Disposable Plastic Buildings: Case Studies in K-12, Healthcare, and Affordable Housing

Habitable (formerly Healthy Building Network)
Perkins&Will

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About the Authors

About Perkins&Will

Perkins&Will, an interdisciplinary, research-based architecture and design firm, was founded in 1935 on the belief that design has the power to transform lives. The firm is committed to creating a better, beautiful, more equitable world through Living Design, an approach that integrates environmental, social, and design considerations to advance ecological health and well-being. *Architizer* named Perkins&Will the world's "Best Sustainable Firm" in 2023, and *Metropolis* named it "Firm of the Year" in 2022 for its industry leadership in advancing climate action and social justice. *Fast Company* named Perkins&Will one of the World's Most Innovative Companies in Architecture three times, and in 2021, it added the firm to its list of Brands That Matter—making Perkins&Will the first architecture practice in the world to earn the distinction.

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About Habitable

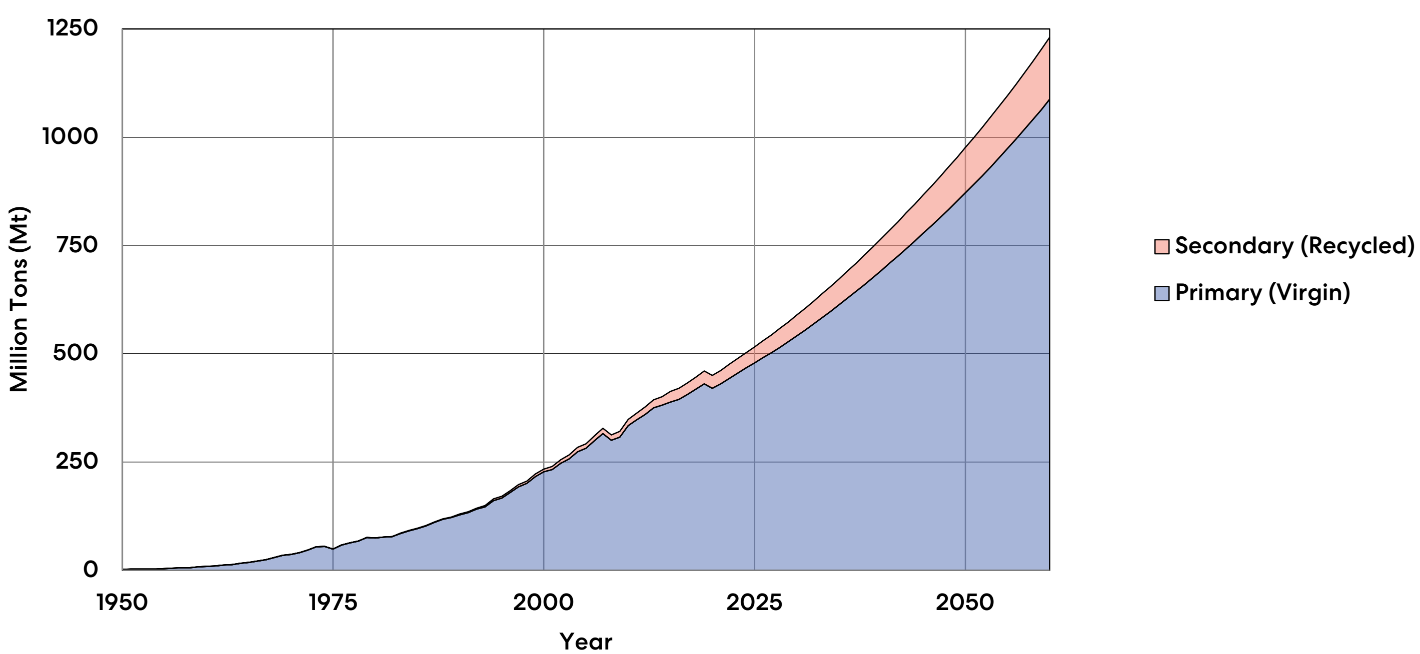
Habitable (formerly Healthy Building Network) believes that all people and the planet will thrive when the materials economy is in balance with earth's natural systems. Our team of researchers activate science to reduce pollution, mitigate climate change, and create a healthier and more equitable future for all. Our Informed™ initiative supports the built environment practitioners in selecting products with safer chemicals to improve the health of humans and the environment.

www.habitablefuture.org

Plastic production is on the rise.

Plastic pollution is compromising planetary health, contributing to both the climate crisis and human and environmental harm.[1, 2,a] Energy efficiency and electrification efforts have led to an overall reduction in energy intensity in the building sector, translating to a reduction in operational carbon for every square foot of building constructed.[3] Unfortunately, as we reduce our reliance on fossil fuel for building operations, plastic production that relies on those same resources continues to grow.[4–6] The building and construction sector, as the second largest consumer of plastics, is a major driver of this fossil fuel growth.[7]

Figure 1: Projected Global Plastic Growth



Source: Global Plastics Outlook - © OECD 2022.[8] Plastics use projections to 2060 - Figure 3.5. Primary plastics will still make up the lion's share of production in 2060. https://stat.link/15rn7z

Plastics are problematic for people and the planet.

The life-cycle of plastics is concerning for several reasons:

1. Plastic products contribute to greenhouse gas emissions.[9]

2. Toxic chemicals are used and produced throughout the life-cycle of plastic that present hazards to human and environmental health.[10]

3. Children, low wealth communities, and communities of color disproportionately bear the burden of exposure to these chemicals, including those from fossil fuel extraction and refining.[11–16]

4. Plastic breaks down into small particles, such as microplastics, in the environment. There is evidence demonstrating that these accumulate in people's bodies[17, 34], and suggesting that they are associated with adverse health outcomes, such as low birthweight.[35]

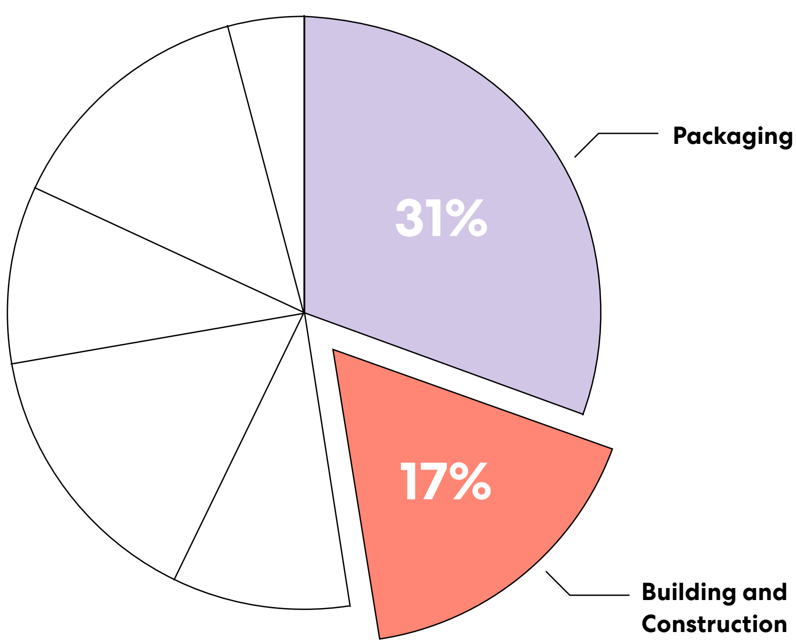
Our Plastic Buildings

Conversations about plastic production, use, waste, and pollution, tend to focus singularly on packaging, failing to address the massive contribution that buildings add to the plastics crisis.

Opportunity and Impact: Plastics and the Building Sector by the Numbers

Building and construction accounts for almost 17% of plastics used globally.

Figure 2. Plastics Use By Sector[7]



Plastic is found in many types of building products. Below are a few examples:

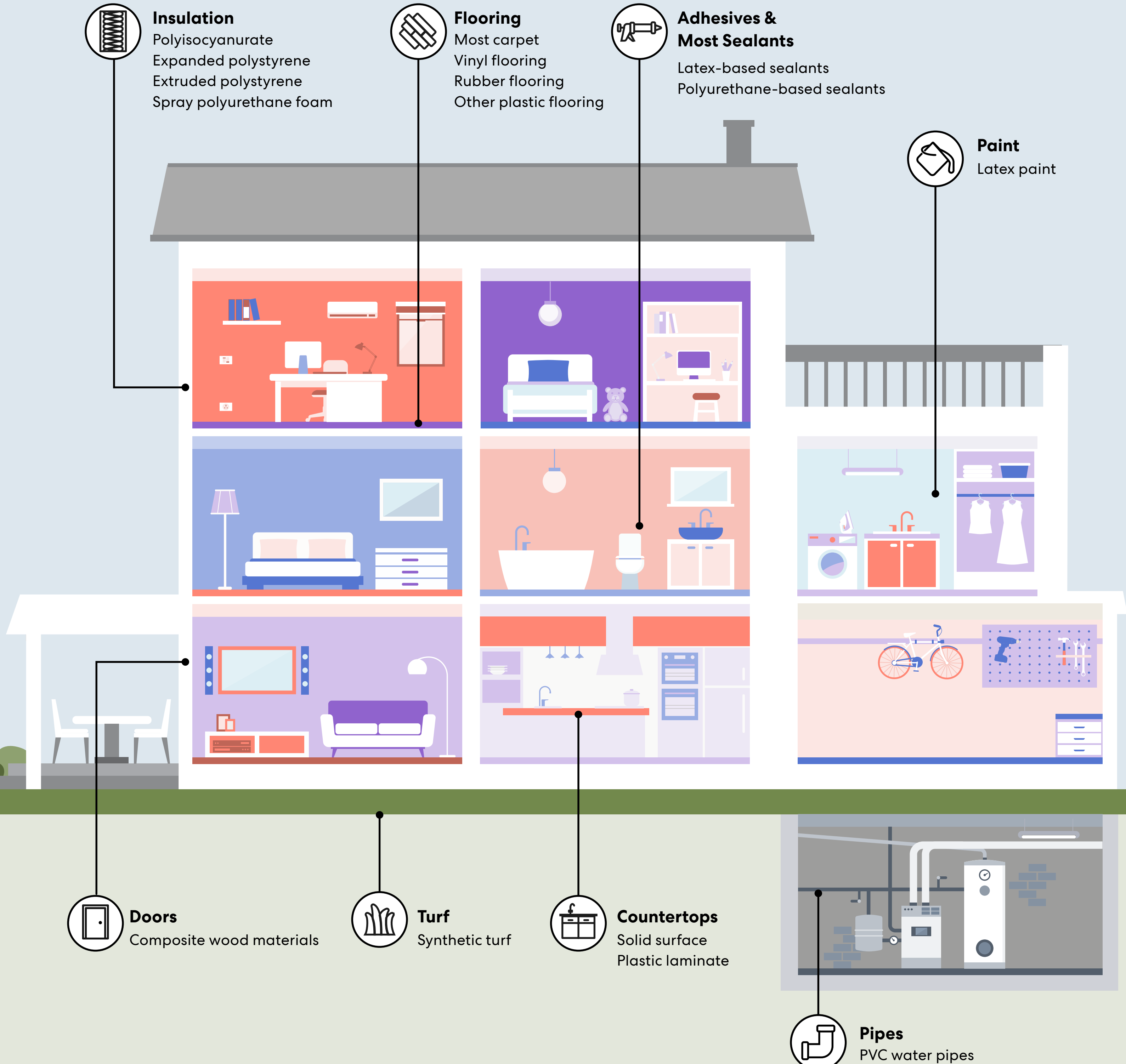


Figure 3. Common places plastic is found in buildings, Habitable[19]

Buildings contribute to plastic waste and pollution.

Most plastic construction and demolition (C&D) waste is landfilled.[19] For example, 2 million tons of carpet is discarded in the U.S. every year. That's 1.2 million tons of plastic—about the same amount as all plastic straws, plastic bags, and plastic water bottles combined (see Figure 4).[b] Moreover, plastic waste from building materials is not confined to landfills. For instance paint, including architectural paint, is estimated to be the largest source of microplastic leakage into oceans and waterways.[20] Paint microplastics can leach toxic chemicals that harm aquatic ecosystems.[21]

For specific examples of how buildings contribute to plastic waste, see Appendix A which has case studies on K-12, healthcare, and affordable housing.

Figure 4. Plastic Waste from Discarded Carpet

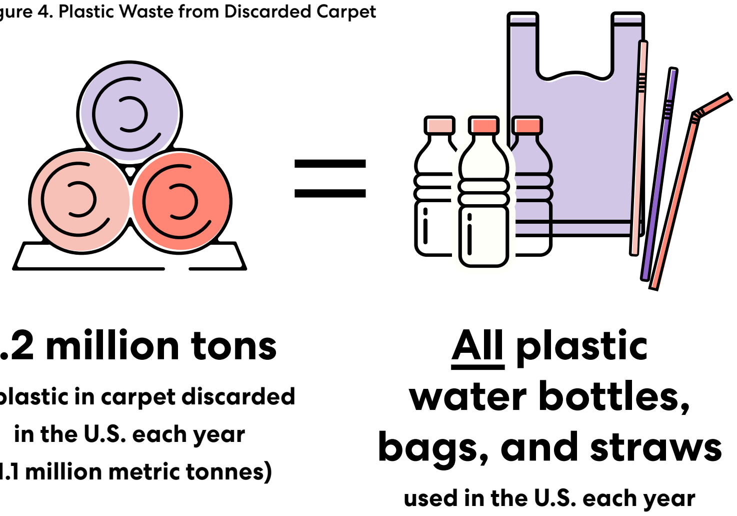
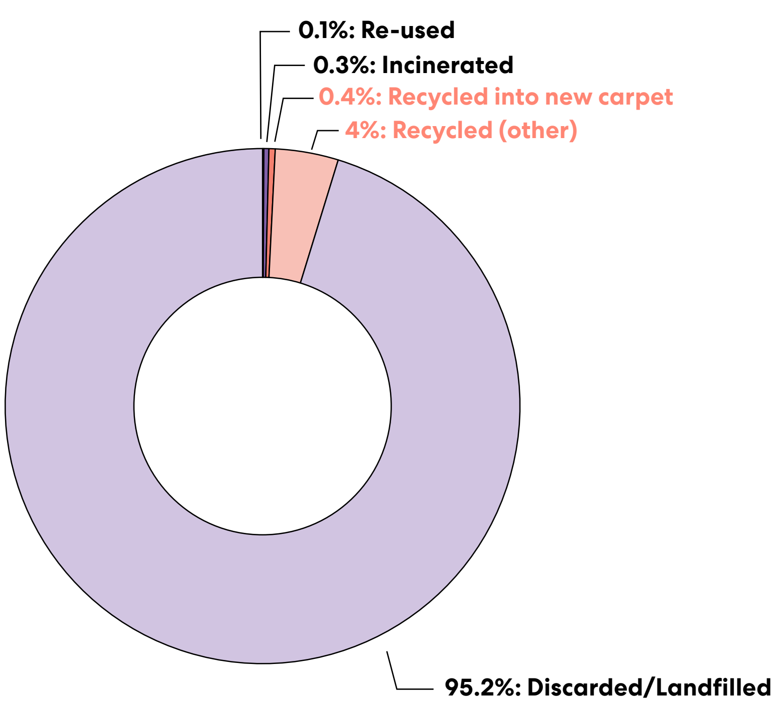


Figure 5. 2019 Carpet End of Life Statistics



Based on Statistics Reported in the CARE 2019 Annual Report

Recycling alone is not a viable solution.

While plastic recycling may appear to align with efforts to move from a linear economy to a circular economy, barriers to recycling mean that most plastic still ends up in landfills or is incinerated.[8,22] Globally, only an estimated 9% of all plastic is recycled, and in the U.S. the estimated percentage is much less: 4%.[23,24] California has one of the most developed recycling programs for building products in the U.S.: the California Carpet Stewardship Program estimates that approximately a third of the carpet discarded in California is converted into recycled output. However, data shows that carpet recycling is much lower nationwide, in fact less than 0.5% of used carpet is recycled into new carpet (see Figure 5).[25,26]

Current product certifications and green building standards don't adequately address plastic's impacts.

Environmental Product Declarations (EPDs) and embodied carbon comparisons can incentivize lightweight plastics products while not accounting for service life or human health impacts, including those resulting from the use and release of hazardous chemicals throughout plastic products' life-cycle.[27,28]

Product certifications focused on the human health impacts of materials used in the building sector are often scoped to solely address the use phase (i.e. occupant health) of plastic products' life-cycle, but typically do not focus on the extraction origins, manufacturing, and end of life stages.

When we don't consider the life cycle impacts we ignore the harms happening to fenceline communities, factory workers, installers, and others along the supply chain.

Since we cannot rely on product certifications and recycling to reduce the amount of plastic waste generated by building materials, and plastic waste has demonstrable adverse effects to human and environmental health, the precautionary principle says that it is critical that we consider eliminating the source of plastic by specifying non-plastic, healthier, long-lasting alternatives.

Non-plastic alternatives exist

Viable no- or low-plastic alternatives exist in the marketplace for most plastic building materials. Tools like Habitable's Informed™ Product Guidance[29] can help project teams find alternative product types that serve the same function, minimize plastic, and are ranked better from a material health perspective. In the example below, Informed™'s color ranking shows that preferring flooring ranked yellow and green will generally direct teams toward options that contain less plastic. As other free science-based transparent tools to identify plastic-free alternatives emerge, we will recommend them in future publications.

See Appendix C: Plastic Content in Various Types of Flooring

Figure 6.

Informed™ Flooring Product Guidance	**High Plastic Use ***
Linoleum	
Solid Wood Floor (pre finished)	
Concrete (no finish/accessories or only densifier without PFAS)	
Ceramic Tiles (no added lead)**	
Solid Wood Floors (site-finished)	
Cork Floors (pre-finished)	
PVC-free Resilient Flooring	///
Engineered Wood Floors (pre-finished)	
Rubber or Rubber/Cork Floors made without tire-derived crumb rubber)	///
Laminate	///
Carpet (with no fly ash, no vinyl or polyurethane backing, and no PFAS)	///
Engineered Wood Floors (site-finished)	
Vinyl Floors (no pthalates or hazardous recycled content)	///
Rubber or Rubber/Cork Floors (made with tire-derived crumb rubber)	///
Carpet (containing fly ash, vinyl or polyurethane backing and PFAS)	///
Vinyl Floors (containing phthalates, hazardous stabilizers, and hazardous recycled content)t	///

*High Plastic Use = greater than 0.19 lbs/ft²

**Ceramic tiles typically do not contain plastic, but plastic will be introduced through accessories such as epoxy and polymer-modified grouts.

The benefits of shifting away from plastic building products.

1 Products manufactured from plant- and mineral-based materials tend to have fewer health and environmental impacts throughout the product life-cycle than fossil-fuel based plastic materials.

2 As revealed in the **Embodied Carbon and Material Health in Gypsum Drywall and Flooring** and **Embodied Carbon and Material Health in Insulation** reports, many healthier alternatives to plastic products also have lower embodied carbon.[27,28]

3 Many healthier alternatives are also more durable than plastic products, with longer expected service lives.

Case Study Highlights

K-12 School Case Study

Based on one school's specifications for 185,116 ft² of floorspace we estimated that 71 tons of plastic waste would be generated over the lifetime of the school due to flooring alone.

Healthcare Case Study

Based on 61,220 ft² of floorspace specified in one inpatient clinic we estimated that 19 tons of plastic would be generated over the lifetime of the clinic due to flooring alone.

Affordable Housing Case Study

Based on data from 36 affordable housing projects in Minnesota, we estimated that 59 tons of plastic waste is generated from flooring alone for a 60-unit multifamily residential building. This amounts to almost one ton of plastic per 1000 ft² living unit over the lifetime of the building. Carpet in bedrooms alone generates nearly a half a ton of plastic waste per unit.

In all three cases, nearly all plastic waste associated with flooring could be avoided by replacing the vinyl, rubber, and carpet flooring with a low- or no-plastic flooring such as linoleum[c] or ceramic tile.

See Appendix B: Estimated Service Life of Building Products

Opportunities for practitioners

Design and build with healthier materials that are safer for human and environmental health, benefiting your clients and many other communities.

- Replace plastic product types with non-plastic product types, selecting those that are better from a material health perspective throughout the product life-cycle using tools like Informed™ Product Guidance.
- If fully replacing all plastic products is not possible, start where you can. For example:
  - Covering 1000 square feet of a building's floorspace with linoleum, ceramic tile, wood, or other no- or low-plastic flooring instead of carpet can eliminate the generation of over one ton of plastic waste throughout the building's lifespan.

See Appendix A for examples of plastic reduction opportunities in K-12, healthcare, and affordable housing.

Integrate product decisions as early and as often as possible into the design and construction process using scalable methods and tools.

- Standardize material health and plastic reduction criteria into project specifications to ensure that the product types chosen meet material health goals while aligning with other project goals and outcomes.
- Create a "Do Not Substitute" list to ensure that contractors receive approval for additional products used in the project, and to ensure that the products used are safe for human and environmental health.

Engage with the supply chain early to address availability, cost, and performance barriers, strengthening the demand for healthier products.

- Participate in demonstration projects that test plastic product alternatives at a small scale before deploying them full scale.
- Talk to your suppliers about providing non-plastic products that meet your needs.

Endnotes

a. Here and throughout this document "plastic" refers to the sum of plastic resin, rubber, and other synthetic polymers included in a product's formulation, and excludes fillers and other additives.

b. Original calculation. See Habitable. Advancing Health and Equity through Better Building Products; 2024. https://habitablefuture.org/resources/advancing-health-and-equity-through-better-building-products/.

c. This recommendation refers to standard linoleum sheet and tile products that are mostly composed of cork and wood dusts, linseed oil, and calcium carbonate or limestone. It does not refer to bio-based flooring products that are fluid-applied on site, which are sometimes referred to as liquid linoleum. The latter contain a high percentage of isocyanates, which are potent respiratory sensitizers,[30–32] and the cured products can be over 20% plastic by weight.[33]

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Appendix A:

Case Studies on Flooring in K-12, Healthcare, and Affordable Housing

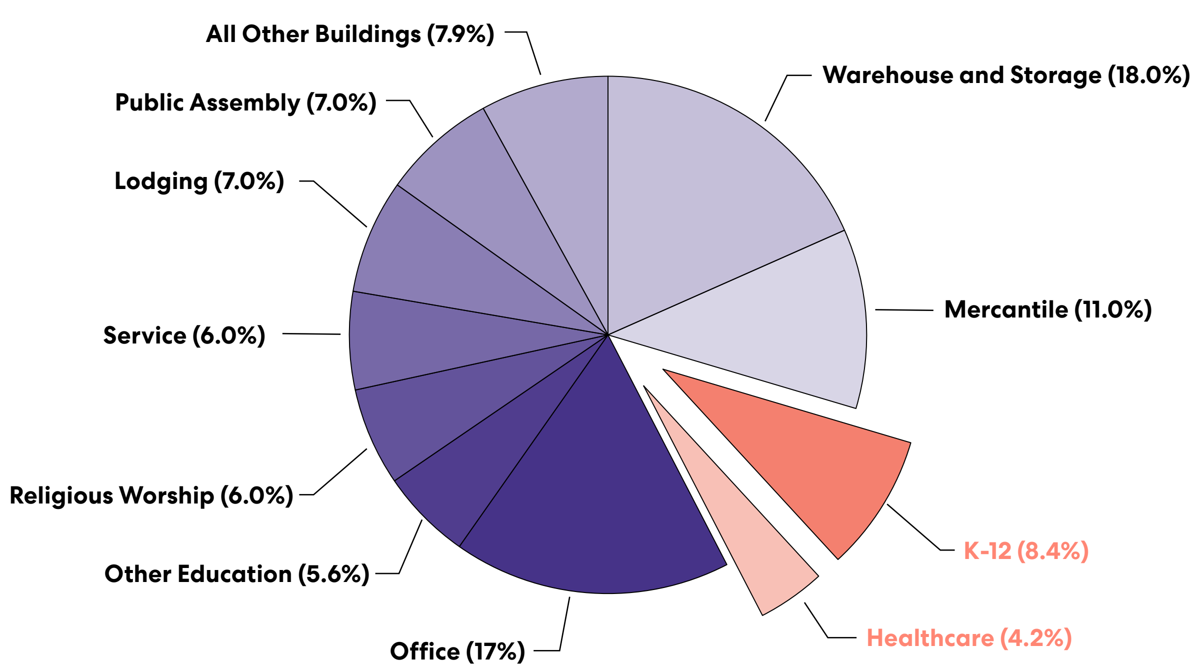
Contribution of K-12, Healthcare, and Affordable Housing to U.S. Building Stock

There are approximately 96.4 billion ft² of commercial floorspace in the U.S.[1] Healthcare accounts for an estimated 4 billion ft² (4.2%) and K-12 accounts for 8.1 billion ft² (8.4%) of this floorspace (see Figure 1).[2,3] Nearly half of renter households in the U.S. spend more than 30% of their income on housing costs, and are in need of affordable housing.[4] These sectors serve the most vulnerable populations. They also present opportunities to use products optimized for material health and reduce the use of building materials contributing to plastic waste.[a]

The goal of specifying these products is to reduce the use of materials that have impacts both inside buildings and among communities affected throughout their life-cycle.[5] The case studies presented here summarize flooring data from real buildings, and highlight the impact that individual buildings can make on plastic reduction efforts by specifying alternative materials. While the scope of these case studies was limited to flooring, further plastic reduction could be achieved by specifying low- or no-plastic materials in other product categories.

Figure 1. Percent of Total Commercial Floorspace by Sector

Data based on estimates of total floorspace used for principal building activities in the U.S. from the 2018 Commercial Building Energy Consumption Survey (CBECS 2018). The CBECS 2018 estimates for education include higher education, so estimates for K-12 floorspace are taken from the 2021 State of Our Schools report. Percentages displayed in the figure are consistent with the source data, which total 98%.[1,3]



Process for Estimating the Amount of Plastic Attributed to Flooring

In order to estimate the amount of plastic attributed to flooring in the healthcare and K-12 sectors we sought out publicly available data on the typical amount of floorspace devoted to specific materials and service life data for these materials. Unfortunately, we found that data on the percentage of floorspace devoted to specific materials are lacking. Actual service life, i.e. the length of time that a product has been in a building when it is replaced, is not typically recorded or stored in a central database. Interviews with school administrators, sustainability professionals, architects and contractors working in both the healthcare and K-12 sectors confirmed these findings.[b] While data were insufficient to provide meaningful estimates of the total amount of plastic attributed to flooring in healthcare and K-12 buildings in the U.S., data were sufficient to estimate the amount of plastic contributed by some individual buildings.

To support this study, Perkins&Will provided data from healthcare and K-12 buildings for existing projects that included the amount of floorspace covered by different product types. Habitable provided flooring specification data from 36 projects funded through the Minnesota Housing Finance Agency (MHFA) in 2019 and 2020. Habitable Common Product data were used to estimate percent plastic by weight for each type of flooring.[c] We combined the coverage data with the median of flooring service life estimates reported from life-cycle costing studies to estimate plastic waste generated by buildings.[6–10] Carpet service life estimates are a median of service life estimates for broadloom carpet and carpet tile combined. Service life estimates for vinyl represent the median service life for products labeled "vinyl" or "VCT" (vinyl composition tile).

The median service life for each type of flooring was used to estimate the number of times a product was installed or replaced. This value was then multiplied by the total area of flooring covered by that product type. The resulting value was multiplied by the weight of plastic per square foot, which was estimated from Habitable's Common Product Data.[16] This number assumes that all plastic from flooring is eventually landfilled or incinerated.[d] It also does not account for overage or attic stock ordered for projects.[e]

These data lack a high degree of precision, so the case studies presented here are intended to highlight the scale of plastic waste that may be generated by real buildings. The data should not be understood to be statistically representative estimates for 'average' buildings.

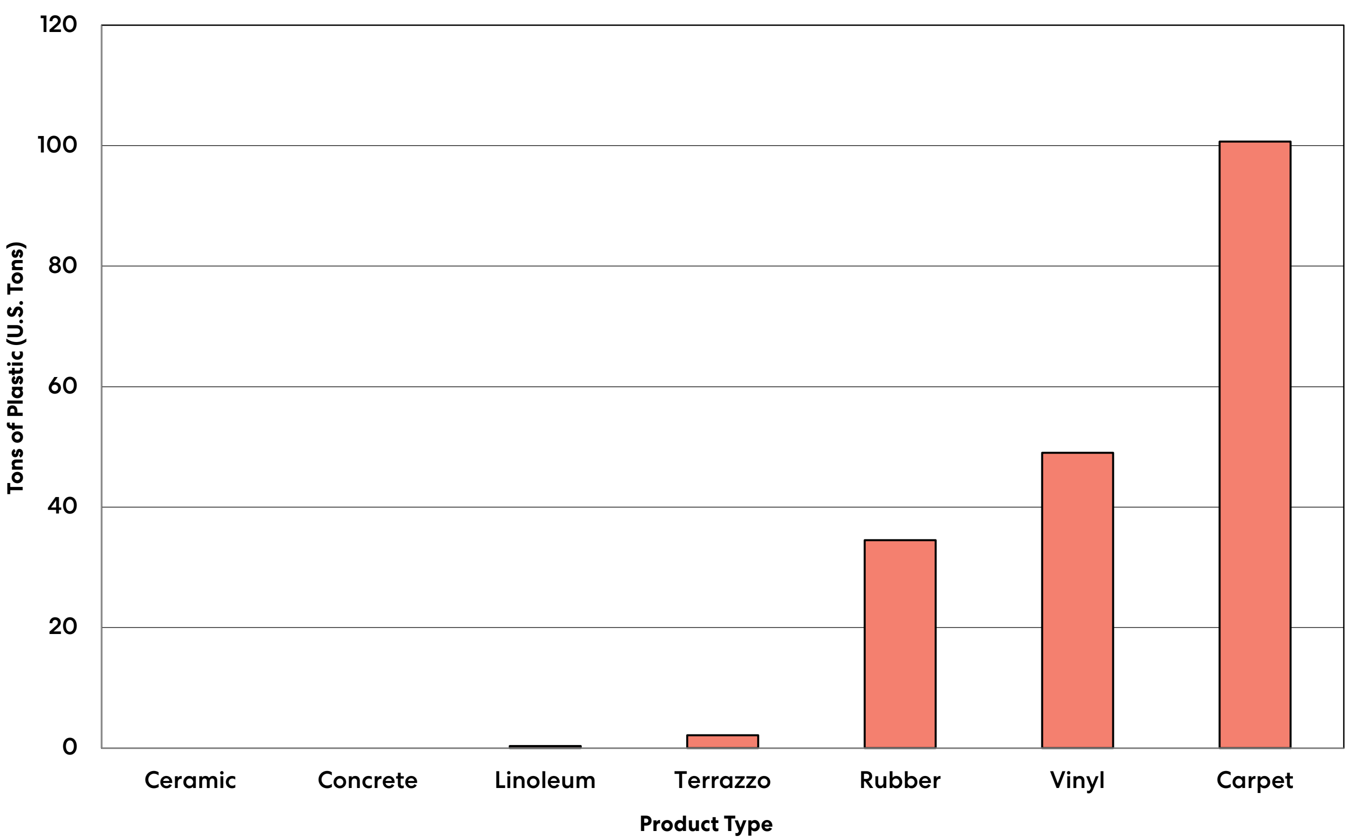
Estimating Plastic Waste from Paint

In addition to collecting data on flooring use and service life, we collected data on paint use and frequency. We conducted a literature review and asked questions about painting frequency in the interviews noted above. Ultimately, we were not able to gather enough paint data on real buildings in the K-12 and healthcare sectors, so an analysis of paint use was not conducted. Based on the literature review we recommend that any future analyses account for paint that is thrown away on paint rollers or washed down the drain, and paint that is discarded at the end of a project. For instance, industry data from the Netherlands estimates that 1.6% of paint in DIY projects is washed down the drain.[11]

Both plastic content and service life determine plastic waste.

Vinyl, carpet, and rubber floors all contain a large amount of plastic, but also need to be replaced at different frequencies based on their durability (see Figure 2). This figure illustrates that, per square foot, carpet contributes the most plastic waste over time with vinyl and rubber flooring close behind. While this figure is for K-12, data are similar for healthcare and affordable housing.

Figure 2. Tons of plastic waste generated over the course of 60 years per 100,000 ft² of flooring material.[7,8]



K-12 Case Study

Estimated plastic waste generated from flooring in a K-12 school.

Service life estimates are based on expected system service life values found in the Ohio School Design Manual and a life cycle costing study of interior materials conducted by Moussatche et al.[8,9]

Table 1. Estimated plastic waste due to flooring over 60-year life of a K-12 Building (based on anonymized data extracted from Tally model).

Product Type	% Flooring type	ft² Product type	Median Service Life (years)	lbs plastic/ft²	Times replaced in 60 years	lbs plastic (U.S. tons)
Solid Wood	13.0%	44,745	30	0.03	2	2,349 (1.2)
Rubber	1.2%	4,033	20	0.31	3	3,796 (1.9)
Vinyl	38.9%	133,994	13	0.20	5	131,364 (65.7)
Carpet	0.7%	2,344	13	0.40	5	4,720 (2.4)
Linoleum	0%	0	30	0.003	2	0 (0.0)
Total		**185,116**				**142,229 (71.1)**

Opportunities to reduce plastic over 60-year lifetime

- Replacing carpet and rubber flooring, which account for less than 2% of its overall floorspace, with linoleum, ceramic tile, or other no- or low- plastic flooring would eliminate about 4 tons of plastic.
- Replacing one third of the vinyl flooring with a no- or low- plastic flooring option would reduce the amount of plastic used in the building by more than 20 tons.
- By replacing vinyl, rubber, and carpet with a no- or low- plastic flooring option this K-12 facility would eliminate around 70 tons of plastic from flooring products.

Healthcare Case Study

Estimated Plastic Waste generated from plastic flooring in an inpatient clinic.

Service life estimates for the healthcare case study are based on usable service life values reported in a study of flooring surfaces in healthcare conducted by Barnes (1998).[6]

Table 2. Estimated Plastic Waste due to Flooring over 60-year life of a Healthcare Facility (Based on anonymized data extracted from Tally model)

Product Type	% Flooring type	ft² Product type	Median Service Life (years)	lbs plastic/ft²	Times replaced in 60 years	lbs plastic (U.S. tons)
Vinyl	21%	48,681	20	0.2	3	28,635 (14.3)
Carpet	0.6%	1,385	5	0.4	12	6,693 (3.3)
Rubber	1.0%	2,440	18	0.3	4	3,062 (1.5)
Ceramic	3.7%	8,714	18	0.0	4	0 (0.0)
Linoleum	0%	0	18	0.003	4	0 (0.0)
Total		**61,220**				**38,391 (19.2)**

Opportunities to reduce plastic over 60-year lifetime

- Replacing carpet and rubber flooring, which account for around 1.6% of its overall floorspace, with linoleum, ceramic tile, or other no- or low- plastic flooring would eliminate almost 5 tons of plastic.
- Replacing all of the vinyl flooring with a no- or low-plastic flooring option would reduce the amount of plastic used in the building by roughly 14 tons.
- By replacing vinyl, rubber, and carpet with a no- or low-plastic flooring option, this inpatient clinic would eliminate about 19 tons of plastic from flooring products.

Affordable Housing Case Study

Estimated plastic waste generated from a typical affordable housing building.

Service life was estimated using median estimated useful life values (EUL) reported by the Department of Housing and Urban Development (HUD) and Fannie Mae.[9,10] To estimate the area of flooring covered by different flooring types we used a model of a two bedroom unit that is 1,000 square feet with sheet carpet used in the bedrooms, vinyl sheet in the bathrooms, and LVT in the remainder of the unit. These flooring products were selected based on a survey of 36 affordable housing projects in Minnesota that found that carpet is commonly specified in bedrooms, and vinyl is commonly specified in living areas and bathrooms[12]. The weight of plastic from flooring in each unit was estimated based on the methodology described above. This number was multiplied by 60, the median number of housing units in the buildings surveyed, to obtain the weight of plastic from flooring for the entire building. This number excludes plastic in flooring used in common areas such as lobbies and common restrooms.

Table 3. Estimated Plastic Waste Due to Flooring over 60-year life of an Affordable Housing Multifamily Residential Building. (Based on a 60-unit multifamily residential building with 1000 ft² two-bedroom apartments. Bedrooms are assumed to contain carpets, and the remainder of the apartment is assumed to contain vinyl flooring.[12]

Product Type	% Flooring type	ft² Product type	Median Service Life (years)	lbs plastic/ft²	Times replaced in 60 years	lbs plastic (U.S. tons)
Vinyl	67.35%	40,410	12.5	0.20	5	39,400 (19.7)
Carpet	32.65%	19,590	7	0.40	10	78,360 (39.2)
Linoleum	0%	0	12.5	0.003	5	0 (0.0)
Total		**60,000**				**117,760 (58.9)**

Opportunities to reduce plastic over 60-year lifetime

- Replacing vinyl, and carpet with linoleum, ceramic tile or other no- or low-plastic flooring would eliminate more than 58 tons of plastic from flooring products-almost one ton of plastic per unit.
- Replacing vinyl flooring with a no- or low-plastic flooring option would reduce the amount of plastic used in the building by roughly 19 tons.
- Replacing carpet in bedrooms with a no- or low-plastic flooring option, would eliminate more than half a ton of plastic per unit.

Appendix B:

Service Life Data

Table 4. Service Life Data Reported in Sources Referenced in Case Studies

	K-12		Healthcare	Affordable Housing	
Product Type	**Moussatche et al (2002)**	**Ohio School Design Manual (2024)**	**Barnes (1998)**	**HUD (2024)**	**Fannie Mae (2019)**
Carpet	10 - 12	15	4 - 6	6	7
Ceramic	30 - 50	40	15 - 20	40	20
Concrete	50	40 - 50		75	50+
Cork	6				
Engineered Wood	25				
Epoxy	12				
Laminate	20			15	
Linoleum*	30	30	15 - 20	15	10
Quarry Tile	35				
Rubber	10	30	15 - 20		
Solid Wood	30			50	
Terrazzo	15	50	15 - 20	75	20
VCT*	15	5 - 10	20		
Vinyl*	15	10 - 15	20	15	10

***** Both HUD (2024) and Fannie Mae (2019) reported service life values for resilient flooring, and did not differentiate between vinyl, VCT, or linoleum.

****** While not confirmed, it is possible that the large range in service life estimates for terrazzo reflects some sources reporting service life estimates for epoxy terrazzo, and others reporting service life estimates for portland cement terrazzo flooring.

Appendix Endnotes

a. Here and throughout this document “plastic” refers to the sum of plastic resin, rubber, and other synthetic polymers included in a product’s formulation, and excludes fillers and other additives.

b. We initially engaged architects, designers, knowledge managers and a specifications writer within the Healthcare, Science & Technology and K-12 practices at Perkins&Will to gauge availability of data sources. Many helped direct us to additional external contacts. We then interviewed and emailed professionals in the K-12 and healthcare sectors, as well as a construction management firm and a flooring supply company.

c. Habitable Common Products derive the mass percentage of each material or substance by taking a median of the quantities identified across multiple industry sources. If the sum of the median percentages does not equal 100%, the percentages are normalized to total 100%, keeping the individual substance percentages within the range reported in the literature. The median densities and thicknesses of flooring product types were derived by taking the median density and thickness values cited across Common Product sources. More details on the Common Product methodology are available at https://pharos.habitablefuture.org/common-products/methodology.

d. Most plastic is not recycled. For instance, OECD estimates that about 9% of plastic is recycled globally, and only about 4% of plastic waste in the U.S. is recycled.[13,14] A 2022 report published by OECD estimates that based on current projections only 17% of global plastic will be recycled by 2060.[15] See The Illusion of Plastics Recycling: Neither Just Nor Circular https://habitablefuture.org/resources/the-illusion-of-plastics-recycling-neither-just-nor-circular/

e. Based on a conversation with an estimator from a flooring supplier, the amount of tile and plank flooring ordered is typically 10% greater than the total square footage covered due to cutoff scrap, and the amount of rolled goods is typically 15-18% greater than total square footage covered. Unused product is sent back, and scrap is typically discarded. Attic stock is less commonly ordered due to space limitations.

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Appendix C:

Plastic Content in Various Types of Flooring

Flooring Type	Median lbs/ft²	% Plastic	Calculated lbs plastic/ft²
Ceramic Tile	3.7	0.0	0.000
Linoleum	0.6	0.5	0.003
Solid Wood*	1.8	1.5	0.026
Engineered Wood	1.7	4.4	0.074
Cork	0.6	15	0.083
PVC-free Resilient	0.6	30	0.19
Laminate	1.3	16	0.21
Vinyl	0.9	23	0.21
Carpet	0.4	62	0.27
Rubber	1.1	29	0.31

Data for lbs/ft² and percent plastic are based on median thicknesses, and percent plastic by weight respectively as reported from sources cited in Habitable's Common Product research.[13] Weights will vary based on the thickness of the flooring product.

*Estimated plastic content in solid wood flooring is due to common factory- and site-applied finishes.