efficient use of resources, including recycling, helps to reduce impacts on the natural systems that support life. However, contamination of recycled-content raw material (or "feedstock") with potentially toxic substances reduces feedstock value, impedes growth of recycling rates, and can endanger human and environmental health. This paper provides findings and recommendations about how progress in resource use efficiency and recycling can occur along with the production of healthier building products. This paper is based on the review of eleven common recycled-content feedstocks used to manufacture building materials that are sold in California's San Francisco Bay Area. It provides manufacturers and purchasers of building products, government agencies, and the recycling industry with recommendations for optimizing recycled-content feedstocks in building products to increase their value, marketability and safety.

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Foreword

The building products industry is at a critical crossroads.

In California and other states where green building is increasingly becoming standard practice, demand for recycled-content building products has never been higher. Insulation products, structural components, roofing, siding, flooring, piping, furnishings, interior finishes and myriad other building materials are now readily available with post-consumer recycled content. These products perform as well as, and are generally priced competitively with, their non-recycled counterparts. This increased demand, in turn, promotes a healthy recycling infrastructure, creates more green job opportunities, and helps us address some of our most pressing environmental concerns such as climate change, pollution, natural resource depletion and habitat destruction.

However, concurrent with this growing demand for recycled-content building products is a growing call for transparency of product ingredients. Increasingly, owners and occupants want assurance that the carpet, furniture, paint, glues, fabrics, plastics and other materials in their buildings are healthy and safe, and that they won't burden future generations with a legacy of pollution and toxic waste.

This push for greater transparency applies to recycled products as well as to those made with virgin materials. While the environmental benefits of recycling and recycled content products are undeniable, some recycled content materials are known to contain toxic substances that we would prefer to avoid. Which materials contain these chemicals? Where do the chemicals come from? Can those chemicals be avoided? The gaps in our knowledge about recycled-content feedstocks represent an opportunity for greater exploration, insight, and improved industry best practices.

This white paper from the Healthy Building Network makes important contributions to our body of knowledge about recycled raw materials. The paper is an umbrella report summarizing research on 11 different recycled feedstocks; each of these will be described in a separate, more detailed report of its own. The effort is intended to help building products purchasers, manufacturers and other stakeholders make decisions that improve the safety, value and marketability of recycled-content feedstocks. These improvements will create greater confidence in the safety and performance of recycled-content products, driving a virtuous cycle that leads to higher recycling rates and greater benefits to public health, the economy and the environment.

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CHAPTER 1
Introduction

Since May 2014, the Healthy Building Network, funded by and in collaboration with StopWaste, with additional support from the City of San Francisco Department of the Environment, has been evaluating post-consumer recycled-content raw materials (or "feedstock") used in the manufacturing of building products. This document contains our overall findings, and we are separately publishing 11 in-depth evaluations of individual materials that are among the most common recycled-content feedstocks found in building products in California.

PROJECT GOAL

To identify best practices that will improve the safety and increase the use of post-consumer recycled feedstock in building products sold in the San Francisco Bay Area.

Our goals are to:

- identify and reaffirm the positive attributes of recycled-content feedstock in building products,
- identify the potential human or environmental health hazards in recycled feedstocks,
- identify feedstock sources or processing practices that reduce those hazards, and
- provide recommendations for optimizing feedstocks to increase post-consumer recycling rates and improve recycled content value.

Table 1 lists the feedstocks that are the subject of this evaluation and building products in which they are commonly found. As of October 2015, HBN has completed the evaluation of post-consumer polyvinyl chloride and glass cullet feedstocks used in building products; evaluation of the nine remaining feedstocks is underway. As each recycled feedstock optimization report is completed, it will be posted at http://healthybuilding.net/content/optimize-recycling.

Examining feedstocks such as post-consumer polyvinyl chloride or nylon 6—as opposed to end products like vinyl floor tiles or nylon carpet—allows us to identify issues applicable to a wide variety of building products. We limited this research to post-consumer recycled-content feedstocks, not post-industrial or pre-consumer feedstocks, since the post-consumer material supply chain tends to be less understood than pre-consumer feedstocks.

This umbrella report and the 11 individual feedstock optimization reports that HBN is developing are intended for the following audiences:

- Manufacturers that use recycled feedstocks in building products;
- Purchasers that buy or specify recycled-content building products;
- Government agencies, organizations that offer product rating systems, and developers of standards pertaining to recycled-content products;
- Recycling industry actors such as collectors, processors, and vendors of recycled-content feedstocks.

TABLE 1. **Recycled-Content Feedstocks Evaluated in this Project**

Recycled-Content Feedstock	Potential Uses in Buildings
Polyvinyl Chloride (PVC)	Window frames, resilient flooring, carpet, roofing membranes, acoustical ceilings, wall protection, wall covering, electrical wiring and cables, pipes, decking, trim and molding, siding, cabinetry, coatings on metals, glazing tape, window blinds, expansion joints, upholstery
Nylon 6	Carpet face fibers, insulation facing, sanitary ware, upholstery, adhesives
Nylon 6,6	Carpet face fibers, resilient flooring wear layer, wall covering, upholstery, adhesives
Polyethylene	Adhesives, flooring, wall protection, carpet backing, insulation, wall protection, grout, sanitary ware, pipes, pipe insulation, vapor barriers, sheet membrane, decking
Glass Cullet	Fiber glass insulation, acoustic paneling, aggregates, Type X (fire resistant) wallboard, window glass, pavement (glassphalt), construction fill, sandblasting, terrazzo floors, tiles, countertops, carpet backings
Recycled Asphalt Shingles	Roofing products, road products, base/fill materials, adhesives, moisture barriers, aggregates, insulation facing, concrete
Reclaimed Asphalt Pavement	Roofing products, road products, base/fill materials, adhesives, moisture barriers, aggregates, carpet backing, insulation facing, concrete
Ground Tire Crumb Rubber	Roofing, fill, flooring, waterproofing membranes, pathway/sidewalks, artificial turf fill, landscape products
Recycled Wood Fiber	Engineered wood flooring, laminates, particleboard, medium density fiberboard (MDF), ceilings, composite wood decking, door and window frames, cellulose insulation, exterior siding
Steel	Fabricated metal products, metal decking, wall studs, conduits, ducts, structural steel, doors, fasteners, flashing, rebar, pipe hangars, wire mesh, drapery, pipes
Flexible Polyurethane Foam	Carpet pad, furnishings

Green Building Drives Growth—and More Scrutiny—of Recycled-Content Products

Once a fringe element of the construction market, green building is now mainstream in California, the United States, and many other parts of the world.[a] Leading government agencies, nongovernmental organizations, companies, and environmental groups have embraced the multiple benefits of green buildings, not least of which is the use of recycled-content building products and the commensurate diversion of waste from landfills and incinerators.

When considering the building industry's full range of impacts on natural resources—including building product manufacturing, building site preparation, construction activity, and building occupancy and operations—this sector accounts for about 40% of all raw materials used globally.[1] Thanks to the rapid uptake of green building, as well as greater overall awareness of the need to conserve resources, recycling rates have increased significantly in California and the United States in the past 15 years.[2]

a. In 2012, 41% of all nonresidential building starts in North America were green, as compared to 2% of all nonresidential building starts in 2005. (McGraw Hill Construction. Green Building Market Sizing, drawn from Dodge Project Starts and Construction Market Forecasting Services, as of March 2012. 2012.) Additional statistics on the green construction market are available at http://www.usgbc.org/articles/green-building-facts

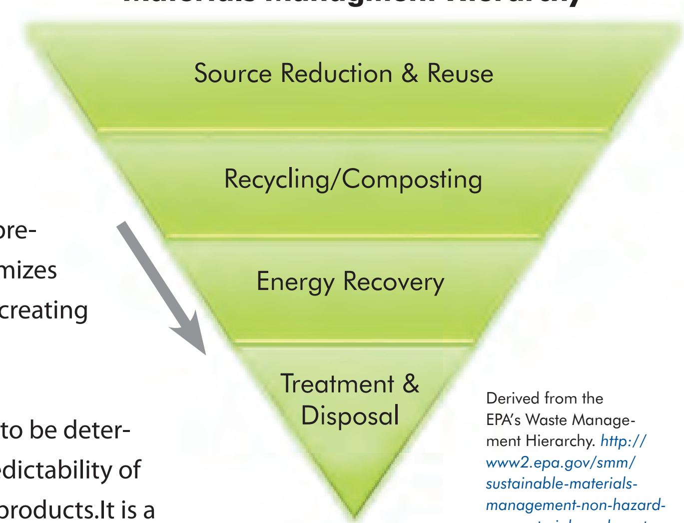
The growth of recycled-content building products, combined with a push for greater supply chain transparency driven by the green building movement and other progressive procurement policies, has led to increased scrutiny of recycled-content products and growing concern that some recycled feedstocks may include questionable substances that have the potential to harm human or environmental health. Building product manufacturers and purchasers are faced with the challenge of balancing the considerable benefits of using or buying certain recycled products with the potential that those products may have less than desirable characteristics. For example, the post-consumer PVC feedstock used to make new vinyl flooring may come from old PVC cables and wires that contain high levels of heavy metals, problematic plasticizers and even polychlorinated biphenyls (PCBs).[3]

There are cases where feedstock contamination may not pose serious human or environmental health risks, and other cases where screening out or being very cautious of the feedstocks is important. In addition, concerns related to the globalization of the materials supply chain, including problematic labor practices in developing countries, and transportation impacts of shipping materials great distances, are contributing to the call for greater scrutiny of recycled-content feedstock.

Materials Management Hierarchy

While this paper focuses on recycling and recycled-content materials, the authors of this report value material reuse as an integral part of a more circular economy. Reuse (and source reduction) is the path of maximal sustainability, and therefore the top of the materials management hierarchy. Reusing materials in their current form represents a product's "highest and best" use, which minimizes pollution, waste, and energy inputs associated with creating new or recycled-content products and materials.

Materials Managment Hierarchy



Derived from the EPA's Waste Management Hierarchy. *http://www2.epa.gov/smm/sustainable-materials-management-non-hazardous-materials-and-waste-management-hierarchy*

Systematic reuse can require material specifications to be determined by opportunity, matched to the scale and predictability of sources—which is not viable for many projects and products.It is a practical necessity, therefore, to optimize recycled content feedstocks because of their widespread use throughout the building products industry.

Many resources are available for project teams to incorporate as many reused materials as possible, including the excellent Design for Reuse Primer by Public Architecture (http://www.publicarchitecture.org/reuse/pdf/Primer-Online.pdf), and from the Building Materials Reuse Association (http://bmra.org).

This report and the 11 individual feedstock evaluations are intended to help building products purchasers, manufacturers and other stakeholders make decisions that improve the safety, value and marketability of recycled-content feedstocks.

Risk Assessment in the Real World

When evaluating the potential environmental and human health impacts of recycled feedstocks, it's important to understand the difference between hazard and risk.

Information about potentially hazardous contents in recycled feedstock (in particular, legacy substances, contaminants incorporated during service life, and cross-contamination from commingled source materials) is more readily available than ever. But to assess risk—that is, the chance that negative impacts will actually occur—it is essential to consider not just the presence of a potentially harmful ingredient but the likely levels of exposure of that ingredient to humans and the environment all along the product lifecycle. The fact that a recycled feedstock contains a hazardous chemical substance doesn't necessarily preclude its use, especially if the amount is present at biologically inconsequential levels, or levels below thresholds of concern.

In a perfect world, a full risk assessment would be available for all contents and all products, allowing for a purely quantitative basis for product design and purchasing decisions. But full risk assessments remain rare and expensive. Those that exist have many challenges that may include a focus on acute rather than chronic or persistent risks, omission of important scenarios for unintentional exposure, lack of applicability to at-risk populations such as young children and pregnant women, or use of a large number of assumptions that render their results questionable. In reality, where we must make decisions based on the imperfect information available, reducing or eliminating hazards is the most effective means for limiting risks to human and environmental health.

In this report and our ongoing research, we have tried to strike a balance between a risk-based and hazard-based approach. We acknowledge the urgency of closing the loop in the manufacturing cycle by incorporating as much recycled material as possible into products. Failure to do so contributes to a suite of devastating problems, including climate

Fly ash landfill, AES Cayuga power plant, Lansing, NY.

change, resource depletion, and pollution. On the other hand, human and ecosystem health concerns—including growing evidence that the rise of certain childhood diseases is connected to environmental exposures to chemicals of concern[4] —may make it essential to limit recycled content where dangerous substances exist and/or systematically remove them from circulation wherever possible. Therefore, in this report and our ongoing feedstock evaluations, we prioritize which hazards found in recycled content feedstocks are the most important to address, and provide recommendations for optimizing recycled-content feedstocks in building products to increase their value, marketability and safety.

Findings and Recommendations Summary

Although HBN's recycled feedstock optimization study is still underway, several major findings have emerged, allowing us to make some general recommendations for improving the safety, value and marketability of recycled-content feedstocks in building products. These are summarized in Table 2 (pp. 8–10) and discussed in detail in Chapter 2.

Developing New Criteria for Evaluating Recycled Content

Green building certification programs such as LEED and GreenPoint Rated and green purchasing guidelines have generally given preference to products with a higher post-consumer recycled content compared to pre-consumer or post-industrial recycled content.[b] The assumption has been that post-consumer recycled content provides more value because it solves an environmental problem—what to do with products that the consumer no longer needs and has discarded. An empty plastic water bottle, for example, can be reprocessed into a new water bottle, a fleece jacket or a park bench. Buying products with post-consumer content changes the conventional linear model of make-use-discard to a closed-loop model of make-use-remake.

Pre-consumer recycled feedstocks (including post-industrial materials) are less likely to be discarded because manufacturers typically consider them to be valuable resources that can be reused in their manufacturing process or sold to another company for reuse. Because good business practice makes it likely that this manufacturing scrap will be reused, it's not as important that purchasers specifically demand products with pre-consumer content.

Green building certification programs such as LEED and GreenPoint Rated and green purchasing guidelines have generally given preference to products with a higher post-consumer recycled content compared to pre-consumer or post-industrial recycled content.

Within the green building industry and among government and private-sector purchasers who adhere to environmentally preferable purchasing guidelines, products with higher recycled content (either post- or pre-consumer) are both typically favored over products with all or predominantly virgin raw materials. Any type of recycled-content feedstock has generally been presumed to have a smaller environmental footprint than virgin raw materials that are harvested, mined or otherwise extracted from the earth.[c]

b. LEED, the predominant green building certification program, defines recycled content "in accordance with the International Organization of Standards document, ISO 14021—Environmental labels and declarations—Self-declared environmental claims (Type II environmental labeling)." Post-consumer material "is defined as waste material generated by households or by commercial, industrial and institutional facilities in their role as end-users of the product, which can no longer be used for its intended purpose." Pre-consumer material "is defined as material diverted from the waste stream during the manufacturing process. Excluded is reutilization of materials such as rework, regrind or scrap generated in a process and capable of being reclaimed within the same process that generated it."

c. Tools like the EPA's WAste Reduction Model (WARM) quantify the lifecycle benefits of recycling and recycled content. http://www3.epa.gov/epawaste/conserve/tools/warm/Warm_Form.html.

TABLE 2. **General Findings and Recommendations for Recycled-Content Feedstocks in Building Products**

Finding	Recommendations
1. Recycling remains an important and preferential result for materials at end of life compared to other options such as land-filling or incineration.	**Manufacturers:** Promote your company's use of recycled-content feedstock. Be transparent and vocal about the positive attributes of recycled-content products, such as reduced lifecycle impacts and resource conservation. Maintain credibility by seeking third-party verification of recycled content and using analysis & disclosure tools like Environmental Product Declarations (EPDs). If sources of recycled feedstock are suspected or known to contain contaminants that can harm human or environmental health, ensure suppliers are providing you with information and/or test results so that you can make appropriate decisions, including avoiding the worst offenders. Review these feedstock reports for additional guidance on specific materials that may have concentrations that cause concern. **Purchasers:** Continue to prioritize recycled content in purchasing decisions. Recognize that in many cases, the benefits of recycling outweigh the negatives, and that products made from virgin materials are not necessarily safer than the recycled products they may be replacing. In instances where the final product is likely to be in direct contact with humans or the environment, be extra vigilant in ensuring hazardous compounds are not present at levels that cause concern. **Government Agencies:** Diversion from landfills is an important strategy for addressing resource constraints and climate change. Continue to push for recycled-content products and invest in expanding recycling infrastructure wherever possible. **Recycling Industry:** Continue to engage with government, manufacturers and suppliers to encourage strong markets for recycled-content materials. Work with all parties, including supply chain actors, to better understand the questions raised in this report about certain feedstocks.
2. Contaminants reduce recycling rates and feedstock value. Product designers have the ability to eliminate or minimize problem-atic substances that can contaminate future recycled-content feedstocks.	**Manufacturers:** When formulating new products, manufacturers and their suppliers should identify and phase out problematic materials in products that can affect the quality of future recycled-content feedstocks. Adopt company-wide guiding principles that seek to substitute or reformulate problematic substances with safer alternatives. Follow green chemistry principles and engage with leading green chemistry industry groups to conduct alternatives assessments that avoid problematic substitutions. **Purchasers:** Ask manufacturers to assess and disclose all parts, materials and substances in their products. Give preference to manufacturers that support circular economy goals and do not use ingredients that will contaminate future recycled feedstocks. **Government Agencies:** Support product manufacturer efforts to better understand alternatives to problematic substances that can affect the future value of recycled-content materials. Encourage or reward manufacturers and suppliers that conduct full alternatives assessments of suspect chemicals to follow green chemistry best practices.

TABLE 2. **General Findings and Recommendations for Recycled-Content Feedstocks in Building Products** (CONTINUED)

Finding	Recommendations
3. Some recycled-content feedstocks contain substances of concern in quantities that exceed allow-able limits for virgin feedstocks. For many recycled feedstocks used in building products, there are no established thresholds of concern for toxicants.	**Manufacturers:** Require processors to screen incoming materials and test final products for substances of concern, and to disclose screening and testing procedures. If purchasing feedstock of unknown origin, screen feedstock to identify potential substances that could affect human or environmental health. **Purchasers:** Buy from manufacturers that acquire feedstocks from known sources, and that screen all feedstocks from unknown sources for contaminants of concern. Request that manufacturers disclose their full ingredient list for all products (including recycled-content substances). Urge regulators to adopt the same thresholds of concern for potential health hazards and exposure pathways for recycled-content and virgin materials, unless a good reason for an exception is found. Use standards and certifications pertaining to feedstock contamination when they are available. **Government Agencies:** Instead of exempting recycled-content materials from regulations, establish limits on concentrations of toxic material in recycled-content materials. Where thresholds exist for substances of concern in virgin materials, those same thresholds may also be suitable for recycled-content materials. In some cases, these thresholds may be categorized by the exposure potential of the final product. Establish best practice guidelines for dealing with banned substances if found in feedstocks or products that enter recycling markets. Encourage public and private investments and incentives for screening and removing contaminants from feedstocks used in building materials. Provide incentives such as subsidies, grants, tax incentives and loans to finance advanced recycling methods that ensure high quality feedstocks. Where market prices do not support the cost of rigorous screening and decontamination technologies, consider providing incentives for manufacturers or processors to innovate through collaborative research and development. **Recycling Industry:** Processors that supply feedstocks to manufacturers should screen incoming materials for substances of concern. Disclose procedures for screening incoming materials, and test final products for common hazardous contaminants and other substances of concern. Invest in processes that can remove problematic substances from feedstocks, such as depolymerization and other chemical recycling processes. Seek grants, subsidies, or other methods to lower the cost. **All Parties:** In the absence of regulatory action regarding toxic content in recycled-content feed-stocks or final products, government agencies, recyclers, industrial hygienists, purchasers and product manufacturers should collaboratively develop unified voluntary thresholds and methodologies for screening and testing, and work to incorporate this information into standards and certifications on recycled feedstocks.

TABLE 2. **General Findings and Recommendations for Recycled-Content Feedstocks in Building Products** (CONTINUED)

Finding	Recommendations
4. The risk of harm is highest where regulations are the most relaxed.	**Manufacturers:** Ensure that supply chain actors comply with labor and environmental regulations for sourcing and processing recyclable materials. Do not use recycled-content feedstock that exceeds thresholds of concern (see #3). Implement a company environmental management system (or augment one that already exists) to account for substances within recycled-content feedstock sources. **Purchasers:** Give preference to recycled-content products that are processed or manufactured in places with high standards for worker safety and handling. Require verified environmental health and safety reports, annual sustainability reports, or other documentation from manufacturers that explain how they protect worker and environmental health. **Government Agencies:** Create incentives such as procurement policies and financing that keep recycled feedstock within the region where it was produced, so that the impacts and benefits are shared by the origin community. Provide incentives such as grants and loans to finance advanced recycling methods that ensure high quality feedstocks. Include recycling workers and fenceline communities in the development of criteria for safe processing of recycled feedstock. **Recycling Industry:** Encourage investments in domestic recycling infrastructure where worker rights, labor laws, and environmental regulations are strong and enforced. Finance studies on the health and environmental impacts of lightly regulated processing facilities, such as those that process ferrous metal, wood waste and polyurethane foam.
5. In most cases, the origin and chain of custody of recycled feedstocks used in building products are not disclosed to purchasers and often are not known by the product manufacturer.	**Manufacturers:** Seek feedstock processors and suppliers that have third-party-verified chain of custody certification and that fully disclose the contents of their recycled feedstocks. In lieu of rigorous supply chain tracking, strategic evaluation including testing of feedstocks for substances of concern is the best option. **Purchasers:** Give preference to building product manufacturers and suppliers that provide third-party-verified chain of custody certification of the recycled content in their products. **Government Agencies:** Report publicly on the fate of materials diverted from the waste stream, including countries to which publicly collected recyclable materials are exported. If the fate of a diverted material is unknown, disclose the lack of data. **Recycling Industry:** Processors should fully disclose the contents of the recycled feedstocks they sell, including the presence of any hazardous substances or contaminants above thresholds of concern. The industry can use tools like the Health Product Declaration, a standard format for disclosing potential hazards in building product substances, to standardize disclosure and communicate the most important information to manufacturers and purchasers in the supply chain. Industry can also seek standards and certifications that validate chain of custody and recycled content sources of feedstocks.
6. There is inadequate infrastructure in California and the United States to process all the available recyclable material. Materials that could be recycled safely continue to be exported or lost to the landfill.	**Manufacturers and Purchasers:** Urge local, state and federal public representatives to promote domestic collection and processing of recyclable materials. Oppose trade deals that put domestic recycling industries at a disadvantage to foreign interests. **Government Agencies and the Recycling Industry:** Increase investments in domestic recycling capacity, especially in California. This includes processing capacity for hard-to-recycle materials like engineered wood products, through a combination of procurement incentives, innovative research and development, and investments in screening and processing technologies.

Recycled Content Terminology

The most widely recognized definition of recycled content is found in the ISO 14021-1999 Environmental labels and declarations—Self-declared environmental claims (Type II environmental labeling) standard, which defines pre-consumer and post-consumer materials as the following:

"**Pre-consumer:** Material diverted from the waste stream during a manufacturing process. Excluded is reutilization of materials such as rework, regrind or scrap generated in a process and capable of being reclaimed within the same process that generated it.

"**Post-consumer:** Material generated by households or by commercial, industrial and institutional facilities in their role as end-users of the product which can no longer be used for its intended purpose. This includes returns of material from the distribution chain."[5]

The terms pre-consumer and post-industrial are often used synonymously in green building product literature, though pre-consumer is a more restrictive term with respect to reclaimed in-house manufacturing scrap. In addition, pre-consumer is also used to classify recycled products such as coal fly ash or slag. The US Green Building Council's LEED rating system clarifies this by stating "the end product must be considered when determining whether a waste product is pre-consumer or post-consumer. For example, a power plant's end product is electricity, so waste products from the combustion of coal may be considered pre-consumer waste but not post-consumer; the power plant is not an end-use consumer of the coal."[6]

For the purposes of this report, we are not investigating pre-consumer recycled content feedstock, but future research efforts by this collaboration may take on this important recycled content material category.

As the green building industry and green purchasing programs have matured, however, it has become clear that the choice is no longer as straightforward as automatically valuing post-consumer content over virgin or pre-consumer content. In many cases, post-consumer content is clearly preferable. But some post-consumer recycled raw materials—due to their composition, their prior uses, or the ways in which they are collected and screened—may pose greater health or environmental hazards than alternatives made from virgin or pre-consumer content. The individual recycled feedstock optimization reports that accompany this umbrella report will help manufacturers, purchasers and the recycling industry to assess these concerns and develop protocols for improving the safety of recycled feedstocks.

This closer scrutiny of recycled-content building products is part of a broader movement in the building industry toward greater transparency of product attributes, material composition, and life cycle impact analysis.[7] The newest version of LEED (v4), for example, replaces credits that were earned for simply buying

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Ceramic cullet. Corning NY.

FIGURE 1. **Summary of Updates to Materials & Resources Credits in LEED v4 compared to LEED 2009.**

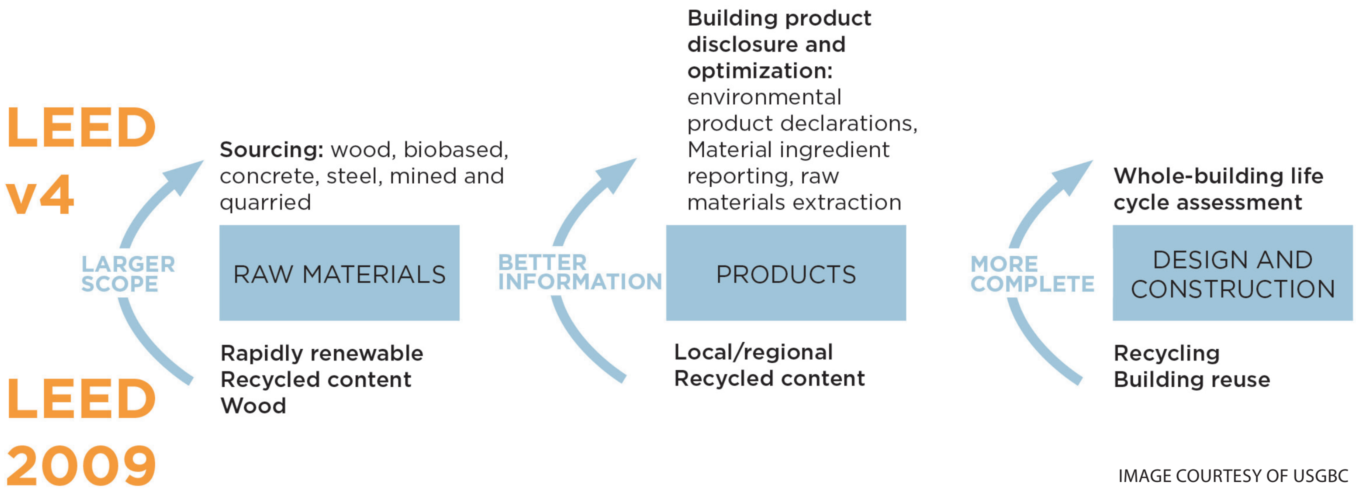


IMAGE COURTESY OF USGBC

recycled-content products with a multi-attribute evaluation framework that rewards disclosure and optimization of systematic product criteria (see Figure 1). Recycled content is now capable of being counted toward credits that focus on materials sourcing, disclosure, and lifecycle analysis of products, but in LEED v4 is no longer is an exclusive credit.

Other rating systems like the International Living Future Institute's *Living Building Challenge* and Build It Green's *GreenPoint Rated* program also have disclosure of product characteristics as part of their labeling programs. For instance, the Living Building Challenge requires the use of building materials that do not contain substances found on a list of chemicals of concern (called their "Red List"). And GreenPoint Rated gives points for selecting building products from manufacturers that have provided published Health Product Declarations (HPDs), a standard format for disclosing building product substances and their potential hazards.

Adding to this trend are recent media reports that draw attention to recycled-content products that may pose health concerns due to high levels of contaminants in the feedstocks. Media reports on synthetic turf play surfaces and their potential linkage to cancer rates in soccer players center on the recycled tire feedstock used as fill in those surfaces.[8] Recent studies have also found that workers in carpet pad factories have elevated body burdens of flame retardants from recycled polyurethane foam feedstock.[9] It is beneficial for the recycling industry and product manufacturers to anticipate criticism of questionable feedstock sources and to identify and disclose any hazards found in those feedstocks. Providing this information to manufacturers and consumers will allow them to make better-informed choices about products and the resulting exposure risk and hazardous content (or lack of hazardous content) of a product.

Four Criteria for Optimizing Recycled-Content Feedstock

As a result of these and other forces, investigations into specific recycled-content feedstocks are needed to better understand their environmental and human health impacts. We are contributing to this effort with our study of eleven recycled feedstocks commonly used in building products. To evaluate each of these feedstocks, we used the four criteria summarized here and described in detail in Chapter 3. From that evaluation, we are developing specific recommendations about each feedstock for manufacturers, purchasers, the recycling industry, and other stakeholders.

Why these four particular criteria? We sought a framework to better understand not only the content of the feedstocks, but also when, where, how and why the feedstocks were being contaminated, and what economic benefits are associated with the feedstock recovery industry. We started with four broad areas of investigation which became the basis of our new criteria for evaluation. First we asked what are the possible contaminants, residuals, additives, or other substances present in recycled-content feedstocks that may cause human or environmental hazard or risk in exposure?

> Investigations into specific recycled-content feedstocks are needed to better understand their environmental and human health impacts. We are contributing to this effort with our study of eleven recycled feedstocks commonly used in building products.

Once we identified those components of concern, we looked at whether there are certain steps in the supply chain that tend to contaminate the feedstocks, and whether those steps can be improved upon to increase feedstock value. How much of the supply chain is known, and how much remains opaque to consumers of feedstocks with respect to how contaminants are being added to feedstocks?

Finally, we asked: If the feedstocks can be cleaned up, through better controlling their sources or through screening or processing to eliminate substances of concern, what would be the value to the market for making such investments? In other words, if every feedstock were as pure as possible, would the economics of supply and demand support greater utilization of these feedstocks? Would the result lead to greater green job potential, or higher recycled content materials being incorporated into products?

Using the above questions to guide our investigations, we developed four criteria for evaluating recycled content feedstocks. The following describes them in more detail:

Environmental and Health Impacts

- Does the recycled feedstock's composition (including legacy content) pose significant hazards for workers, fenceline communities, building occupants, and the wider environment?
- Do the additives used in processing the recycled feedstock pose significant hazards?
- Can the hazardous constituents of the feedstock be removed from the waste stream, and if so, how and at what cost?

Supply Chain Quality Control and Transparency

- To what extent (scope and frequency) do recyclers of the feedstock screen for toxic contaminants?
- Are there industry practices in place throughout the supply chain to remove hazardous contents from the process, thereby maximizing the value of these materials?
- Do they have publicly available protocols?
- Do they disclose feedstock contents and residuals through transparency tools, such as the Health Product Declaration?[d]

d. The Health Product Declaration (HPD) is a format for disclosure of contents and associated hazards in building products. For more information, see http://hpdcollaborative.org.

Green Jobs and Other Local Economic Impacts

- Where are the feedstock's source materials recovered from, and where does the recycling take place?
- How many jobs are created by recovery and recycling of the feedstock source material? Specifically, what are the associated job and economic benefits and impacts from feedstocks collected from or manufactured in California and/or the western United States?

Room to Grow

- Is there potential to increase the recycling rate of the feedstock source material?
- Can the reprocessing of the feedstock and manufacturing of building products made with the recycled feedstock be increased domestically?
- Can demand for building products made with the recycled feedstock be increased?

We believe that the process of analyzing each feedstock with these four criteria will help to target areas for improvement and lead to actionable outcomes that will ultimately improve feedstock value. Specific recommendations for individual feedstocks are based on these criteria, and can be found in the corresponding evaluations published separately from this paper. Table 3 provides a preliminary summary of our evaluation of each feedstock using these four criteria. This table may change as HBN's research progresses and we finalize the individual feedstock evaluation reports.

Shredded tires and other recycled feedstocks, Lockport, NY.

TABLE 3. **Preliminary Post-Consumer Recycled-Content Feedstock Evaluation Summary**

	Criteria			
Post-Consumer Recycled Content Feedstock	**Environmental & Health Impacts**	**Supply Chain**	**Green Jobs**	**Room to Grow**
Nylon 6 Scrap	🟢	🟢	🟢	🟡
Glass Cullet	🟢	🟡	🟢	🟢
Polyethylene Scrap	🟢	🟡	🟡	🟢
Recycled Asphalt Shingles	🟡	🟡	🟢	🟢
Nylon 6,6 Scrap	🟡	🟡	🟢	🟡
Reclaimed Asphalt Pavement	🟡	🔴	🟢	🟡
Ground Rubber (from tire scrap)	🔴	🟡	🟡	🟡
Recycled Wood Fiber	🔴	🔴	🟡	🟢
Steel Scrap	🔴	🔴	🟡	🟡
Flexible Plyurethane Foam Scrap	🔴	🔴	🟡	🟡
Polyvinyl Chloride Scrap	🔴	🔴	🔴	🟡

KEY

🟢 **Very good:** As commonly supplied to manufacturers of building products sold in California, these post-consumer recycled feedstocks are as good (or superior) to comparable virgin or pre-consumer feedstocks.

🟡 **Room for improvement:** Some uses of these feedstocks in building materials are best choices, but in some cases additional analysis or research is needed before deciding on appropriate use. There is room for improvement, but overall, these feedstocks are frequently better options than using similar virgin or pre-consumer materials in building products.

🔴 **Significant concerns:** These feedstocks showed potentially higher levels of concern than their virgin or pre-consumer counterparts, and should be prioritized for deeper investigation and/or improvements in the supply chain.

⬜ Some of these feedstocks can be obtained from clean sources and will result in a very good (or "🟢") score. See feedstock evaluation report for recommendations.

🟩 Some of these feedstocks can be tested, processed or screened via identified best practices that will result in a very good (or "🟢") score. See feedstock evaluation report for recommendations.

CHAPTER 2

Findings and Recommendations

Recycled content continues to be a strong driver for choosing building products, especially those used in building projects that are LEED certified or GreenPoint Rated or that have to comply with green building codes, such as California's CALGreen code. In many cases, the benefits of recycling outweigh many of the concerns with the feedstock quality, sourcing, manufacturing processes, and end of life scenarios. Regardless, there are opportunities to improve all feedstocks, and important roles in this process for manufacturers, procurement bodies, government regulators, and the recycling industry.

> Many materials discarded in this country are exported to manufacturers outside of the United States who in turn supply building products, which can be contaminated by legacy pollutants, back to U.S. purchasers.

A major finding from our research thus far is that many recycled feedstock materials sold to building products manufacturers are not fully optimized to consider health and safety issues throughout the lifecycle of the feedstock or the end product. Some feedstocks are more contaminated than they need to be. This contamination reduces the feedstock's usefulness to manufacturers and can threaten the health of workers and users throughout the global supply and use chain. Many materials discarded in this country are exported to manufacturers outside of the United States who in turn supply building products, which can be contaminated by legacy pollutants, back to U.S. purchasers.

The good news is that opportunity lies within these challenges. Investments and incentives can greatly increase the capacity to produce safe, high value recycled feedstocks for domestic manufacture and use. For this to succeed, these three steps are critical:

1. **Manufacturers must make products more easily and safely recyclable** at the end of their useful life by eliminating substances that are hazardous to human or environmental health, and designing products for easy separation/reclamation from recycling processors.
2. **Materials collected for recycling should be processed locally whenever possible**, because of the more stringent health and environmental safety manufacturing standards in California (and much of the US as a whole) compared to many other parts of the world.
3. **Recycled feedstock processors must obtain materials from known sources and/or screen for problematic substances**, and ensure that the feedstock does not introduce toxic content above established thresholds of concern.

Combined, these efforts will improve recycled material recovery rates, reduce virgin material production, generate jobs and domestic manufacturing, and make buildings healthier and safer.

Each of the eleven individual feedstock reports identifies specific improvements in the supply chain that can optimize use of that feedstock in building products. Specific recommendations for each feedstock are found within those reports.

This chapter presents major findings that are broadly applicable across the range of recycled feedstocks we examined and provides general recommendations for improving the safety, value, and marketability of recycled-content feedstocks in building products. For a summary of these findings and recommendations, see Table 1 in Chapter 1.

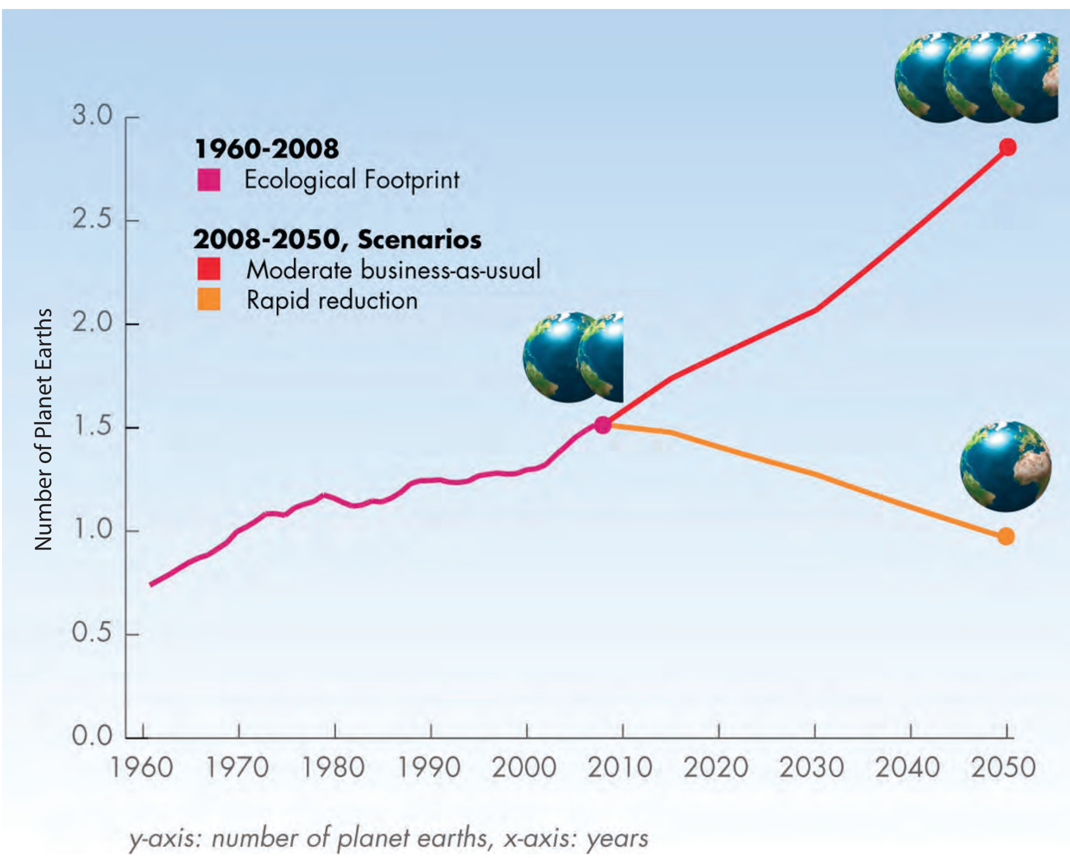
FINDING #1

Recycling remains an important and preferential result for materials at end of life compared to other options such as landfilling or incineration.

Discussion

Recycling matters. Generally, making use of materials in a closed-loop system is a superior materials management practice compared to landfilling, energy recovery, or incineration. This is especially true in today's global materials markets because the majority of products manufactured today will be discarded as waste within a year (see G-7 Alliance sidebar, see p. 19). As the US EPA's top waste official, Mathy Stanislaus, recently stated in an article with Bloomberg News, "We simply can't depend on new materials to drive the economy anymore.... We have to really recapture and recirculate these materials again."[10]

FIGURE 2. **World Footprint**



Residents of the United States generate nearly a ton of waste per person per year.[e] This is dwarfed by the nearly 50 tons of natural resource usage per person, per year that result from our industrial economy.[f] Put another way, the Global Footprint Network estimates that humanity uses the equivalent of 1.5 planet Earths to regenerate the amount of resources extracted and used in a single year. And developed countries have much larger footprints than those of developing countries; if all citizens of the world were to live by US standards, for example, the GFN estimates it would require the resources of approximately five planet Earths to sustain that quality of life.[11] The world demand for resources can not sustain this rate of extraction and the corresponding waste generation without serious consequences.

Optimizing recycling can play a major role in reducing or even reversing negative impacts associated with materials sourcing and extraction, and is a critical component of today's building materials manufacturing industry. Not only does it make good environmental sense, but recycling often makes good business sense as well.

In the US EPA's recently released report, *Advancing Sustainable Materials Management*, the agency estimates that 42 percent of U.S. greenhouse gas emissions are associated with the extraction or harvest of materials and food, production and transport of goods, use and end-of-life management.[12] Clearly, recapturing and reusing materials is important. The growing demand for finite resources on our planet makes the extended use and reuse of every material, and, ultimately, the establishment of circular material cycles, a vital target. Though recycling by itself won't result in a circular economy, continuing to incorporate recycled content feedstocks in products is an important step toward designing circular material flows.[13]

Optimizing recycling can play a major role in reducing or even reversing negative impacts associated with materials sourcing and extraction, and is a critical component of today's building materials manufacturing industry. Not only does it make good environmental sense, but recycling often makes good business sense as well. And recycling is the most well known environmental attribute on the planet.[14] Therefore, recycling and recycled content materials should be prioritized over new materials, and their impact reductions and success stories should be celebrated by manufacturers.

Recommendations

Manufacturers: Promote your company's use of recycled-content feedstock. Be transparent and vocal about the positive attributes of recycled-content products, such as reduced lifecycle impacts and resource conservation. Maintain credibility by seeking third-party verification of recycled content and using analysis & disclosure tools like Environmental Product Declarations (EPDs).

If sources of recycled feedstock are suspected or known to contain contaminants that can harm human or environmental health, ensure suppliers are providing you with information and/or test results so that you can make appropriate decisions, including avoiding the worst offenders. Review these feedstock reports for additional guidance on specific materials that may have concentrations that cause concern.

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e. US EPA estimates that US residents generate 4.40 lbs of waste per person per day, which equates to 0.80 tons per person per year ("Advancing Sustainable Materials Management: Facts and Figures 2013." Last updated July 29, 2015. Accessed September 2015 from http://www3.epa.gov/epawaste/nonhaz/municipal/pubs/2013_advncng_smm_fs.pdf).

f. Industrial economies require 45,000 to 85,000 kilograms of natural resources per person per year, equating to 50-94 tons per person per year impact (World Resources Institute. Resource Flows: The Material Basis of Industrial Economies. 1997. http://www.wri.org/publication/resource-flows).

The G-7 Alliance on Resource Efficiency

The recent Group of Seven (G-7) world leaders summit in Schloss Elmau, Germany, resulted in several important worldwide declarations and goals related to resource efficiency and recycling. Notably, the G-7 Declaration includes the establishment the G-7 Alliance on Resource Efficiency which places materials management (recycling) and resource efficiency near the top of the international bodies' priority list. The Declaration and its Annex state:

"… Data indicate that global raw material use rose during the 20th century at about twice the rate of population growth… Furthermore, *much of the raw material input in industrial economies is returned to the environment as waste within one year*."

The June 8, 2015 G-7 Declaration and Annex can be found at https://www.whitehouse.gov/the-press-office/2015/06/08/g-7-leaders-declaration and https://www.whitehouse.gov/the-press-office/2015/06/08/annex-g-7- leaders-declaration, respectively.

Purchasers: Continue to prioritize recycled content in purchasing decisions. Recognize that in many cases, the benefits of recycling outweigh the negatives, and that products made from virgin materials are not necessarily safer than the recycled products they may be replacing.

In instances where the final product is likely to be in direct contact with humans or the environment, be extra vigilant in ensuring hazardous compounds are not present at levels that cause concern.

Government Agencies: Diversion from landfills is an important strategy for addressing resource constraints and climate change. Continue to push for recycled-content products and invest in expanding recycling infrastructure wherever possible.

Recycling Industry: Continue to engage with government, manufacturers and suppliers to encourage strong markets for recycled-content materials. Work with all parties, including supply chain actors, to better understand the questions raised in this report about certain feedstocks.

FINDING #2

Contaminants reduce recycling rates and feedstock value. Product designers have the ability to eliminate or minimize problematic substances that can contaminate future recycled-content feedstocks.

Discussion

Contaminated feedstocks reduce recycling rates. For example, in Europe more than 66% of glass cullet is recycled, whereas in the United States the rate is under 30%. Glass manufacturers in the United States point to inconsistent supplies of quality cullet as the reason for lower utilization rates. Europe recycles more glass because it more aggressively identifies and eliminates contaminants. European glass fiber insulation manufacturers severely restrict non-ferrous metal content, a contaminant frequently found in recycled glass. For their part, European processors have invested in sophisticated technologies to scan cullet for non-ferrous metals and other contaminants. This is an indication of a virtuous cycle in which both recycling rates and recycled content are optimized. Clearly, manufacturers' design choices and purchasing specifications play a role in fostering a healthier recycling economy.

In a true closed-loop circular economy,[15] the materials that make up new products today will become the feedstock used to manufacture products in the future. Achieving this circular economy will reduce virgin material extraction and make use of the ample materials already in circulation, thus closing the loop. Designing new products that are free of problematic contaminants will reduce possible future harm and increase recovered feedstock value. These upstream solutions are preferable to downstream fixes like screening and separation discussed in Finding #3 below.

To facilitate future recycling, product designers who are designing new products or reformulating existing ones should avoid introducing unnecessary complexity and toxicity, like PVC wrappers on polyethylene bottles, biodegradability additives in plastic bags, and flame retardants in furniture foams. Designers should also continually evaluate opportunities to replace problematic substances with safer ones, especially as new materials become available. Where gaps in safer substitutions exist, designers should collaborate with industry, governments, NGOs and others who are seeking to solve the problem.

> "As increasing amounts of materials are diverted and recovered from the landfills, the markets for the recycled, reused, and remanufactured materials must grow. The State can take a leadership role in market development by having public agencies increase procurement of products with low-waste or no-waste attributes. In addition, greater producer responsibility for end-of-life product management, along with product design changes that minimize impacts on human health and the environment at every stage, will be increasingly important."
>
> —California Air Resources Board[19]

There is a growing "green chemistry" movement that seeks to substitute the worst chemical offenders with alternatives that are safer, equally or more effective, and often lower in cost as well.[16] Building on this movement in greener chemical synthesis is a push to encourage informed substitutions toward safer chemicals throughout the manufacturing industry. This has been developing in the building industry through programs starting with HBN's Pharos Project and continuing in the US Green Building Council's LEED program through its version 4 "Building Product Disclosure & Optimization—Material Ingredients" credit. A growing number of industries are using tools such as Clean Production Action's GreenScreen for Safer Chemistry, and the BizNGO Safer Chemicals project, where manufacturers in a diverse range of industries adopt guiding principles that encourage informed substitutions of priority chemicals with safer alternatives and share resources for bringing those principles to reality.[17]

The success of this revolution in the synthesis and use of chemicals requires broad open sharing of data to facilitate informed decision-making and innovation. The Health Product Declaration Collaborative (HPDC. now has created an industry standard for disclosure of building product contents.[18] Recycled-content product manufacturers and suppliers can use the HPDC tool (and others) to communicate, disclose, and share best practices for managing hazardous components in recycled feedstocks throughout the supply chain.

A number of innovative manufacturers are already moving toward the circular economy model, with the most recent examples including vinyl flooring companies using non-phthalate plasticizers, tire companies replacing distillate aromatic extracts with less hazardous process oils, and furniture companies eliminating all flame retardants from furniture foams. Although HBN's work focuses on buildings and building products, we believe that this forward-looking design paradigm should be implemented for all products, not just for building products that will enter the recycling stream.

Recommendations

Manufacturers: When formulating new products, manufacturers and their suppliers should identify and phase out problematic substances in products that can affect the quality of future recycled-content feedstocks. Adopt company-wide guiding principles that seek to substitute or reformulate problematic substances with safer alternatives. Follow green chemistry principles and engage with leading green chemistry industry groups to conduct alternatives assessments that avoid problematic substitutions.

Purchasers: Ask manufacturers to assess and disclose all materials and substances in their products. Give preference to manufacturers that support circular economy goals and do not use substances that will contaminate future recycled feedstocks.

Government Agencies: Support product manufacturer efforts to better understand alternatives to problematic substances that can affect the future value of recycled-content materials. Encourage or reward manufacturers and suppliers that conduct full alternatives assessments of suspect chemicals to follow green chemistry best practices.

FINDING #3

Some recycled-content feedstocks contain substances of concern in quantities that exceed allowable limits for virgin feedstocks. For many recycled feedstocks used in building products, there are no established thresholds of concern for toxicants.

Discussion

Establishing thresholds for substances of concern in recycled feedstocks

For many substances of concern, there should be strict tolerance levels in recycled feedstocks. For example, for neurotoxic lead and carcinogenic PCBs in recycled cable insulation that becomes a feedstock for vinyl flooring, there is no safe threshold of exposure for children. Other legacy pollutants, like perfluorinated chemicals, are persistent, bioaccumulative toxicants (PBTs). Their impacts, by definition, increase with time. International scientific bodies have noted that some recycling practices have the outcome of dispersing PBTs indefinitely.[g]

There are regulations intended to keep certain toxic chemicals out of new products manufactured from virgin feedstocks. But when old products containing these toxic chemicals are recycled without proper screening, public health can be compromised. The longer that regulations, codes, standards and green building programs do not consider the issue of legacy pollutants in recyclate, the longer the waste stream will be unnecessarily contaminated and underutilized, and the more these legacy pollutants will accumulate in people's bodies and the environment.

g. Some contaminants, such as halogenated flame retardants used in plastics, or long-chain perfluorocarbon stain repellants used in carpets, are toxic, highly persistent and bioaccumulative when released into the environment. In response, some authorities have contemplated destroying potential feedstocks rather than recycling them. For example, a European Union proposal in 2011 considered setting a limit of 10 ppm for perfluorooctane sulfonate (PFOS, a long chain perfluorocarbon) in carpet recycling, which would require the separation (and destruction) of carpets possibly containing PFOS. "PFOS would be destroyed and thus withdrawn from the ecocycle. Hence it can be guaranteed that they will not... bioaccumulate and cause adverse environmental and health effects." However, the impacts of destroying these molecules via incineration are not without consequences and should be considered carefully. (Expert Team to Support Waste Implementation (ESWI). "Study on waste related issues of newly listed POPs and candidate POPs." European Commission. April 13, 2011. http://ec.europa.eu/environment/waste/studies/pdf/POP_Waste_2011.pdf. p. 744 & 756.)

It can take many decades of accumulating evidence and public pressure before a substance is phased out of use. Given the long service lives of many building products, it can be many more decades before products containing those banned substances become waste; and when these substances are reused in new building products, it can extend public exposures to these banned chemicals for many more decades.

A United Nations committee has urged the elimination of some substances, such as brominated flame retardants (BFRs), from recycling streams "as swiftly as possible… Failure to do so will inevitably result in wider human and environmental contamination."[20] For decades, BFRs have been added in large quantities to foam in residential and commercial furniture. Flame retardants are not bound to the foam; over time they can migrate out of the furniture and settle into dust in the building. Children and other building occupants can ingest the flame retardants through hand-to-mouth contact with the dust.[21] These chemicals "are associated with a variety of serious health concerns, including disruption of hormones, developmental and reproductive problems,"[22] according to the Green Science Policy Institute, a watchdog organization focusing on human and environmental health.

When furniture foams containing BFRs are disposed of across the world, much of the discarded material is shipped to carpet padding manufacturers in the United States. Numerous studies have found that furniture foam recycling plants and carpet pad manufacturing plants release BFRs into indoor and outdoor air. These flame retardants contaminate a lot of carpet padding manufactured in the United States. Carpet cushion is a $15 million industry that a UN Environment Programme study found causes health damage in the order of $6 billion per year.[23]

Even basic recycled feedstocks—like wood fiber and glass—can be highly contaminated by severely restricted substances, such as banned pesticides, lead, and mercury. The presence of contaminants, or at least the lack of transparency about how or whether these substances are being eliminated from feedstocks, limits the marketability of these feedstocks.

Above: Mechanical processing by a German exporter of flexible polyurethane foam scrap to the US rebonding industry. (YouTube video: https://www.youtube.com/watch?v=DLNWDnFk8oI)

Left: Carpet pad made of recycled polyurethane foam.

Disclosures, as well as methods to identify and eliminate contaminants in recycled materials, are integral to any strategy for optimizing their use in building products.

The building industry does not currently have a common and comprehensive standard for limiting toxic content in products that incorporate recycled materials. Cradle to Cradle Certified, a product labeling program, is one of the few published third-party standards that integrates material health and recycled content in their criteria for evaluating products.

Milled recycled asphalt pavement.

Public systems in place are piecemeal, such as restrictions in California (by regulation) and Europe (by industry) on heavy metal content in cullet used in fiber glass insulation, and U.S. regulations that prohibit the reuse of roofing material containing more than 1% asbestos. In addition, many regulations, standards and green building rating systems encourage or reward the use of recycled-content products but are silent on the question of potential contaminants in the recycled feedstock used to make those products.

Methods for removing contaminants

Processing recycled materials in a way that eliminates residuals of concern results in higher value feedstocks. Some contaminants can be removed through mechanical processes, but many require more costly methods, such as chemical processing. This technology is in commercial use for some high value feedstocks, like recycled nylon 6 carpet fiber. Chemical recycling—also called depolymerization—breaks down source materials into their original chemical components, allowing each component to be reused in the production of new material, or be segregated from the feedstocks for management as a hazardous waste.

Mechanical processes are far more common than chemical methods in feedstock processing. But mechanical methods do not remove some contaminants of concern from the feedstock, such as perfluorinated stain repellants that are intimately blended with carpet fiber waste.

While chemical processing may be cost prohibitive for certain feedstocks, the process has great advantages over mechanical processing because it strips additives from the basic materials. It can provide a way to recycle materials without carrying along problematic substances. Future efforts at recovering recyclable materials should investigate the full cost and value of chemical processing, including the cost of recovery versus the value of the feedstock in commodity markets. Additional indicators to consider include the amount of energy used to chemically process materials compared to the embodied energy in the existing feedstock, and whether or not additives used for processing feedstock can introduce new hazards, such as rejuvenating agents used to reprocess asphalt pavement. These types of analyses could provide direction for when the value of the recycled feedstock does (or does not) outweigh the means and methods used in the recovery process.

Recommendations

Manufacturers: Require processors to screen incoming materials and test final products for substances of concern, and to disclose screening and testing procedures. If purchasing feedstock of unknown origin, screen feedstock to identify potential substances that could affect human or environmental health.

Purchasers: Buy from manufacturers that acquire feedstocks from known sources, and that screen all feedstocks from unknown sources for contaminants of concern. Request that manufacturers disclose their full ingredient list for all products (including recycled-content substances). Urge regulators to adopt the same thresholds of concern for potential health hazards and exposure pathways for recycled-content and virgin materials, unless a good reason for an exception is found. Use standards and certifications pertaining to feedstock contamination when they are available.

Government Agencies: Instead of exempting recycled-content materials from regulations, establish limits on concentrations of toxic material in recycled-content materials. Where thresholds exist for substances of concern in virgin materials, those same thresholds may also be suitable for recycled-content materials. In some cases, these thresholds may be categorized by the exposure potential of the final product. Establish best practice guidelines for dealing with banned substances if found in feedstocks or products that enter recycling markets.

Where market prices do not support the cost of rigorous screening and decontamination technologies, consider providing incentives for manufacturers or processors to innovate through collaborative research and development.

Encourage public and private investments and incentives for screening and removing contaminants from feedstocks used in building materials. Provide incentives such as subsidies, grants, tax incentives and loans to finance advanced recycling methods that ensure high quality feedstocks. Where market prices do not support the cost of rigorous screening and decontamination technologies, consider providing incentives for manufacturers or processors to innovate through collaborative research and development.

Recycling Industry: Processors that supply feedstocks to manufacturers should screen incoming materials for substances of concern. Disclose procedures for screening incoming materials, and test final products for common hazardous contaminants and other substances of concern. Invest in processes that can remove problematic substances from feedstocks, such as depolymerization and other chemical recycling processes. Seek grants, subsidies, or other methods to lower the cost.

All Parties: In the absence of regulatory action regarding toxic content in recycled-content feedstocks or final products, government agencies, recyclers, industrial hygienists, purchasers and product manufacturers should collaboratively develop unified voluntary thresholds and methodologies for screening and testing, and work to incorporate this information into standards and certifications on recycled feedstocks.

FINDING #4

The risk of harm is highest where regulations are the most relaxed.

Discussion

The more contaminated the recycled feedstock, the more it tends to flow to places with fewer environmental, labor and public health protections. Most often, the United States exports these problematic wastes, but in some cases, the United States is an importer of toxic scrap.

The United States has not yet adopted many of the material content thresholds established by European countries through REACH and other legislation for priority pollutants such as brominated flame retardants (BFRs) used in furniture foam, which was discussed above in Finding #3. Even within the United States, some states have stronger public health and environmental protection regulations than others. For example, Toxics in Packaging laws, restricting the heavy metal content in glass bottles, have been adopted by 19 states (including California); this helps to ensure a cleaner supply of cullet for building products like insulation than in other states.

Whether in this country or abroad, unprotected and underprotected workers at feedstock processing plants may be exposed to a wide range of harmful substances, such as hexavalent chromium fumes that are emitted from the torching of steel scrap, occupational asthmagens in plastic wastes, flame retardants in flexible polyurethane foam, and banned preservatives in wood products that are mechanically ground. These same substances can be dispersed through the air, water and soil from recycling facilities into neighboring communities and the environment.

Photo Courtesy of Art Wickman/Georgia Tech Research Institute

Torch cutting in a scrap metal facility in Georgia, ca. 2010.

A 2007 fire at a scrap processing facility in the Port of Redwood City. Four more fires have followed at this plant.

Many processing facilities are not regulated by environmental agencies. A recent study on air emissions from the ferrous metal shredding industry in Houston, for example, was the nation's very first.[24] Export-oriented metal processing facilities have polluted the San Francisco Bay, and unfortunately have caught fire with some regularity, sending plumes of metal-laden smoke into the Bay Area's air.[25] "It has been kind of a neglected industry in terms of regulation," said a California state senator in 2014.[26]

Manufacturers can leverage their buying power to push for standards to protect worker health and environmental contamination in countries or regions where none exist or are lax. Specifically, manufacturers or suppliers that influence the collection and processing or refining of recycled-content feedstocks should investigate their suppliers' labor practices and environmental standards and compare those practices to global best practices.

Cleaning up processing conditions will enhance recycling rates, benefit local communities and generate more green jobs. It also provides a more level playing field for domestic manufacturing where the costs of complying with worker safety and environmental regulations are incorporated in the overall price of products.

Recommendations

Manufacturers: Ensure that supply chain actors comply with labor and environmental regulations for sourcing and processing recyclable materials. Do not use recycled-content feedstock that exceeds thresholds of concern. Implement a company environmental management system (or augment one that already exists) to account for substances within recycled-content feedstock sources.

Purchasers: Give preference to recycled-content products that are processed or manufactured in places with high standards for worker safety and handling. Require verified environmental health and safety reports, annual sustainability reports, or other documentation from manufacturers that explain how they protect worker and environmental health.

Government Agencies: Create incentives such as procurement policies and financing that keep recycled feedstock within the region where it was produced, so that the impacts and benefits are shared by the origin community. Provide incentives such as grants and loans to finance advanced recycling methods that ensure high quality feedstocks. Include recycling workers and fenceline communities in the development of criteria for safe processing of recycled feedstock.

Recycling Industry: Encourage investments in domestic recycling infrastructure where worker rights, labor laws, and environmental regulations are strong and enforced. Finance studies on the health and environmental impacts of lightly regulated processing facilities, such as those that process ferrous metal, wood waste and polyurethane foam.

> If the manufacturing of exported recyclable commodities into usable materials was done domestically, it would create 58,000 new jobs in California.
>
> —CalRecycle[27]

FINDING #5

In most cases, the origin and chain of custody of recycled feedstocks used in building products are not disclosed to purchasers and often are not known by the product manufacturer.

Discussion

Manufacturers generally know the constituent parts that make up their products, and recycled content is no different. However, the level of disclosure of recycled content that is provided from suppliers to manufacturers is not necessarily extensive enough to allow for accurate knowledge of all potential hazardous components in a recycled feedstock. Often, a feedstock supplier will communicate known hazards to the purchaser to the extent required by regulation, but as illustrated in Finding #2 above, that level of disclosure may not be effective in protecting human and ecosystem health. Furthermore, regulatory-level reporting, such as Safety Data Sheet reporting thresholds, will not meet the requirements of some ingredient disclosure platforms that are gaining in popularity in the green building industry.[28]

For some high-value domestic materials, like metal, the origin of the recycled content is well understood because the flow of materials is very well documented and follows a linear process from collection to remanufacture. For a few other materials, such as wood, there are organizations such as the Forest Stewardship Council that provide voluntary certification of the material's chain of custody for major steps within the supply chain. Though not perfect, chain of custody standards provide some assurance that materials have followed best practices and are tracked from harvest to production. However, for most recycled feedstocks used in building products, the full origin and chain of custody of the material are either unknown or are not disclosed well enough to allow manufacturers or purchasers to make informed decisions about their use.

Chain of custody information can help to target substances to be tested and eliminated from recycled feedstock, when necessary, or to find suitable uses where they will not impact human health or the environment.

Recommendations

Manufacturers: Seek feedstock processors and suppliers that have third-party-verified chain of custody certification and that fully disclose the contents of their recycled feedstocks. In lieu of rigorous supply chain tracking, strategic evaluation including testing of feedstocks for substances of concern is the best option.

Purchasers: Give preference to building product manufacturers and suppliers that provide third-party-verified chain of custody certification of the recycled content in their products.

Government Agencies: Report publicly on the fate of materials diverted from the waste stream, including countries to which publicly collected recyclable materials are exported. If the fate of a diverted material is unknown, disclose the lack of data.

Recycling Industry: Processors should fully disclose the contents of the recycled feedstocks they sell, including the presence of any hazardous substances, impurities, or contaminants above thresholds of concern. The industry can use tools like the Health Product Declaration, a standard format for disclosing potential hazards in building products, to standardize disclosure and communicate the most important information to manufacturers and purchasers in the supply chain. Industry can also seek standards and certifications that validate chain of custody and recycled content sources of feedstocks.

FINDING #6

There is inadequate infrastructure in California and the United States to process all the available recyclable material. Materials that could be recycled safely continue to be exported or lost to the landfill.

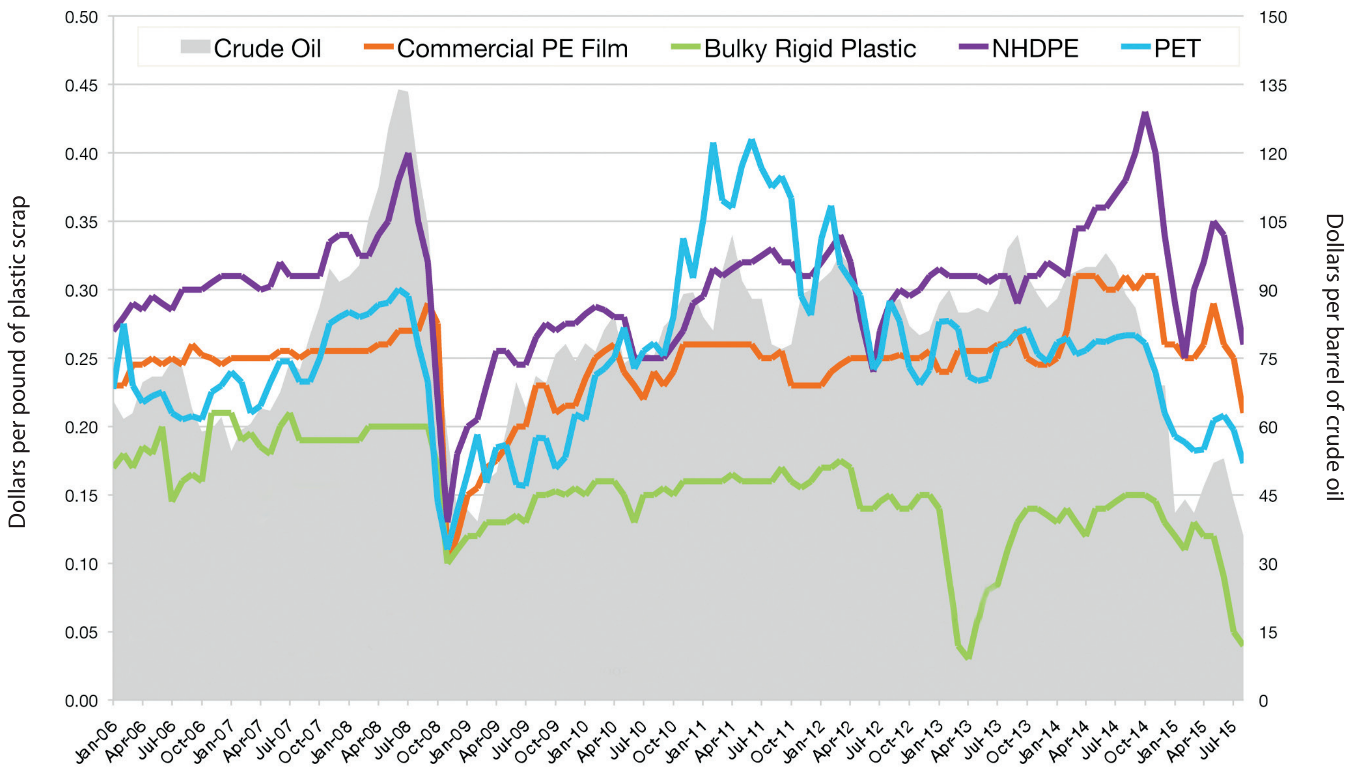
Discussion

Clean, nonhazardous, safely recyclable materials continue to be lost to the landfill or exported because of inadequate domestic infrastructure to process recyclable scrap. For example, if all of the reported material from recycling processors of glass, paper and plastics went to manufacturing facilities in California, the supply would exceed the manufacturing capacity by more than 300%.[29]

The cost of recovery can affect the recycling potential of feedstock materials. Some materials, such as acoustic ceiling tiles or carpet, can be recycled, but require an investment in time on behalf of contractors and waste management companies in order to get those products back into the manufacturing cycle. Therefore, it is generally less cumbersome and less expensive to send many materials to local landfills than to recycle, even if recovery incentives or rebates exist.[30] This equation needs to be reversed; landfill disposal and exporting waste should be less convenient and more expensive than recycling.

Economic instability in raw materials markets can contribute to fluctuations in commodity pricing, which has a direct effect on the value of recycled feedstocks. In the case of crude oil and plastics, this effect can be beneficial to recycling markets in good years, but place recycled materials at a disadvantage compared to virgin materials in lean years (see Figure 3).[31]

FIGURE 3. **Historical Price of Scrap Plastics Compared to Crude Oil Prices**



© Graph courtesy of Moore Recycling Associates, Inc.

Other barriers to recycling are technical. Sorting facilities that handle commingled recyclables—also known as material recovery facilities—have been optimized for common recycling streams like paper, plastic, glass and metals.[32] But manufacturers seeking to reduce their products' embodied energy are making their products and packaging lighter than they used to be. This "light-weighting" of consumer goods has led to products with multiple parts and packaging that are not easily separable. These factors can lead to fewer materials being reclaimed than there is potential to recover until such time as the sorting facilities catch up to the new marketplace for recoverable materials.[33]

> "If we increase our recycled content manufacturing capacity, then more of these materials could be processed into new products here in California. It would mean more green jobs created in California, less greenhouse gases associated with long distance transport, and ensure that these resources stay in California's material stream and economy."
>
> —CalRecycle[34]

Despite these countervailing factors, the use of recycled feedstocks in building products and construction projects continues to expand. There remains plenty of room for further growth that leads to good green jobs and reduced environmental footprints.

Our planet cannot sustain the burden of continued extraction without strong markets for recovery and reintroduction of those extracted materials at end of use. Therefore, if we are to realize a true circular economy, the materials recovery and manufacturing industries need to overcome economic and technological barriers. The economic barriers can be solved if product design and selection decisions account for the environmental costs of competing feedstocks. When the full impacts of production are considered, recycled materials almost always win compared to virgin materials. And the technological barriers can be overcome through partnerships between building owners, manufacturers, haulers, processors, and government agencies to invest in better materials recovery technologies.

Recommendations

Manufacturers and Purchasers: Urge local, state and federal public representatives to promote domestic collection and processing of recyclable materials. Oppose trade deals that put domestic recycling industries at a disadvantage to foreign interests.

Government Agencies and the Recycling Industry: Increase investments in domestic recycling capacity, especially in California. This includes processing capacity for hard-to-recycle materials like engineered wood products, through a combination of procurement incentives, innovative research and development, and investments in screening and processing technologies.

CHAPTER 3

Criteria and Methodology

Overview

This chapter explains the process we used to develop the recommendations provided in the individual feedstock optimization reports.

We began this research by identifying the most common building product categories that tend to include recycled-content materials. Since product categories can be very broad (like "carpet" or "flooring"), we decided to investigate specific recycled feedstocks that go into end products, and identify commonalities. For example, carpet products may contain recycled-content feedstocks, but those feedstocks can vary widely depending upon where they are used in the finished product: backing, tufting, yarn, and so on. Furthermore, the recycled-content feedstocks can end up in several different types of building products. Recycled nylon 6 feedstock, for example, is used to make carpet face fibers, insulation facing, upholstery, and even some adhesives. For these reasons, we decided to evaluate the feedstocks rather than final products.

Additional considerations for deciding which feedstocks to investigate included whether there are current or suspected concerns about contaminants in the feedstock, the availability of information about the feedstock, and the project funders' desire to focus on specific feedstocks.

As the basis for our evaluation of the eleven common recycled feedstocks in building products, we focused on each material at a specific phase of its life cycle: when it is delivered to the building product manufacturer.

As the basis for our evaluation of the eleven common recycled feedstocks in building products, we focused on each material at a specific phase of its life cycle: when it is delivered to the building product manufacturer. The condition of the recycled feedstock at that moment, and its preceding history, is the basis for evaluation. We also limited the scope of research geographically, and focused on feedstock delivered to manufacturers of building products that are sold in the United States (especially San Francisco and Alameda County). We examined trade and market data to determine likely locations where the manufacturing takes place and the sources of the recycled materials used by these manufacturers.

To understand market conditions and environmental impacts, the HBN research team examined shipping records and other trade data, identified the companies and countries through which each feedstock flows, sought data about environmental impacts from the material flows (such as Toxics Release Inventory data), explored regulations or policies that address contaminants in recycled materials, and sought protocols from recyclers and manufacturers that identify and screen out contaminants.

We evaluated each feedstock addressed by this project by using the four criteria summarized here and discussed in detail later in this chapter:

1. **Environmental & Health Impacts**
   - Do the recycled feedstock's materials and substances (including legacy content) pose significant hazards for workers, fenceline communities, building occupants, and the wider environment?
   - Do the additives used in processing the recycled feedstock pose significant hazards?
   - Can the hazardous constituents of the feedstock be removed from the waste stream, and if so, how and at what cost?
2. **Supply Chain Quality Control & Transparency**
   - To what extent (scope and frequency) do recyclers of the feedstock screen for toxic contaminants?
   - Are there industry practices in place throughout the supply chain to remove hazardous contents from the process, thereby maximizing the value of these materials?
   - Do they have publicly available protocols?
   - Do they disclose feedstock contents and residuals through transparency tools, such as the Health Product Declaration?[h]
3. **Green Jobs & Other Local Economic Impacts**
   - Where are the feedstock's source materials recovered from, and where does the recycling take place?
   - How many jobs are created by recovery and recycling of the feedstock source material? Specifically, what are the associated employment or economic benefits and impacts from feedstocks collected, processed or manufactured in California and/or the western United States?
4. **Room to Grow**
   - Is there potential to increase the recycling rate of the feedstock source material?
   - Can the reprocessing of the feedstock and manufacturing of building products made with the recycled feedstock be increased domestically?
   - Can demand for building products made with the recycled feedstock be increased?

BASIS FOR EVALUATION

HBN's investigation focuses on each material at a specific phase of its life cycle: when it is delivered to building product manufacturers. The condition of the recycled feedstock at that moment is the basis for evaluation.

Results from each feedstock evaluation are summarized in Table 3 (see p. 15). As the table shows, some feedstocks are very good choices from an environmental and human health perspective. Other feedstocks may need to be evaluated in greater depth before their use can be recommended. Finally, there are significant concerns about some feedstocks that could affect the recommendation to use them.

Refer to the individual feedstock evaluations at http://healthybuilding.net/content/optimize-recycling for detailed guidance on the feedstock recommendations.

h. The Health Product Declaration (HPD) is a format for disclosure of contents and associated hazards in building products. For more information, see http://www.hpd-collaborative.org.

Key Criteria

A. Environmental and Health Impacts

Ideally, recycled feedstocks should not introduce worse hazards than the virgin feedstocks they replace in a product. Currently, for some recycled feedstocks used in building materials, this is not the reality.

Purchasers and manufacturers must balance the need to make use of existing waste materials that are already in circulation in the world markets with the allure of new and virgin "safer" products that are being created every day. There are some situations where feedstock contamination may not pose serious threats, and others where screening out and being very cautious about the feedstock materials will be important.

Understanding this reality is the first step toward optimizing the use of recycled content in building materials. Purchasers are driving innovation in green building by demanding transparency and green chemistry. Recyclers, and manufacturers who use recycled content, may face a credibility gap unless they assess how hazardous substances may enter recycled waste streams, develop protocols for controlling sources and screening feedstocks, and move to optimize their feedstocks' content.

Our examinations of the potential human and environmental health impacts of recycled feedstocks focus on two primary considerations:

1. During use of the end product, do its recycled feedstocks contain substances that may adversely affect the health of building occupants and surrounding ecosystems?
2. During processing of the feedstock for use in end products, are chemicals used and released that may adversely affect local ecosystems, workers, and residents in fenceline communities?

Evaluating the potential scope of exposures requires a first step of identifying the type of content in a feedstock. Using the Pharos Project (a database developed by the Healthy Building Network), we can screen these different types of content against 60 authoritative lists of health and environmental hazards.[36] From this cross-referencing we can compare the potential health impact of each feedstock's common composition.

> "Consumers put their health first. Claims that addressed health concerns (e.g., toxic content and indoor air quality) were consistently rated more important for purchase influence, perceived value, and positive brand impact than were claims about manufacturing practices (e.g., zero waste) and recycled content."
>
> —Study commissioned by UL Environment[35]

Types of Content in Recycled Feedstock

Content in recycled feedstock may be of four types:

1. Standard content, materials and substances common in modern products as currently produced;
2. Legacy content; that is, substances no longer used in standard products of this type;
3. Contaminants picked up during the service life of the original product;
4. Additives used in processing the recycled feedstock.

Standard Content

Compositions of building materials and other consumer products that become the recycled feedstocks of the future are ever-changing. In recent years, we have seen radical shifts in the substances that make up insulation, decking, paints, and carpets, to name just a few examples. Building product recipes now feature innovative binders, preservatives, surfactants, stain repellants, and other chemicals that affect product quality, durability and beauty. Understanding potential chemicals of concern in feedstocks, therefore, has become increasingly complex. When looking at what comprises "standard" materials in products, we must begin with an accounting of the modern methods of manufacturing for each of the source materials as produced today.

Legacy Content

Many building materials are quite long-lived, and enter the waste stream after several decades of use. During the service lives of these products, the use of some particularly hazardous substances has been phased out due to human or environmental health concerns. However, the recycling of products with legacy toxic contents is largely unregulated. Most regulations consider only the manufacture of new chemicals, not the reuse of old chemicals found in recycled feedstocks used to make new products.

Sometimes authorities specifically exempt recycled feedstocks from toxic content regulations. In 2009, the parties to the Stockholm Convention prohibited polybrominated diphenyl ethers (PBDEs) from production, use, import or export. However, the parties exempted the recycling of products that contain PBDEs.[37] The United States, which has signed but not ratified the Stockholm Convention, is a net importer and leading recycler of polyurethane foam containing PBDEs, much of which becomes carpet padding.

Flame retardant activist Arlene Blum and other scientists say this loophole leads to prolonged exposures for workers and the general public. "Due to this exemption for recycled materials, carpet cushion that is contaminated with penta-BDE continues to be produced; recycling and carpet cushion installation workers are highly exposed; and the exposure of the general public will continue for many more decades," according to a paper by Blum and others.[38]

> The presence of legacy toxicants represents a great challenge for optimizing some recycled feedstocks. Given the long service lives of many building products, hazardous legacy substances will continue to enter the recycling trade for decades to come.

The presence of legacy toxicants represents a great challenge for optimizing some recycled feedstocks. Given the long service lives of many building products, hazardous legacy substances will continue to enter the recycling trade for decades to come. For example, heavy metals in cable insulation are being recycled 40 years after their original manufacturing into new PVC floors. A trickle of asbestos-bearing shingles continues to contaminate construction and demolition debris, while treated wood floods the wood fiber waste stream. Eliminating priority pollutants from recycled feedstocks will prevent decades of harm.

This challenge is rarely recognized in the United States, either in the marketplace or in public policy. Elsewhere, efforts appear to be further ahead. The European Commission is considering whether to adopt a "strict application of the precautionary principle," which would eliminate persistent organic pollutants (POPs) from recycling. "It will be much more difficult to identify and eliminate the concerned substances at later stages when recycled products will become waste," stated an EC-commissioned report in 2011.[39]

Polychlorinated Biphenyls (PCBs)—Banned But Still in Use

PCBs, which are classified as persistent organic pollutants (POPs), are considered to be carcinogenic and can have serious effects on the immune system, reproductive system and other functions. In 1977, the U.S. federal government prohibited the manufacture, processing, use and distribution in commerce of PCBs. Production of PCBs is also prohibited under the Stockholm Convention.[i]

Prior to 1977, PCBs were used in an enormous array of products, from transformers, fluorescent lights and other electrical devices to paints, plastics, fire retardants and pesticides.[40]

National government efforts to restrict recycling of PCBs "mainly focus on closed systems,[j] such as cooling fluids in electrical equipment," according to the United Nations Environment Programme (UNEP).[41] Unfortunately, unregulated "open" products containing PCBs routinely enter the recycling stream and eventually end up in recycled feedstocks, including cable sheaths, carpet fibers, acoustical ceiling tiles, and debris containing adhesives, caulk, plaster or paint.

"Don't reuse, recycle or sandblast PCB suspect materials," warns a UNEP brochure.[42]

Despite UNEP's admonition, screening for PCBs or other legacy toxicants in recycled feedstock appears to be more exception than rule.

More research on legacy substances will provide additional clarity on potential concerns in recycled feedstocks, and will help inform the development of screening protocols.

Contaminants

Feedstock can become contaminated by contact with other hazardous substances during use. This can occur over long periods of time, such as when tires become contaminated from years of contact with lead tire weights and leaded highway paint, or rapidly, such as when mercury captured in flue gas desulfurization devices at coal-fired power plants contaminates combustion waste.

Shell Chemical has described "contaminants resulting from consumer misuse of containers… (such as) pesticides and heavy metal compounds" as "the greatest challenge to any recycle [sic] process… because of toxicological considerations."[43]

i. The Stockholm Convention on Persistent Organic Pollutants is an international environmental treaty that entered into effect in 2004. There are 179 ratifying parties to the convention. The United States is not one of them.

j. A "closed system" in this context is one in which the chemical in question is contained within the product with a physical barrier separating it from release into the environment, such as a cooling fluid contained in a heat exchanger. The chemical is only released to the environment when the system is broken (for example, in a pipe leak). In an "open system," the chemical is exposed to the environment by design, such as existing in a carpet fiber, and hence subject to release by normal abrasion, weathering, or other degradation.

We examined common scenarios of feedstock contamination to understand where it may exceed established thresholds of concern, such as those established by the global automotive industry.[44] If thresholds were not available, reasonable estimates and professional judgment were used to arrive at placeholder thresholds within each of the eleven individual feedstock reports. These thresholds are crucial for developing screening protocols for optimized recycled feedstocks. We view these thresholds as only a starting point, and not absolute, as we plan to explore this concept more in future phases of this research project.

© California Department of Toxic Substances Control

Lead weights, still allowed in many US states, can contaminate tire waste.

Additives Used in Processing Recycled Feedstock

In many cases, reprocessing of collected waste into feedstock for new products involves the addition of new (virgin) substances to achieve desired characteristics. Additives used in recycled feedstock processing operations must be screened to assess whether they are introducing toxicants into the processing operations and the feedstock, with potential impacts on workers, the environment, and people exposed to products containing the recycled feedstock. For example, several chemical manufacturers have developed "compatibilizers"—additives that aid the processing of mixed plastic streams, especially polyolefins like polypropylene and polyethylene.[45] These compatibilizers may comprise as much as 20% of the processed feedstock by weight, although proportions between 5% and 10% are more typical.[k]

Some additives, whether they are used in the initial manufacturing of a product that will later be recycled or used when processing feedstock, can migrate out of the material and pose an exposure risk to people and the environment.

The Danish Ministry of the Environment in December 2014 published a survey of hazardous substances in plastics. It evaluated the potential for people to be exposed to these substances in use, including building materials. It also examined the fate of these additives used in recycling.[46] The study notes that "most hazardous substances used as additives are not chemically bound in plastics, but are able to migrate. Migration is the phenomenon that takes place when chemical substances in the plastic move to the surface of the plastic item or to a medium in contact with the item. At the surface the substance may evaporate or be removed e.g. washing or contact with human skin. Both plasticizers, e.g. phthalates, and flame retardants, e.g. brominated flame retardants, are substances well known to migrate, but many other substances migrate too." The study also found that most of the hazardous substances remain in the material throughout mechanical recycling processes.

k. The declared recycled content of a product typically assumes that 100% of the recycled feedstock is actually recycled from prior uses and does not discount anything added to the feedstock, such as compatibilizers. This means that manufacturers may overstate the recycled content of a product by the amount of additives used in processing the feedstock.

A recent study by the Consumers Union, the advocacy arm of *Consumer Reports* magazine, also found evidence that phthalates migrate out of vinyl flooring. In fact, Consumers Union now recommends that to protect children's health, | vinyl floors where children play should be regularly wet-mopped and children's hands cleaned after crawling or playing on the vinyl floor.[47]

Where possible, our evaluations consider additives used in the processing of waste into feedstock, as delivered to building product manufacturers.

> "[The] potential excessive and uncontrolled use of additives during manufacturing [is] often employed to compensate for the low quality grades used as raw materials," notes a 2013 International Solid Waste Association report about recycling plastic waste in China. ISWA says the use of additives like "toxic plasticizers," Bisphenol A, brominated flame retardants, and fluorinated surfactants leads to "human exposure and environmental dispersion."
>
> —International Solid Waste Association's Globalisation and Waste Management Task Force[48]

Key Criteria

B. Supply Chain Quality Control & Transparency

As described above, an optimized recycled feedstock is one that does not contain toxicants or hazardous contaminants, is third-party certified to meet healthy product standards and protocols, and whose composition is fully and publicly disclosed. This section describes the supply chain quality control and transparency criteria for optimized recycled feedstocks.

Best supply chain practices for ensuring safer recycled feedstocks include:

- Third-party certification of chain of custody for the sourcing of feedstock materials;
- Standards, protocols and practices that screen toxic contaminants from the feedstock prior to processing;
- Appropriate reuse: ensuring that feedstocks are used in applications that are appropriate to their content (for example, exposure pathways in a childcare setting are very different than in road-bed fill[l]).

Transparency means that information about the feedstocks' composition is communicated throughout the supply chain and is disclosed through credible product reporting systems. Best practices for supply chain trans-parency include:

- Disclosure of feedstock contents through systems including Pharos, Declare, and Health Product Declarations to 1,000 ppm (or better) for substances of concern, including residuals (preferred);
- Assurance of data quality through Pharos data review, industry testing, or third-party-certified eco-labels and product declarations;
- Establishment of public testing/certification protocols for priority substances, which may vary by material type and exposure pathways for highly toxic trace elements.

l. While toxic content in road bed fill may have relatively little direct impact on human health, it can migrate into surrounding ecosystems and water supplies.

Recycled Feedstock Screening Procedures

There are multiple methods to screen materials for substances of concern and to eliminate them from the feedstock used to make building products. Screening methods range from high-throughput screening automation (like recovery technology that uses magnets or optical sorters to separate out metals, plastics and other contaminants in recycling streams), to lab-based tests, to spot-checking prior to acceptance of a batch of feedstocks. Understanding the best use and applicability of each screening procedure should involve manufacturers, regulators and processors. Some screening methods are expensive or underutilized, requiring further investments in these technologies in order to optimize recycling.

Each of our feedstock evaluation reports provides examples of current and best practices employing these screening methods. In general, the more that hazardous materials are present (or are suspected of being present) in a feedstock, the more frequent the feedstock should be tested to ensure safe levels are met.

Decontamination Methods

Many methods are used to decontaminate recycled feedstocks and prepare them for reuse, including washing and chemical recycling. Decontamination methods vary widely in their effectiveness at separating contaminants and undesirable additives from the desired materials, depending on the feedstock and the substances that need to be removed. As with screening technologies, optimizing recycled-content materials will require greater investments in decontamination technologies.

> "By investing in advanced sorting and cleaning technologies, domestic plastic recyclers can truly raise the bar and give manufacturers the materials they need to produce quality products for their customers. This approach means less waste, a reliable domestic source of materials for producers and a lower carbon footprint as fewer low-quality materials are shipped overseas. It's a win-win for everyone."
>
> —Denton Plastics[49]

Washing

Washing removes residues from feedstock, such as detergents, pesticides, gasoline and motor oil. "Washing is the most expensive activity of the postconsumer plastic recycling process," according to the Chico Research Foundation.[50]

Washing only works when contaminants are not chemically bound to the waste. And even when it works, the results may be incomplete. Bradford and Blakistone found that after washing, melting and extruding high density polyethylene (HDPE) scrap into pellets, high concentrations of some residuals remained, particularly copper conjugate (only 4% was removed in one process).[51] One company manufactures the only FDA-approved recycled HDPE food packaging by washing and grinding the polyethylene into flakes, which it then blasts with heated gas. It claims that this process removes "essentially all" volatile and semi-volatile organic compounds.[52]

Chemical or Feedstock Recycling

Two forms of recycling — chemical or feedstock recycling — change the chemical structure of the original material. Conversion approaches are considered "tertiary"[m] forms of recycling, in which processors depolymerize the scrap material, then purify the resulting chemicals and reprocess them into new polymer resin. When the resulting chemicals are reused

m. Primary recycling involves no change to the material or product. It is reused for its original purpose as is with no physical change. Recycling of a beverage bottle is an example of this. Secondary recycling involves using the feedstock in another product, with physical modification but without chemical processing. Shredding polyethylene bottles for use as insulation in jackets is an example of this.

in the same application, it is called chemical recycling; when the resulting chemicals are used for another purpose, it is called feedstock recycling. According to the U.S. Food & Drug Administration, "The primary goal of tertiary recycling is the regeneration of purified starting materials."[53]

China Customs officials investigating imported plastic wastes in 2014.

Key Criteria

C. Green Jobs and Other Local Economic Impacts

By federal definition, any job related to reprocessing waste into recycled feedstocks is a green job.[54] Occupations include manufacturing engineering technologists, trainers, technicians, industrial hygienists, coordinators, collectors, drivers, sorters, dismantlers, mechanics, manufacturing production technicians, machinists, marketers and managers—essentially anyone involved in handling, delivering, and processing recycled materials.[55]

The Occupational Information Network, sponsored by the U.S. Department of Labor, says recycling jobs have a "bright outlook," and are a new and emerging occupation that is expected to grow much faster than average through the year 2022.[56]

A national report released in 2011, *More Jobs, Less Pollution*, has a similarly positive outlook: "Recycling 75 percent of the nation's waste will create nearly 1.5 million jobs by 2030 while significantly reducing pollution, saving water and energy, and building economically strong and healthy communities."[57] The report was sponsored by the BlueGreen Alliance, Teamsters, Service Employees International Union (SEIU), Natural Resources Defense Council (NRDC), Recycling Works, and the Global Alliance for Incinerator Alternatives (GAIA).

However, this projection assumes that the waste is processed and used in the United States. A footnote reads, "The job growth estimates for the recycling-based manufacturing industry are based on all recycled materials being used by domestic manufacturers. While currently a significant fraction of recycled material (e.g., paper) is exported to China and elsewhere, the 2030 scenarios assume that several factors contribute to this material staying in the U.S.: implementation of climate legislation resulting in a carbon tax or cap and trade program; significantly higher transportation costs; and adoption of a U.S. industrial policy aimed at retaining/growing domestic manufacturing that results in recycled materials staying in the U.S. for processing and use as inputs to manufacturing."[58] Keeping recycling close to home is therefore essential in growing the domestic green economy.

Some drivers of waste exports are macroeconomic, including, but not limited to, free trade, economic inequality, disparities in labor practices, and differing levels of environmental regulations. These global forces complicate the ability to enact quick or streamlined solutions for growing green local jobs.

While recycling is on the rise domestically—and that is a success story—domestic remanufacturing infrastructure for many collected recyclables has not kept pace with the growth of overseas remanufacturing capacity. With burgeoning collection systems in the United States and the resultant growing volumes of recyclables, remanufacturing capacity has expanded overseas, mainly in China.

This dependence on a single importing country poses risks, according to a report by the Globalisation and Waste Management Task Force of the International Solid Waste Association. China may eventually "become self-sufficient in high-quality secondary plastics" because they will have enough feedstock available locally and won't need imports of recovered (secondary) plastics." Also, advanced recycling collection programs in North America and Europe were developed with the goal of achieving sustainable resource recovery. "However, this is questionable when almost half of the collected plastics are exported to countries with lower environmental standards," according to the report. "Global plastic recycling markets in themselves may not lead to the required balance between environmental protection, clean material cycles and resource utilisation."[59]

> To grow the recycling industry requires investments in infrastructure and a steady supply of materials so that processors and collectors can cope with market volatility.

The recycled materials industry depends heavily on market prices, both domestic and foreign. As shown in Figure 4, California prices for commodities rise and fall with economic forces. Depending on the commodity and the price, the motivation for collecting and recycling materials can wax and wane substantially over time. Therefore, to grow the recycling industry requires investments in infrastructure and a steady supply of materials so that processors and collectors can cope with market volatility.

When California passed Assembly Bill 939 in 1989—statewide legislation that mandated local action to increase recycling rates—the state's waste diversion rate was around 10%. It is now about 65%, higher than any other state. This increase has supported the development of "more than 140,000 green jobs in California."[61] But keeping recyclables in-state would increase the number of green jobs for Californians even more. According to CalRecycle, exports of recyclables increased from less than 5 million tons in 1998 to around 20 million tons in recent years (see Figure 5). As a result, many of the jobs created from manufacturing recycled products have been developed outside the United States.

"The exported recyclable commodities are currently collected and processed, but if the manufacturing were done domestically, it would create 58,000 new jobs that would boost local and regional economies," concluded CalRecycle in 2013. "Infrastructure will play a critical role in achieving the 75 percent recycling goal and realizing the full potential job growth in California.... [A]s evidenced by the significant amounts of recyclables being exported, California has a limited remanufacturing infrastructure."[62]

California's current goal is to recycle, compost or reduce 75% of its waste (source reduction means preventing the creation of waste in the first place). Meeting this goal raises the potential for even more green jobs, if the infrastructure can catch up.

FIGURE 4. **Normalized Recycling Material Prices (CalRecycle, 2015)**

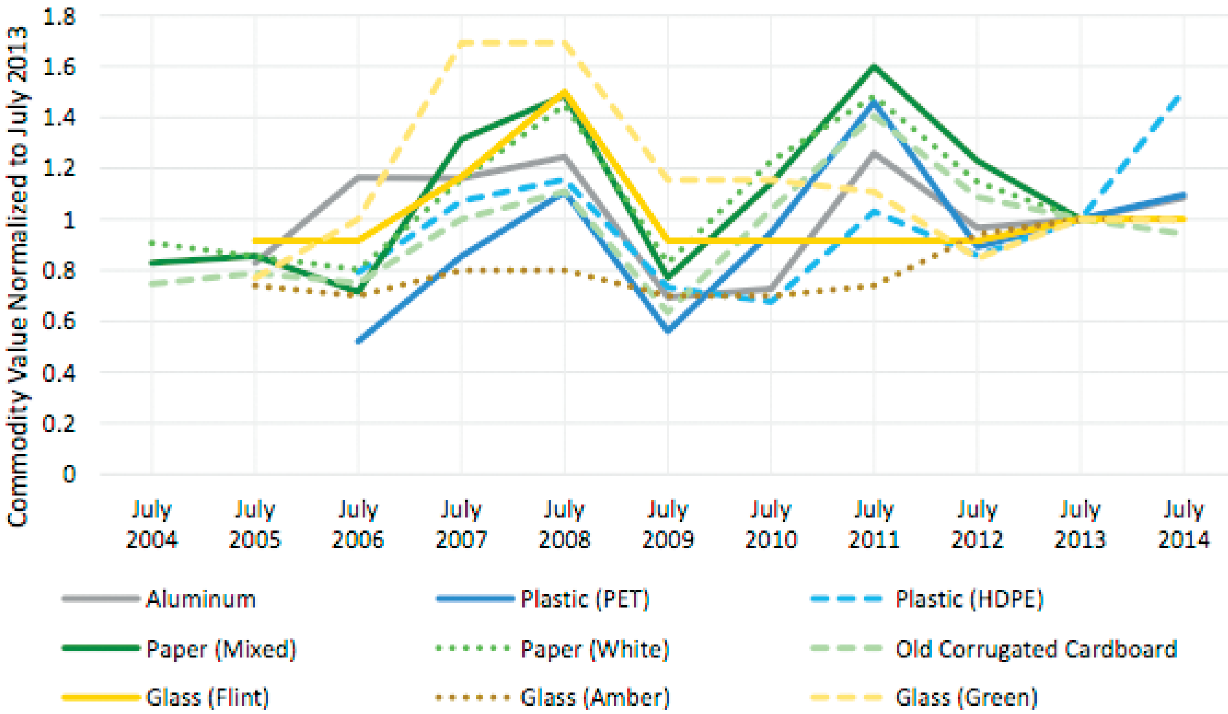
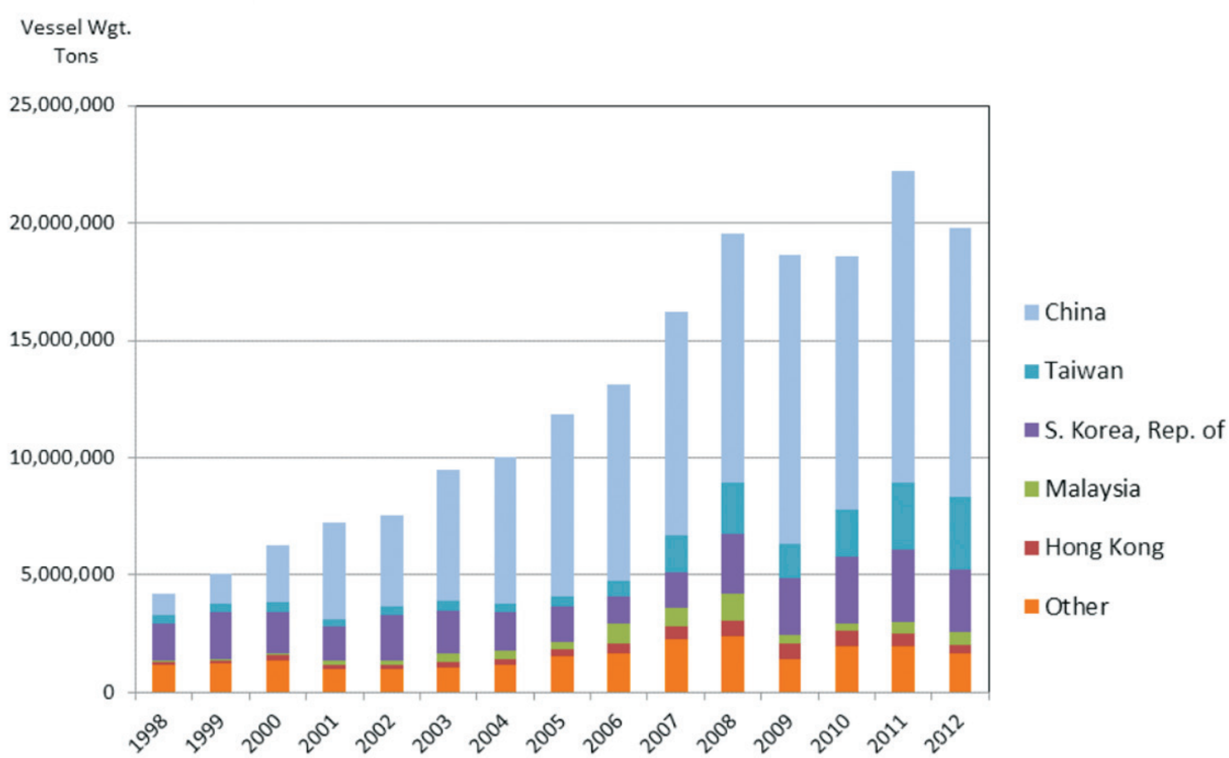


FIGURE 5. **Recyclables Exports from California by Destination Country**



Graph reproduced from *AB 341's 75 Percent Goal and Potential New Recycling Jobs in California by 2020*, CalRecycle. This report estimates that "about 70 percent of the recycled exports originated in California."[63]

Key Criteria

D. Room to Grow

Optimizing recycling is more than just finding the best products or solutions for recyclable materials; it requires the right economic and market conditions. Unfortunately, the environmental value of using post-consumer content, compared to post-industrial or virgin materials, may be undercut by economic factors:

- Pre-consumer content (including post-industrial) tends to be less expensive to collect and process than post-consumer content.
- In many regions of the United States and the world, the cost of operating landfills is much less expensive than the cost of operating a recycling facility. In most places recycled materials do not compete on a level economic playing field with other forms of waste management.
- Domestic virgin plastic resin production is at an all-time high, thanks to consumer demand and record domestic oil and gas supplies. "The fall in oil prices has dragged down the price of virgin plastic, erasing recyclers' advantage," the Wall Street Journal recently reported.[65] Until life-cycle costs are factored into virgin production, this may be one of the most intractable hurdles facing the use of recycled materials in building products.

> "The expansion of the recycling economy must require a redesign of dangerous recycling jobs into a sustainable source of job growth. Los Angeles is leading by example through their Zero Waste franchise plan by implementing and enforcing standards that require facilities to be safer workplaces and workers receive quality training and a living wage. A nation-wide effort to redesign recycling jobs can provide even greater job growth and a needed stimulus to the economy."
>
> —*Waste to Resource: Restoring Our Economy with Recycling Careers*[64]

Increasing the use of post-consumer content requires a reversal of these economic equations, and the shifting of investment and subsidies into domestic recycling. The State of California is an early adopter of this paradigm shift.

California Leadership

California has long been a leader on environmental issues nationally and globally, and has taken strides to take ownership of the waste generated in the state. California has ambitious waste diversion goals and has made substantial investments in recovering waste. And with a larger emphasis on waste management as part of the state's recently updated Scoping Plan for the ambitious Global Warming Solutions Act (Assembly Bill 32, 2006), more enhancements to the state's waste recovery systems are on the way.

California also has taken the lead in requiring its state agencies to purchase recycled-content products. Specifically, the updated AB 32 Scoping Plan recommends that "CalRecycle and the Department of General Services will need to take the lead in improving the State procurement of recycled-content materials through the State Agency Buy Recycled Campaign reform."[66]

Specifications and Quality Control

Landfill diversion and recycling can be increased by downstream specifications, such as transportation department allowances for recycled asphalt pavement (RAP) in new mixes. Some states, for example, do not allow any RAP, whereas Wisconsin allows up to 45% RAP binder replacement in paving underlayment. While there are climate-specific performance considerations, some state transportation specifications have not been updated to reflect the latest technologies for incorporating recycled content.

> "Our vision for the Waste Management Sector for meeting GHG emissions and waste reductions goals out to 2050 is based on the principle that California must take ownership of the waste generated within the State. To carry out this vision, we must maximize recycling and diversion from landfills and build the necessary infrastructure to support a sustainable, low-carbon waste management system within California."
>
> —California Air Resources Board"[67]

While externalities such as these are certainly at play, many post-consumer feedstocks' recycling rates can grow through internal improvements. In some cases, the potential to capture market share can be greatly increased by improving the quality of the product.

Most of the feedstocks that we have examined suffered from a surprising lack of attention to processing quality controls. Much of the recycling industry has been less than transparent about potential contaminants in their products, and has published few protocols for identifying or removing these contaminants in processing. Yet such measures are opportunities, not threats, to the business of recycling. Many manufacturers are hesitant to incorporate recycled materials without reassurance of purity needed to assure performance. Reducing contamination can increase feedstock marketability and value, leading to greater potential for recycled materials to truly replace virgin materials in products and realize a true circular economy. There is much room to grow if the right collection mechanisms, pricing structure, and manufacturer demand are in place.

With greater marketplace demand and investments in quality improvements such as chemical recycling technologies, recycling rates and market shares have the potential to grow significantly. When it works, depolymerization processing has created a reliable, clean, valuable feedstock with growing industry adoption.

One major success story for this type of recycling processing is nylon 6, a common carpet face fiber. The basic form of nylon 6 results from the reaction of caprolactam (about 90% of the nylon), water (5-10%) and acetic acid (0.1%).[68] The presence of these chemicals in building materials poses no known significant human health or environmental hazards. Some additives can turn a relatively benign fiber into a critical problem for the global environment. The most significant treatments are stain repellants, in particular perfluorooctanesulfonic acid (PFOS) and perfluoroocatanoic acid (PFOA), which are long-chain perfluorinated chemicals (PFCs).

A great advantage of chemical processing is that it strips additives from the basic materials, and can provide a way to recycle nylon 6 without carrying along problematic substances (like PFOSs, PFOAs, and PFCs). At least three carpet fiber manufacturers[69] use depolymerization processes to recycle nylon 6, proving that, despite its high costs, chemical feedstock recycling can deliver larger volumes of recycled nylon, devoid of hazardous contaminants, for more building products in the future.[n]

Every added step toward optimization of any recycled feedstock means local growth and jobs. Diverting waste from landfills, kilns, and incinerators sets into motion far more creative processes.

n. One of our collaboration's forthcoming feedstock evaluation reports looks at recycled nylon 6 and nylon 6,6 used in building products.

CHAPTER 4

Conclusion and Next Steps

This report summarizes the major themes and findings that have arisen to date during our examination of post-consumer recycled feedstocks commonly used in building materials in California.

The many issues raised in this report reveal how much work remains to optimize recycled-content products. But the future is promising: by identifying problems, we are also identifying solutions and pathways to ensure that materials are not wasted and human and environmental health are prioritized.

The tools required to fully quantify potential health and environmental impacts of recycled feedstocks are now beginning to be developed. To increase transparency and optimize use of recycled-content materials, it will be important to support further development of these tools and implement the best practices described in this report. Forward-thinking strategies for evaluating product components, as illustrated by leading manufacturers and regulations, can reduce the potential for contamination from problematic feedstocks. Improving the quality of recycled feedstocks will increase their value, which can lead to higher recycling rates in the long term, improve product performance, and enhance the environmental attributes of materials and products.

The building industry, including owners, designers, workers, certifiers and manufacturers, has a major role to play in the optimization of recycled feedstocks. Given its massive appetite for materials, and the daily exposure of building occupants to them, it is perhaps even the industry's obligation to specify optimized recycled feedstocks.

Following the publication of this report and the individual feedstock evaluations, the research team will expand its present collaboration in order to engage more stakeholders. We seek to foster the optimization of recycling feedstocks used in building products through deliberate engagement and learning, including:

- Open, transparent discussions between recycling authorities (from local to global), scrap processors, health and environmental researchers, recycling workers, fenceline communities, green chemists, product designers, process engineers, and building product manufacturers who share the goal of optimizing recycling's benefits;
- Identification of short-, medium- and long-term targets for recycled feedstock optimization;
- Continued research on current and best practices for the full range of feedstocks used in building products (see Phase Two, p. 46);
- Examination of potential pathways for exposure to toxic recycled content in different end use products in various scenarios, such as old PVC material in low-cost residential flooring.

Potential goals of this ongoing collaboration include:

- Creating a common platform for tracking development and adoption of best practices;

Contaminated soil, Fort Edward, NY. Processed soil is sold for construction fill and topsoil.

- Establishing an agreed-upon set of criteria, including thresholds for contents of concern,[o] to evaluate recycled content that are appropriate to different use scenarios;
- Encouraging the development of third-party certifications and other verification methods using this criteria;
- Securing greater participation by the recycling industry in content disclosure tools like the Pharos Project, Health Product Declaration and Declare programs, including disclosure of residual content;
- Seeking local, state, and federal level financing and incentives for increased capacity to screen and process post-consumer recyclables close to where they are generated;
- Addressing other life-cycle impacts, including CO2 emissions, global warming, ozone depletion and smog potentials, acidification and eutrophication, and social impacts;
- Addressing best disposal options for contaminants removed from recycled feedstocks;
- Evaluating post-industrial waste streams such as coal combustion wastes and slag.

We look forward to the next stage of this project, in which we will expand the present collaboration to engage more stakeholders who share these goals and framework for action. With this engagement, the criteria we developed to evaluate recycled feedstocks for this project can be further refined and incorporated into green chemistry, recycling, green jobs, and healthy building programs. Through collaboration, we can optimize recycling's many benefits and minimize its impacts on workers, fenceline communities, building occupants, and the environment.

For further information on our collaboration and to view specific feedstock evaluations, visit http://healthybuilding.net/content/optimize-recycling.

o. Many of the substances identified in this report, such as PBTs, are high-stakes substances for which there should be zero tolerance in recycled feedstocks. For toxic contaminants like lead, there is no safe threshold of exposure for children.

Phase Two — Additional Feedstocks

In the first phase of this project, HBN researched current and best practices for 11 recycled feedstocks used in building products. Additional feedstocks that could be evaluated in the second phase include:

- Alumina Sand
- Aluminum
- Carpet
- Cast Iron
- Cathode Ray Tubes
- Cellulose
- Cement Kiln Dust
- Ceramic Cullet
- Coal Tar Pitch
- Copper
- Concrete/Aggregate
- Construction and Demolition Debris
- Contaminated Soil
- Cotton/Denim
- Dredged Material
- Electroplating Waste
- Ground Blast Furnace Slag
- Filter Cake
- Fly Ash and Other Coal Combustion Waste
- Food Processing Waste
- Foundry Sand and Slag
- Milk Cartons
- Mineral Slag Wool
- Mining Tailings
- Mixed Shoe Waste
- Municipal Incinerator Ash
- Paint
- Papermill Waste
- Polyethylene Terephthalate (PET)
- Polylactic Acid (PLA)
- Polypropylene
- Polystyrene
- Polytrimethylene Terephthalate (PTT)
- Phosphogypsum
- Polyvinyl butryal (PVB)
- Rubber (except tires)
- Silica Fume
- Solar Panels
- Spent Sandblast Abrasives
- Wallboard
- Wastewater Treatment Ash & Sludge

Glossary

Alternatives Assessment. An alternatives assessment is an action-oriented process to identify the safest practical alternative to the use of a hazardous chemical. The alternative may be a replacement chemical, an alternate product design, or a change of production methodology. The primary objective of alternatives assessment is to reduce potential for harm to humans and the environment by selecting inherently safer alternatives that meet performance needs and economic criteria. A thorough scientific assessment minimizes potential unintended consequences of uninformed materials substitutions.

Asthmagen. An asthmagen is "a specific agent which causes the onset of asthma in someone who did not previously have the condition," according to the *Healthy Building Network report, Full Disclosure Required: A Strategy to Prevent Asthma* (2013). Asthma onset is commonly broken down into two major causes: sensitization or irritation. Asthmagens are not limited to common environmental allergens such as dust mites, but also include many substances that can be found at work or in the home."

Contaminant. A contaminant is an unintentional component of a material. Contaminants can be incorporated into materials during service life, and from cross-contamination from other materials. For example, lead oxides in cathode ray tubes can contaminate container glass cullet if the two materials are commingled. When present in recycled feedstocks, these substances may cause an undesirable physical effect upon processing and manufacturing operations. Contaminants may also negatively impact the human health of recycling workers, surrounding communities, and the global environment.

Cullet. Cullet is waste or broken glass destined for remelting. It comes from a variety of glass types, including soda-lime glass used in packaging, flat or float (window) glass; cathode ray tubes, crystal glass, fluorescent lamps, and Pyrex.

Environmental Product Declaration (EPD). An EPD is an independently verified and registered document that c ommunicates transparent and comparable information about the life-cycle environmental impact of products.

Green Chemistry. Green chemistry is an approach to chemical and process design that reduces or eliminates the need for and generation of hazardous substances through the application of 12 design principles. The philosophy behind green chemistry is that if chemicals and chemical processes are designed in an inherently safer and benign manner, there will be less need for controls to mitigate exposure, ultimately reducing risk over the life cycle of a given material.

Fenceline communities. Fenceline communities are neighborhoods that are directly affected by the emissions, noise, odors, traffic, parking, and other activities of industrial facilities.

Persistent Organic Pollutants (POPs). POPs are chemical substances that persist in the environment, bioaccumulate through the food chain, and pose a risk of harming human health and the environment, as defined by the United Nations Environment Programme.

REACH. REACH stands for Registration, Evaluation, Authorisation and Restriction of Chemical Substances. This European Union regulation, managed by European Chemicals Agency, that went into effect in 2007. REACH requires all chemicals produced or imported into the European Union in quantities of at least one metric ton per year to be registered in a central database and prioritized for evaluation and possible avoidance based on their hazard profile. REACH also maintains several lists of hazardous chemicals, including a candidate list for Substances of Very High Concern (SVHCs).

Residuals. Residuals are unintentional content including chemicals used in the production of a product or its ingredient, and can include monomers, catalysts, non-reactive additives, pollutants and contaminants.

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Optimizing Recycling:
Criteria for Comparing and Improving Recycled Feedstocks in Building Products

Healthy Building Network Mission

Transform the market for building materials to advance the best environmental, health and social practices.

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