Post-Consumer Flexible Polyurethane Foam Scrap Used In Building Products

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About the Optimizing Recycling Series

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

This briefing paper on post-consumer flexible polyurethane foam scrap is part of an ongoing series of papers that examine ways to optimize recycled content feedstocks commonly used in building materials. The most common conditions of post-consumer feedstocks, as consumed in California, establish the baseline for assessments found in this report.

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

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

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

The Optimizing Recycling series can be found on HBN’s website, at http://healthybuilding.net/content/optimize-recycling.
Executive Summary

- Feedstock Health and Environmental Hazards
- Supply Chain Quality Control and Transparency
- Green Jobs and Other Local Economic Impacts
- Room To Grow

OVERALL: Most flexible polyurethane foam (FPF) scrap that is recovered for recycling is used in bonded carpet cushion. This industry is centered in the United States. Most of this scrap has historically been post-industrial from furniture manufacturing where toxic flame retardants have been heavily used to meet flammability standards. The majority of post-consumer FPF currently recycled comes from old carpet cushion that has incorporated these legacy flame retardants. The common practice of mechanically recycling this scrap has been found to elevate workers’ body burden of flame retardants and can disperse these highly toxic substances into the global environment. Building occupants, particularly crawling children, can be exposed to flame retardants released from carpet pad.

SUITABLE BUILDING APPLICATIONS: Because of contamination of the main component of the post-consumer FPF feedstock (bonded carpet cushion) with toxic flame retardants, use of these materials in building applications is not recommended unless it can be verified that flame retardant content in the end product is less than 0.01% (100 ppm) by weight, and that workers are protected from exposure to flame retardants.

PATHWAYS FOR OPTIMIZATION: The recycling of materials can offer many advantages over other waste management options, but the benefits of recycling must be weighed against negative impacts on humans and the environment. There is no easy solution to the problem of flame retardant contaminated foam, but there is an opportunity to develop pathways for dealing with current contaminated foams and assure clean future feedstocks.

Many furniture manufacturers have started using flame retardant free foams, creating flame retardant free post-industrial scrap. This scrap is already being incorporated into new bonded carpet cushion, but post-consumer FPF continues to contaminate these products with flame retardants. Further efforts should be made to remove unnecessary flame retardants in new products and to track flame retardant free foam throughout the supply chain for future recycling. Bonded carpet cushion that is flame retardant free should be labeled. This will help to provide a safer feedstock for future materials recycling.

Better understanding of flame retardant use in mattress foam is needed to determine its potential as a post-consumer FPF feedstock. There is a need to develop effective labeling and screening practices that segregate contaminated post-consumer foams, including carpet pad, so that manufacturers can readily identify and recycle clean foams.
and pads. Further development of chemical feedstock recycling practices should be pursued as a method to remove these additives of concern. Any methods for recycling or disposal of contaminated foams should ensure no discharge of hazardous materials to humans or the environment.

We present detailed recommendations for various stakeholders at the end of the report.

**Introduction**

Flexible polyurethane foam (FPF) is found in nearly all upholstered furniture and mattresses, in car seats, and in carpet cushion. About 600,000 tons are incorporated into products purchased by Americans each year. At the end of life, these mattresses, carpet cushions, and articles of furniture make their way into the waste stream for disposal. Most waste FPF is landfilled or burned, but some old carpet cushion is diverted from disposal as post-consumer scrap. In some regions, such as California metro areas, mattresses are increasingly recovered for their valuable metals, clean wood, and foams.

The majority of post-consumer FPF is blended with post-industrial waste (out of spec foam from manufacturing, trim scrap from furniture, etc.) to become new carpet pad or cushion, also known as “rebond” or “bonded”. The Carpet Cushion Council estimated that in 2011, up to 200,000 tons of post-consumer FPF was reprocessed into carpet cushion (enough to fill almost 650 olympic-size swimming pools), making up as much as 40% of the total foam recycled into rebond. The remaining recycled FPF was primarily post-industrial, sourced from the U.S., Europe, or Asia.
As part of the Optimizing Recycling initiative, this report evaluates post-consumer FPF feedstock against a set of four criteria gauging impact on human health and the environment, the extent to which supply chain controls screen for and remove hazardous content, the availability of green jobs, and opportunities to expand use of the feedstock. Each criterion is judged on a three-part scale with green indicating “very good,” yellow indicating “room for improvement”, and red indicating “significant concerns.” The review is focused on California’s San Francisco and Alameda counties wherever possible, and on California more generally. The evaluations of health and environmental impact and supply chain controls are broadly applicable throughout the United States. Details regarding job availability and room to grow will vary based on region.

Because post-consumer FPF feedstocks in the form of bonded carpet cushion contain both post-consumer and post-industrial content themselves, some information on post-industrial foam is also provided.
Behind the Ratings

Feedstock Health and Environmental Hazards

Flexible polyurethane foam is commonly produced using isocyanates (which are under increasing regulatory scrutiny for respiratory hazards\(^\text{vi}\)), blowing agents (some of which have been potent ozone-depleting substances and global warming agents\(^\text{vii}\)), polyols, amines, and other functional additives, often including flame retardants and, in some cases, antimicrobials. There is a huge variety in the chemistry of FPF products across the industry and even for a single manufacturer. One foam manufacturer may produce more than 150 different FPF products, each tailored to have unique properties for specific applications.\(^\text{viii}\)

While many of the ingredients can harm human health and the environment during their production and life cycles, one of the most significant impacts on recycling FPF arises from the flame retardant additives. Current post-consumer FPF feedstocks are primarily old carpet cushion with a small but increasing amount of recovered mattress foam.

Carpet Cushion

Typically, carpet cushion is installed in residential applications or light-duty offices. Over 85% of carpet cushion sold in the U.S. is bonded carpet cushion (other types include fiber, rubber, and virgin FPF).\(^\text{ix}\) Bonded foam products are made almost entirely from recycled FPF: post-industrial furniture foam and, more recently, starting around 1993, post-consumer foam. Old carpet cushion accounts for the majority of the post-consumer FPF that is recycled.\(^x\)

“The padding used under broadloom carpeting is not subject to flammability tests; however, padding often contains harmful flame retardants because the most common “rebond” product is made from recycled polyurethane foam from furniture, which is often loaded with high levels of halogenated flame retardants." -- Dedeo & Drake, 2014\(^\text{xi}\)

The flame retardant pentaBDE was used extensively in flexible polyurethane foam for upholstered furniture until 2005,\(^\text{xii}\) and a significant amount of post-industrial foam from this process was incorporated into bonded carpet cushion. PentaBDE comes from a class of persistent organic pollutants (POPs) called polybrominated diphenyl ethers (PBDEs), which have been banned or phased out in North America and Europe.\(^\text{xiii}\) These flame retardants are semi-volatile and can migrate from products, concentrate in household dust, and expose building occupants who inhale or ingest this dust. Besides being persistent and bioaccumulative, PBDEs are associated with cancer,\(^\text{xiv}\) exhibit reproductive and neurodevelopmental toxicity, and have been found to affect the thyroid hormones of mammals and aquatic organisms.\(^\text{xv}\)
With the phase out of PentaBDE, a suite of other flame retardants were incorporated into foam for furniture applications in order to continue to meet flammability standards. As post-industrial furniture foam was incorporated into carpet cushion, so were these replacement flame retardants. Firemaster 550, TDCPP, TCEP, TCPP, and V6 (a chlorinated organophosphate also used in automobile foam) have been identified in studies of furniture foam, and these replacement flame retardants have been found to be similarly toxic.xvi

All of these materials have been assessed by the EPA to have a high hazard for at least one of the following human health effects: carcinogenicity, acute toxicity, reproductive, developmental, and neurological as well as medium to very high aquatic toxicity.xvii These are all additive flame retardants so are not bound to the foam itself and can migrate out over the life of the product. TDCPP, Firemaster 550, TCEP, and TCPP have been found both in indoor air and dust, as well as in people.xviii All are halogenated flame retardants, a class which has been identified as persistent and bioaccumulative.xix

Many organizations, including the U.S. EPA and the United Nations, have expressed concerns about consumers’ continued exposure to these hazardous flame retardants through reincorporation of recycled materials into new products. “Millions of pounds of foam that is flame retarded with pentaBDE or an alternative have been, and will be, sold and used in homes throughout the United States as carpet cushions. Direct exposure to millions of consumers from these sources is possible,” warned the EPA in 2005. The report explains, “as carpet padding ages, foam dust will be generated and become airborne with traffic on carpet. This presents a particular exposure potential for children, who spend time on the floor.” Additionally, the flame retardants volatilize and are deposited onto household dust, which creates further potential exposure.xxx A 2016 study indicates that inhalation is also a significant exposure route for several of the replacement flame retardants.xxxi

In 2009, parties to the Stockholm Convention targeted PentaBDE and other PBDEs for global elimination. But, as global POPs experts Joe DiGangi and Jitka Strakova reported, “the decision included specific exemptions which may last until 2030 allowing the recycling of materials containing these substances such as plastics and foam into new products.”xxxii A UN review committee, however, subsequently recommended that the Stockholm Convention decision be amended to “eliminate brominated diphenyl ethers from the recycling streams as swiftly as possible,” stating that “failure to do so will inevitably result in wider human and environmental contamination.”xxxiii

Studies have confirmed the presence of high levels of PBDEs and replacement flame retardants in bonded carpet cushion. The Carpet Cushion Council tested two new bonded carpet cushion samples in 2004 (materials currently or soon to be entering the post-consumer recycling supply chain)xxxiv and found up to 0.807% (8,070 ppm) PentaBDE by weight. A study of new cushion conducted from 2005-2006, just after the phase-out of PentaBDE from the post-industrial feedstock, indicated that the average PentaBDE content in bonded carpet cushion was 0.106% by weight (1,060 ppm); however, no results were provided for replacement flame retardants.xxxv
information is available on the amount or degree of carpet cushion contamination with replacement flame retardants, but based on their extensive use in furniture foam, it is expected to be very significant. In 2014, the state of Washington tested for and identified replacement flame retardants in new carpet cushion. Of the five products tested, all contained at least four different flame retardants with total flame retardant content ranging from 0.4-8.6% by weight (4,000-86,000 ppm).\textsuperscript{xxvi,xxvii}

“Plastics and foam containing flame retardant chemicals are often recycled into other consumer products. This raises concerns about toxic chemicals moving from one product to another and continuing human and environmental exposure. The Stockholm Convention prohibits disposal operations that may lead to recovery, recycling, reclamation, direct reuse, or alternative uses of the substances. However in 2009, when flame retardant chemicals such as PentaBDE and OctaBDE were listed in the treaty, delegates agreed to make an exemption to allow the recycling of foams and plastics containing these substances. Due to concerns about the practice, they requested the expert committee, the POPs Review Committee (POPRC) to examine the practice. The POPRC recommended eliminating the flame retardant chemicals from recycling “...as swiftly as possible.” The POPRC said that simply recycling the products would disperse the chemicals into other products and continue exposure.” -- Joseph DiGangi\textsuperscript{xxviii}

**Mattress Foam**

Mattress foam currently represents a very small portion of the post-consumer foam feedstock, but many states are instituting mattress recycling programs in order to improve recovery rates.\textsuperscript{xxix} California’s Mattress Stewardship Program took effect in 2016, leading to a 30% increase in business in just the first eight days of the year at DR3 Mattress Recycling in Oakland, the largest mattress recycler in the United States.\textsuperscript{xxx}

There is conflicting information about the extent of flame retardant use in mattresses. PentaBDE was used in some mattresses at least until the phase-out of its production in 2005.\textsuperscript{xxxi} According to the Polyurethane Foam Association, these mattresses were generally for high-risk institutional applications like prisons or some hospitals, but a small number of consumer mattresses, marketed as having specific flame resistance between 2003 and 2006, likely contain halogenated flame retardants.\textsuperscript{xxxii}

A recent survey by Clean & Healthy NY, however, found that some new mattresses may still contain flame retardants in the foam. The report states: “When it comes to mattresses, conventional wisdom has been that because the federal flammability standards mandated a decade ago could not be met by relying on FR chemicals in the foam, mattress makers had stopped using them. Our survey suggests that this is not the case...” Of the 11 mattress manufacturers that responded to the survey, five do not actively source flame retardant free foam for at least some product lines, and one specifies foam free of some, but not all, flame retardant chemicals.\textsuperscript{xxxiii} More research
(and manufacturer disclosure) is needed to determine the extent of flame retardant use in mattress foam, both historically and currently, in order to assess post-consumer mattress foam as a recycled feedstock.

- **Processing Operations**

Current operations to recover and process foam from carpet cushion and mattresses are mechanical and potentially very unhealthy.

At recycling facilities, old carpet cushion is checked for physical contamination like tack strips and carpet, which requires rolling out the cushion by hand. Rebond is separated from ‘prime’ (virgin) scrap and there may be additional sorting (by density, for example) before each type is baled for shipment to a rebond manufacturer. Mattress dismantling is also performed primarily by hand and foam is similarly baled for shipment.

At the rebond facility, the collected polyurethane foam is shredded into small pieces. These flakes are then mixed with a polyurethane-based binder, which makes up about 5% to 10% of the product by weight. The mixture is heated and pressed to form shapes from which new foam products are produced.

In 2008, Heather Stapleton et al. found that FPF recycling workers and people who install rebond carpet cushion “have body burdens [of PBDEs] that are an order of magnitude higher” than the general public. Recycling workers and carpet installers may therefore be at higher risk of the negative health impacts associated with exposure to flame retardants.

Recycling plants can also disperse flame retardants into the global environment. According to a 2007 United Nations report, “Studies of the working conditions in recycling plants have detected levels of PentaBDE in the indoor air, and indicate that PentaBDE also can be spread as diffuse emissions from recycling plants.” No studies considering worker exposure or emissions of the replacement flame retardants were identified.

Rebond manufacturers cite worker safety as a high priority. Mohawk recently invested in new dust collection systems in all five of their rebond facilities to reduce the amount of particulate matter in the air. Improvement in engineering controls is a positive step, reducing the reliance on personal protective equipment to prevent worker exposure. The potential for worker exposure to hazardous flame retardants in foam and dust exists at various steps of the collection and recycling process. The most effective way to protect workers and consumers is to remove these hazardous materials from the supply chain.
“The main recycling route, rebonding to carpet padding, is shown to expose recycling workers and carpet installers along with hundreds of thousands or even millions of consumers. Dust ingestion is the main uptake route of PBDE for more highly exposed individuals. The incorporation of PentaBDE in carpet cushion which generates the highest levels of dust in the zones where children are playing is therefore of particular concern. It is notable that dust release increases as carpet ages thus exposing the children of poorer families more heavily – an exposure reflected in the published literature. An indicative assessment of the health costs associated with polyurethane foam recycling shows that total damages can be estimated at close to $USD 6 billion/year. The commercial value of the North American rebond market, by contrast, is estimated to be less than $USD 15 million/year.”
- UNEP POP Review Committee xlii (emphasis added)

**Supply Chain Quality Control and Transparency**

Rebond itself is a heterogeneous material with varying content within a single product and even more variation from product to product. There is currently no content labeling for new bonded carpet cushion and, therefore, no content information for post-consumer carpet cushion. For example, according to the Carpet Cushion Council, “A bonder would not ordinarily know or reasonably ascertain what PBDEs, if any, are in the post-consumer (take up) foam scrap it is purchasing for use with other flexible polyurethane foam in its mixing formula for bonded.”xliii This is expected to be the case for other flame retardants as well.

Despite the fact that some states have imposed limits on the quantity of PentaBDE, neither incoming FPF scrap nor outgoing shipments of new bonded carpet cushion are tested for PentaBDE or other flame retardants. The Carpet Cushion Council has conducted several surveys of PentaBDE content in carpet cushion, starting in 2005, and states that in order “to gauge the PentaBDE-content of the finished product, producers of bonded cushion are obliged to blend post-industrial and post-consumer scrap in the context of what is known about the PentaBDE-content, on average, of post-consumer scrap being collected at the time.”xliv Other flame retardants do not appear to be considered.

- Best Practices

Some bonded manufacturers are taking action to clean up their post-industrial supply of foam. Over the last three years, Mohawk has worked with its post-industrial foam supply chain to understand the presence of flame retardants and, where possible, source foam that is flame retardant free or from suppliers who have a plan to reduce and eventually eliminate flame retardants. They continue to work toward defining content for supply streams that are currently unknown with a long term goal of sourcing only flame retardant free foam for their bonded carpet cushion. Mohawk does incorporate post-consumer foam in some of their products, stating that it currently must be utilized based on the market of available foam. xlv
To address this void of content information, the United Nations recommends screening flexible polyurethane foam for bromine using XRF or other appropriate technology and segregating these materials (as is done in the electronics industry). xlvi

While XRF has been shown to be a useful screening technique for brominated flame retardants, it does not seem to be as reliable for chlorinated FRs, but research groups continue to look for faster and cheaper methods of screening for these common flame retardant chemicals. Scientists from the California Department of Toxic Substances Control recently published an article outlining screening methods for flame retardants and found that ICP-OES was a reliable laboratory technique for identifying foams containing organophosphate flame retardants (which include the chlorinated FRs used in FPF) xlviii. Another recent study identified PIXE (particle-induced X-ray emission) as a rapid screening method for chlorinated flame retardants in polyurethane foam. xlviii Development of field techniques that can be integrated into the recycling process is still needed.

Even with appropriate screening technology, testing is most feasible for large, uniform pieces of foam like mattresses and virgin FPF carpet cushion. Use of screening methods for bonded carpet cushion (which is made up of many small pieces of foam from different sources) and smaller foam scraps may be infeasible, so instituting content tracking and pursuing other recycling methods, like chemical recycling, may be better options for these types of materials.

Chemical recycling breaks down the foam into its constituent substances and could potentially be used to remove legacy flame retardants from FPF feedstocks. Depolymerization of polyurethane foam and further processing can produce pure polyols, isocyanates and amines depending on the method used. xlix This process requires grinding of the foam, so controls are still needed to prevent worker exposure and environmental releases.

While researchers have been studying chemical recycling of polyurethane foam for a while, large scale reprocessing is still in the early stages. There does, however, seem to be progress on this front, at least on the post-industrial side. In 2013, a Polish slabstock manufacturer began operating “the world’s first industrial-scale system to recover polyol from flexible foam waste,” which is used in a post-industrial, closed-loop application. li

In 2015, Emery Oleochemicals opened an industrial-scale facility for production of their INFIGREEN® recycled content polyols in Cincinnati, OH. These polyols are made from recycled polyurethane foam scrap (flexible and rigid). According to the company, they can be used as “a direct replacement for petroleum-based polyols.” xliii The current focus is on post-industrial scrap, largely for closed-loop processes. Because of the closed loop nature (recycled content polyols go back into the same polyurethane foam process from which they originated), there has not been a need to remove flame retardants or other additives. Mark Kinkelaar, the Business Director for Emery’s Eco-Friendly Polyols, noted that chemical recycling of post-consumer foam can be done in principle, but at this point, demand is only emerging. "As mattress recycling is mandated more broadly and the Circular Economy starts to take off in the EU," Mr. Kinkelaar said, "many in the
foam industry are anticipating an oversupply of scrap – leading to anticipated demand for chemical recycling. These markets don’t change quickly, so we need to develop the technology ahead of the anticipated market trend. I expect this to be a critical market need in the next five years.” Emery advertises six recycled content polyols that could be used for a variety of construction and building products.

Due to the halogens present in the flame retardants, and the likely formation of dioxins and dibenzofurans, burning FPF in incinicators or kilns, also called “thermal recovery”, should not be considered to be best practices.

- Industry Associations

In general, U.S. carpet cushion manufacturers have no mechanisms in place to screen for or remove flame retardants from FPF feedstock. The Carpet Cushion Council argues that, “The ability to continue recycling such foams in the production of new bonded carpet cushion is in the public interest as the process dilutes the PentaBDE content and helps reduce the necessity of disposing of the bulky solid waste in landfills.” As recognized by the Stockholm Convention POPs Review Committee, continuing to process and dilute these persistent, bioaccumulative, and toxic materials is not in our best interest and will lead to “wider human and environmental contamination.” Diluting persistent, bioaccumulative compounds like halogenated flame retardants is not recommended because it does not decrease the overall amount that exists in the environment and contaminates a larger quantity of foam when added back into new products. The current processing and use of these materials also lead to the release of flame retardants into the environment and people.

- State and Federal Law

State and federal regulations have, in the past, led to unnecessary inclusion of toxic flame retardants in FPF products. “From 1971-1995, HUD imposed flammability requirements led to the intentional inclusion of flame retardants (not PBDEs) in some carpet cushions,” notes the Carpet Cushion Council. Additionally, the open flame requirements for furniture foam in California TB117, which had become the de facto national standard, generally could not be easily met without the inclusion of flame retardants. In 2014, California removed this part of the requirement due to evidence of negative health impacts of added flame retardants and the limited benefit in terms of fire safety. California and seven other states have also enacted laws prohibiting use of PentaBDE at greater than 0.1% (1,000 ppm), but there are often exemptions for recycled materials. The basis of this threshold could not be determined, but it corresponds with the EU POPs regulations delineation below which a substance is considered a contaminant versus intentionally added content. This is not believed to be a health-protective threshold for PBDEs or the other common flame retardants identified in FPF.
- Transparency

Foam manufacturers do not generally disclose the flame retardants they use, claiming this information as proprietary. End use manufacturers who source foam for use in furniture and mattresses may not even know the specific flame retardants used in the foam they incorporate into their products.

The Polyurethane Foam Association (PFA) advocates for a degree of transparency through its CertiPUR-US® program. The CertiPUR-US® testing applies to foam producers, and the certification label can be applied to products that incorporate certified foam. This voluntary industry-run program uses independent laboratory testing to certify that polyurethane foam does not contain ozone depleting chemicals, certain flame retardants, heavy metals, or certain phthalates, and is low-VOC. The program prohibits use of certain flame retardants including PBDEs and, as of January 15, 2015, TDCPP and TCEP, but does not certify whether foam is flame retardant free. CertiPUR-US® applies only to prime (or virgin) FPF, so there are no rebond products certified under this program.

The Carpet Cushion Council has an indoor air quality program and label (CRI Green Label and the new Green Label Plus), but this only requires testing for specific VOCs. The flame retardants found in carpet cushion are generally semi-volatile organic compounds which can escape into air and dust, but are not covered by this testing.

New labeling requirements have gone into effect in California (SB1019) that require upholstered furniture labels to indicate whether or not there are added flame retardants. The Center for Environmental Health reports in a recent survey that, despite the fact that labeling is only required in California, 78% of the 37 residential furniture companies surveyed report that they are labeling products nationwide regarding their flame retardant content. These requirements do not currently apply to mattresses or carpet cushion.

- Green Jobs and Other Local Economic Impacts

Most of the recycling of post-consumer polyurethane foam scrap takes place in the United States and Canada. Given that this recycling industry is largely domestic and employs Californians in related facilities, these jobs are found “close to home.” But we can not give FPF a “Green Jobs” green rating at this point, given recycling workers’ elevated body burden of flame retardants.

- Bay Area/California Connections

There are several bonded manufacturing facilities located in California and in close proximity to the Bay Area: Leggett & Platt in Tracy, Carpenter Co. in Lathrop, CA, and FXI in San Leandro.

There are also several carpet pad collection facilities in California and the Bay Area. See CalRecycle’s web page for a full list.
The largest mattress recycling facility in North America is California-based DR3 with locations in Oakland and Woodland. In 2014, DR3 recycled 130,000 mattresses in California. That translates to about 620 tons of foam annually.

**Room to Grow**

According to an industry market survey released in 2000, the carpet cushion industry used about 55,000 tons of post-consumer foam annually, accounting for 13% of the FPF recycled into bonded. This amount has tripled. In 2005, according to the Carpet Cushion Council, the industry recycled about 150,000 to 200,000 tons of post-consumer carpet cushion annually with estimates remaining the same for 2011. This accounts for an estimated 30-40% of the total recycled FPF used in carpet cushion (the remainder being post-industrial, both imported and domestic). The increase in the percentage of recycled foam that is post-consumer may be tied to polyurethane foam industry efforts to decrease the amount of post-industrial scrap generated (meaning less post-industrial scrap is available) as well as implementation of the Carpet America Recovery Effort (CARE) initiated in 2002 to divert carpet from landfills (many carpet recyclers also accept polyurethane carpet cushion, including bonded). The percentage of post-consumer foam within a specific product varies by manufacturer and density.

Due to contamination of this post-consumer foam with legacy flame retardants, it is questionable whether it should continue to be mechanically recycled, contaminating new products with hazardous substances.

Labeling, screening, and tracking flame retardant free foam would enable uncontaminated material to be separated from foams containing flame retardants. Current sources of uncontaminated material include post-consumer virgin FPF carpet cushion and flame retardant free post-industrial foam. Chemical recycling means should be explored for removing hazardous flame retardants from contaminated foams like post-consumer rebond. Additionally, organizations like the Green Science Policy Institute are researching responsible disposal methods for foam containing flame retardants.

Post-consumer mattress foam represents a potential room to grow the recycled FPF feedstock. Additional work is needed to determine the extent of flame retardant use and identify field screening techniques to segregate foams with flame retardants.

According to the Mattress Recycling Council, in the U.S., up to 20 million mattresses and boxsprings are discarded each year. This is an estimated 60,000 tons of FPF annually. Currently only about 2% of mattresses are recycled nationwide. A 2012 CalRecycle Case Study estimated that 4.2 million mattresses and box springs (an estimated 12,500 tons of FPF) are discarded in California alone with less than 5% being recycled. CalRecycle estimated that based on this recycling rate “fewer than 30 full time employees work in mattress recycling [in California]. The recycling of all 4.2 million units would require around 575 fulltime employees. Additional jobs would be created in the industries that process the secondary outputs of the mattress recyclers, i.e. the steel
scrap, the polyurethane foam, the cotton, the cover (toppers), and the wood. EPR measures that lead to the collection and recycling of 4.2 million mattress and box spring units per year are therefore estimated to generate in the order of 1,000 jobs, most of which are entry-level positions.\textsuperscript{lxxxiv}

California’s Mattress Stewardship Program which took effect at the start of 2016 is already impacting recycling businesses. DR3 Mattress Recycling manager Robert Jaco reported a dramatic uptick in business in just the first few days of the year and that a second crew may be needed by the end of January.\textsuperscript{lxxxv} As the recycling of mattresses continues to increase, screening processes should be identified and implemented to segregate foam that contains flame retardants. Studies should be conducted to ensure that workers doing this screening are not exposed to flame retardants.

With proper screening or certification, additional foam supply could potentially come from an increase in imported scrap. Flame retardants have primarily been used in products sold to North America and the United Kingdom,\textsuperscript{lxxxvi} so post-industrial and post-consumer scrap from other markets may provide additional sources for flame retardant free foam. Additional study is needed to determine specific markets.

Over the longer term, improved transparency and chain of custody throughout the supply chain could result in the availability of a much larger quantity of flame retardant free post-consumer foam. The recent changes to CA TB117 allows for flame retardant free furniture foam, and a new survey indicates that many furniture manufacturers are already sourcing flame retardant free foam.\textsuperscript{lxxxvii} Post-industrial FPF scrap without flame retardants is already becoming available for use in bonded carpet cushion. A December 2015 report from the Commission for Environmental Cooperation reported that there has been industry speculation that up to 90% of upholstered furniture companies would stop use of flame retardants in foam, but did not provide a timeline or overall quantity estimates.\textsuperscript{lxxxviii} Post-industrial scrap from new furniture manufacturing and post-industrial only rebond that is free of flame retardants should be labeled for future recycling. Changes made now can impact the post-consumer FPF supply within the next 5-15 years.\textsuperscript{lxxxix}

**Conclusions**

Standard practices of post-consumer FPF recycling create health hazards for workers in the recycling and carpet installation industries as well as for children and other building occupants. However, there are at least two pathways to optimize the use of this waste stream.

**Source flame retardant free foams whenever possible and test when flame retardant content is unknown:**

As more upholstered furniture products are labeled with content information, this information can be transferred through the post-industrial FPF supply chain with foam scrap and can also be used to identify flame retardant free post-consumer furniture foam in the future. Additional study is needed to determine the degree of flame
retardant use in mattress foam domestically and its potential as a flame retardant free post-consumer feedstock. In the meantime, mattress manufacturers and bonded manufacturers using only flame retardant free foam should also label products for future recycling. If transparency about content is propagated throughout the supply chain, safer post-consumer FPF feedstocks can be domestically sourced in the future.

**Chemical feedstock recycling:** Investments in these technologies could segregate hazardous flame retardants from feedstocks being reused in building products. Progress has been made in industrial scale chemical recycling of polyurethane foam, but efforts are needed in exploring this avenue for post-consumer FPF, including the effective removal of flame retardants.

Recycling foams is a great benefit to the environment, reducing not only landflling impacts at end of life, but also decreasing the supply chain and upstream impacts of new foam production. These benefits must be balanced against the multi-billion dollar per year health impact, according to the United Nations, that current recycling practices create. Therefore, investigating ways to optimize FPF recycling via improved labeling, screening, and recycling technologies is a relatively small price to pay.

**Recommendations**

For the Recycling Industry:

Sources of FPF that do not contain flame retardants are increasingly available, especially from new post-industrial and post-fabrication scrap sources. Track, label and separate these flame retardant-free foams from other contaminated recycled sources.

Track sources of scrap foam (post-consumer and post-industrial) that are known or suspected of containing flame retardants and separate those from sources that are flame retardant free, and label accordingly.

Work with researchers and agencies to evaluate and implement screening processes when presence or absence of flame retardants in foam is unknown. Invest in research and development of chemical recycling for removal of toxic flame retardants.

For recycling entities involved in the handling, processing, and transportation of FPF, institute occupational protections including deployment and use of of additional inhalation and dermal exposure Personal Protective Equipment (PPE) for all occupational workers. Work to minimize and contain exposure pathways to all work areas where possible hazardous flame retardant chemicals may be in materials that are collected, processed, or transported.

For Manufacturers:

For manufacturers using recycled content, work with the recycling supply chain to ensure that end products do not contain flame retardants above a 0.01% (100 ppm) threshold.
Prefer cleaner sources of foam; specify flame retardant free post-industrial feedstocks whenever possible. Incorporate methods to track composition throughout the supply chain. Implement testing to ensure specifications are met. For bonded products containing only post-industrial content, identify and label those that are flame retardant free for future post-consumer recycling.

Train all workers on best practices in handling materials that contain flame retardants. Create manufacturer precautionary information and instructions to reduce occupational exposures for workers that may collect, process, or transport possible hazardous flame retardant chemicals.

FPF can be recycled several times if the feedstock is of suitable quality. Therefore, foam producers should remove flame retardants from new foam production whenever possible. To prevent contamination of future recycling streams, label products and scrap indicating whether the foam contains flame retardants.

Foam fabricators who trim foam for use in furniture should separate and label scrap indicating whether flame retardants are present for tracking throughout the recycling supply chain.

Mattress and furniture manufacturers should pursue inherently safer designs that do not require flame retardants and specify flame retardant free foams whenever possible. Label products and scrap indicating whether flame retardants are present for tracking throughout the recycling supply chain.

For Purchasers:
Encourage a flame retardant free supply chain by purchasing products that are labeled as flame retardant free. If products are not labeled, request product literature that discloses material ingredients—including residuals and contaminants—down to 100 ppm (0.01%). Ask for Health Product Declarations from manufacturers.

For Certifiers:
Expand the CertiPUR-US® certification program to certify products as being free from all classes of flame retardants.

Seek labeling or other indicators of the CertiPUR-US certification information that stay with the materials throughout the recycling supply chain. Include this information with scrap so that recycled content building products—such as bonded carpet cushion—can be certified if made with certified foam.

For Agencies:
Review current fire safety requirements for consumer products and seek situations where flame retardants are not needed or inherently safer designs are possible. Invest in research to determine the extent of historical and current flame retardant use in mattress foam. Support studies of the scalability of testing and screening techniques and subsidize equipment. Incentivize supply chain quality controls and labeling to track flame retardant content throughout the recycling supply chain.
Encourage development of chemical recycling infrastructure. For foams that should not be recycled, investigate responsible disposal methods that do not release hazardous chemicals into the environment (air, water or land).

Encourage circular manufacturing processes by seeking solutions that encourage or require manufacturers of these products to help carry physical and/or financial responsibility for their fate at end of life. Encourage extended producer responsibility (EPR) programs, regulation, or other incentives for manufacturers to take-back or be responsible for disposal costs if suitable recycling markets are not available for products.

Work with recycling processors to ensure worker exposure is minimized by the use and deployment of adequate Personal Protective Equipment (PPE). Assess processing facilities to ensure facilities are not creating conditions of public exposure.
ENDNOTES


vii The primary blowing agent in FPF is carbon dioxide which is created when isocyanates react with water. CFC-11, a potent ozone depletor and global warming agent, was used as a secondary blowing agent until its phase out in 1994. Replacement secondary blowing agents are methylene chloride and acetone which have some human health concerns associated with their use. Due to the open-cell structure of the foam, however, these blowing agents are not expected to be present in the post-consumer FPF feedstock. (Kaufman, C.M., and M.R. Overcash. “Waste Minimization Strategy: Flexible Polyurethane Foam Manufacture,” June 1990. http://infohouse.p2ric.org/ref/04/03214.pdf; Protection of Stratospheric Ozone; Final Rule, 59 Federal Register 13044, March 18, 1994. https://www.gpo.gov/fdsys/pkg/FR-1994-03-18/html/94-4753.htm;


In 2003, the European Union banned the manufacturing of products containing more than 0.1% penta- and octaBDE. The EU banned the use of decaBDE in electrical and electronic equipment in 2008. Some individual states in the U.S. (starting with Maine and Washington) have banned PBDEs. U.S. manufacturers voluntarily phased out the production of penta- and octaBDE in 2004 and decaBDE at the end of 2013.


Bonded cushion is a heterogeneous material. The results for the area tested may not be representative of the entire product and are expected to vary greatly between products. For this testing, samples were ground to create a homogeneous test sample. PBDE’s, TDCPP, TCPP, TCEP and V6 were all identified in the carpet cushion samples. TPP (a component of Firemaster 550) was also identified in the samples but the other components of Firemaster 550 (TBB and TBPH) were not tested for.


Personal communication with Robert Jaco, Manager DR3 Recycling, Jan. 8, 2016.


Personal communication with Jon England, Sr. Director of Mohawk Pad and Cushion Division, Feb. 1, 2016; Personal communication with Randy Dye, Product Development/Marketing Manager Leggett & Platt Carpet Cushion, Jan. 21, 2016.

Personal communication with Jon England, Sr. Director of Mohawk Pad and Cushion Division, Feb. 1, 2016.


Personal communication with Jon England, Sr. Director of Mohawk Pad and Cushion Division, Feb. 1, 2016.


Personal communication with Mark Kinkelaar, Business Director for Emery’s Eco-Friendly Polyols, March 24, 2016.
In its guidance on best available techniques for PBDEs, UNIDO acknowledges that “the thermal treatment of POP-PBDE containing wastes… is a challenge for thermal facilities because of its high halogen content…. Since POP-PBDE-containing materials are flame retarded, their flammability is reduced, which can result in increased formation of products of incomplete combustion in facilities not equipped with optimally efficient combustion chambers… DecaBDE can degrade in thermal processes, environmental processes and in biota to… polybrominated dibenzofuran and, depending on conditions, polybrominated dibenzo-p-dioxins.” (United Nations Industrial Development Organization. “Guidance on Best Available Techniques and Best Environmental Practices for the Recycling and Disposal of Articles Containing Polybrominated Diphenyl Ethers (pbdes) Listed Under the Stockholm Convention on Persistent Organic Pollutants,” 2012.


Stockholm Convention. “Information unintentional trace contaminants and low POPs content for waste,” July 2012,


http://www.pfa.org/Library/NPR_Statement%20(2).pdf


http://certipur.us/faq/.


DR3 recycled an additional 40,000 mattresses at their Oregon facility.


Low density (3-4 lb) bonded does not contain post-consumer scrap, medium density bonded cushion can contain up to 20% and high density up to 50%. (Haines, Bill. “Recycling Carpet Cushion Revealed.” Carpet Cushion Council, February 4, 2008. http://www.carpetcushion.org/recycling.cfm.) Some bonded manufacturers use only post-industrial FPF scrap.


An estimated 10 weight% of a mattress/box spring set is foam. An average mattress/box spring set weighs about 54.4 kg. (Geyer, Roland, and Kuczenski, Brandon. “Mattress and Box Spring Case Study: The Potential Impacts of Extended Producer Responsibility in California on Global Greenhouse Gas (GHG) Emissions.” California Department of Resources Recycling and Recovery (CalRecycle), May


Personal communication with Robert Jaco, Manager DR3 Recycling, Jan. 8, 2016.


