Why Choose Carpeting?

What building occupants, managers, and planners should consider when choosing carpeting as a flooring material.

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Undergraduate Thesis
May 2008

This Thesis Has Been Submitted In Partial Fulfillment of the Requirements for the Degree in Bachelor of Arts in the Center for Environmental Studies at Brown University

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Acknowledgments

I would like to pay special thanks to the following people for their continued support and contributions throughout the duration of this project:

Kurt Teichert
Caroline A. Karp
Angela Sherwin
Maysa Jarudi
Taryn Martinez

This thesis would not have been possible without your direction and consistent feedback.

I also want to thank everyone who took part in various conversations with me about the many facets of this project.

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Executive Summary

Carpeting is the dominant flooring material for residential spaces in the United States. Yet today it is the direct and indirect cause of various indoor environmental health illnesses. Although the carpet and rug industry has responded to public concern on a wide range of health issues resulting from their products, carpeting still plays a major role in the high potential for poor indoor air quality and negative impact on the environment through landfills. Three significant problems surrounding carpeting that persist are: a lack of flooring decision-making power amongst renters, limited response by the carpet and rug industry and U.S. government on the health issues linked to carpeting, and inconsistent consideration of the internal and external costs of carpeting on behalf of building managers.

This paper seeks to identify the major reasons why carpeting is still a cause of poor indoor environmental health and damage to the environment after more than ten years of response by the carpet and rug industry and U.S. government. It is clear through analyzing the persisting problems with carpeting that an environmental injustice is likely occurring with renters in regards to their health as it is affected by limited flooring choice. Additionally, there is a need for government policy that can decrease, limit, or diminish the remaining health risks from living with carpeting, and a need for more building managers to utilize a comprehensive cost/benefit analysis when choosing flooring for their tenants.

Introduction

Carpeting is the most popular flooring material in residential buildings throughout the United States. Advancements in industrial technology and a growing market for residential and commercial buildings during the twentieth century were two of the strongest variables that increased the overall production of carpeting (Walters and Wheeler 1984). As a result, carpeting covers approximately 70% of U.S. interior floors today (CRI 2008). The shifting trend from other flooring materials, such as hardwood flooring, to carpeting is largely due to the increase in synthetic carpet production, which lowered producer and consumer costs. In addition, people began to desire carpeting because of its unique qualities that other flooring materials lacked. A soft cushioned surface, an excellent sound absorber, and the ability to help retain heat in a room are three central qualities of carpeting that building occupants, managers, and developers quickly began to see the benefits of (Hammer 2001).

Carpeting, however, also has its drawbacks. For the past two decades it has taken considerable blame for the primary source of many indoor related illnesses. Through studies conducted on asthma, indoor allergies, the effects of mold on health, and Sick Building Syndrome (SBS) by various government and non-governmental agencies, carpeting is considered to have a significant negative impact on indoor environmental health. Despite these facts, residents with asthma or indoor allergies, particularly children, often still live with carpeting (Kattan et. al 1997). The discrepancy between scientific information demonstrating why carpeting negatively affects indoor environmental health and trends showing that the majority of building occupants live with carpeting poses many questions. Are residents uninformed about the effects of

carpeting on indoor environmental health? Or are residents, specifically renters, unable to choose an alternative flooring material to live with? Both of these questions raise environmental justice concerns. The first question is addressed in this paper through an examination of the various methods our government and non-governmental agencies use to educate residents on the impacts of carpeting. The latter is addressed through a brief study on the flooring decision-making privileges that tenants either posses or lack.

In addition to indoor environmental health problems, many negative impacts on the environment through our waste-stream are also the result of carpeting. The primary concern is that synthetic carpeting takes approximately 50 years or more to biodegrade and uses 2-3% of landfill space (EPA 2007)**.** This issue is primarily influenced by two factors: reclamation efforts for carpeting, and non-biodegradable materials used by carpeting manufacturers. In response to public concern on these issues, the carpet industry and U.S. government launched efforts during the 1990s to divert carpeting from landfills and began to create carpeting from reclaimed material, as well as carpeting that could be reclaimed at the end of its usable life (CARE 2008). Approximately 1% or 2.7 million tons of municipal solid waste in 2001 was classified as carpet (EPA 2001). The percentage, however, of total carpet discards from landfills that were recycled rose from approximately 1% in 2002 to approximately 4.6% in 2006, and the total carpet discards that were diverted from landfills rose from approximately 1.2% in 2002 to 5% in 2006 (CARE 2007). Yet, the amount of total carpet discarded into landfills was approximately 5.2 billions lbs. in 2006, which is an increase from approximately 4.6 billion pounds in 2002 (CARE 2007). Thus, although recycling and diversion efforts have increased in the

past 10 years, carpeting discards into landfills are also on the rise, which may shadow these efforts.

There is, then, a missing link between available information on how carpeting affects indoor environmental health and the outdoor environment through the waste-stream, and how decisions to use carpeting in buildings and dispose of it are made by flooring decision-makers. This gap between our nation's current carpeting trend and its effects on indoor environmental health and the outdoor environment is the focus of this paper: Why choose carpeting? What should building occupants, managers, and planners consider when choosing carpeting as a flooring material? The emphasis in is this question is on the importance of flooring choice. This provides a framework for assessing the gap between information on carpeting's impact and the decisions that certain people make to implement carpeting into buildings, as well as dispose of it.

The primary goals of this paper are to explain why flooring decision-makers currently have the highest influence over the issues surrounding carpeting, and demonstrate how they can implement carpeting or alternative flooring materials without compromising the needs of a building, the health of its occupants (i.e. renters), or negatively impact the environment. The necessity of providing a document of this type is supported by the lack of government issued policy on carpeting to protect occupant health, and the limited choice on flooring material with which many renters are faced. In order to meet these goals, three analyses of the major areas surrounding carpeting are provided. The first is a look into how carpeting affects indoor environmental health and the outdoor environment through the waste-stream. The second is a discussion of the carpet industry and government initiatives created to alleviate these problems. The final

analysis is on economically advantageous alternative flooring materials that have, relative to carpeting, little or zero impact on indoor environmental health and the outdoor environment.

References

Carpet America Recovery Effort. *Memorandum of Understanding for Carpet Stewardship (MOU)*. 2008. CARE. 4 August 2007. < http://www.carpetrecovery.org/mou.php>

Carpet America Recovery Effort. *2006 Annual Report*. 2007. CARE. 4 August 2007. < http://www.carpetrecovery.org/pdf/annual_report/06_CARE-annual-rpt.pdf>

The Carpet and Rug Institute (CRI). *The Carpet and Rug Industry*. 2008. The Carpet and Rug Institute. 4 August 2007. <http://www.carpet-rug.org/carpet-and-rug-industry/>

United States Environmental Protection Agency. *Environmentally Preferable Purchasing (EPP): Department of Energy's Carpet Contract*. Washington: EPA 2007.

United States Environmental Protection Agency. *Municipal Solid Waste in The United States: 2001Facts and Figures*. Washington: EPA 2003.

Kattan, Meyer MD, Mitchell, Herman, PHD, Eggleston, Peyton, MD, Gergen, Peter, MD, MPH, Crain, Ellen, MD, PhD, Redline, Susan, MD, Weiss, Kevin, MD, Evans III, Richard, MD, MPH, Kaslow, Richard, MD, Kercsmar, Carolyn, MD, Leickly, Fred, MD, Malveaux, Floyd, MD, PhD, Wedner, H. James, MD. "Characteristics of Inner-City Children with Asthma: The National Cooperative Inner-City Asthma Study." *Pediatric Pulmonology*. 24 (1997): 253-262.

Hammer, Marie S. *What's Underfoot: Carpet Choices for the Home (FCS 3107)*. 2001. University of Florida IFAS Extension. 8 April 2008. <http://edis.ifas.ufl.edu/pdffiles/HE/HE78300.pdf>

Walters, Billie J., Wheeler, James O. "Localization Economies In The American Carpet Industry." *Geographical Review*. 74 (1984): 183-191.

Methodology

To complete the first two analyses on how carpeting affects indoor environmental health, the outdoor environment, and what the government and industry's responses to these effects have been, available information on these issues from the carpet industry, government health departments, and non-governmental agencies is closely examined. Primary sources of this information from government agencies include the National Institute of Health (NIH), National Institute of Environmental Health (NIEH), and U.S. Environmental Protection Agency (EPA). Key sources of information from non-governmental agencies include the Carpet America Recovery Effort program (CARE), several carpet manufacturing firms, such as Interface Carpet and The Mohawk Group, the INFORM public education organization, and the Carpet and Rug Institute (CRI). Information from various research studies on asthma, mold, and indoor allergies are also used to validate claims made by the various government and non-governmental agencies.

In addition to the information from multiple agencies under examination, a brief study on the flooring decision-making privileges that renters' posses or lack is used to address the potential environmental justice problem with carpeting. For the purposes of this study, information on renters' choice in flooring material was collected from one urban area, Providence, RI. Providence is an ideal location to study because it offers a wide variety of tenant housing in addition to standard homes and condominiums, as opposed to a small variety of tenant housing that might have similar flooring constraints. To complete this study, twenty tenant buildings in Providence County were chosen at random. Information on flooring material in the buildings was then obtained, and the results are discussed in the first analysis and referenced throughout this paper.

The third analysis on comparing the economic advantages and disadvantages of alternative flooring materials to carpeting is completed through the use of a scenario. To complete this scenario, information on material cost, lifespan, and individual material qualities was collected from up to five flooring manufacturers or retailers for each flooring material. The lowest and highest costs attainable from each manufacturer and retailer were collected, and the average lowest and highest costs were calculated. Average costs for each manufacturer and retailer were not calculated because of the uncertainty in attaining complete cost information from up-to-date sources. For the purposes of this study, cost information is used to represent each flooring material, not the manufacturer or retailer. Therefore the average lowest and highest costs for each flooring material are used as estimates. Information on approximate lifespan for each flooring material was obtained from studies conducted on different flooring materials, flooring manufacturers, and flooring retailers. Finally, a standard area of 700 square feet and a building lifespan of 100 years are used to calculate replacement and total costs of different flooring materials over time. These numbers are not accurate representatives of tenant living spaces or building life-spans. They are constant variables used to compare replacement and total costs across different flooring materials in the scenario.

The Impact of Carpeting on Indoor Environmental Health

In order to understand the multiple pathways through which carpeting impacts indoor environmental health, one must first know what carpeting is and the different characteristics that come with it. In a basic definition, carpeting is a collection of soft fibers that are attached to a backing by adhesives or fastenings, which is then secured to the floor of an indoor space. In addition to its softness, carpeting is an excellent sound absorber and provides great traction for walking (Citizens 2003). In the U.S. carpeting can be viewed as one of the most popular home accessories, or even necessity, depending on why it is chosen. Covering approximately 70% of U.S. floors, carpeting dominates over all other indoor flooring materials (CRI 2008).

At the same time, however, more than 40 symptoms of indoor allergies or illnesses are associated with over 43 commonly used chemicals in the manufacturing of synthetic carpeting, which is the dominant type of carpeting used in residences today (Natural Home 2007). How, then, is carpeting the most popular floor covering if it is linked to so many health problems? Through an exploration of the various ways that carpeting impacts health, and a discussion on how residents, installers, and building managers can overlook or be uninformed on critical methods to prevent carpeting from affecting indoor environmental health, this chapter attempts to answer that question. Documented cases that relate carpeting to indoor environmental health problems amongst building occupants are minimal, and perhaps that is one key reason why many carpet users remain unaware of the product's harmful characteristics. Consequently, medical costs for carpet related illnesses may not be factored into the decision to purchase carpeting. These external costs can however be anticipated or alleviated if flooring

decision-makers (i.e. building managers) and building occupants know which harmful characteristics of carpeting to pay attention to during installation and throughout the product's life in a home. Such characteristics can be defined to the following categories: off-gassing, installation, moisture retention, sinks, and maintenance.

Off-gassing

Any smell is sensory information processed by the brain, but first captured by the nose from particles in the air. When carpeting is first installed it too can be sensed through smell because one or more particulates from the product get released into the air. This process of particulates, usually in chemical form, breaking away from an object and entering the air is referred to as off-gassing. Various chemicals and potentially toxic solutions that off-gas are used in the manufacturing process of carpeting for a variety of reasons. Common reasons are to retain a carpet's color and increase its resistance to mold growth (Roberts 2007), which can be a more desirable product than untreated carpeting that is more prone to mold growth. However, carpeting manufactured with chemicals and toxic solutions raises the potential for off-gassing, and therefore increases the risk of poor indoor air quality.

More often then not, however, off-gassing of toxins do not result from the surface layer of carpeting. Instead they often come from adhesives used in installation and a carpet's backing. These kinds of toxins are known as Volatile Organic Compounds (VOCs) because they come from organic chemicals used in the manufacturing process or adhesives used during installation (EPA 2007). The secondary backing of broadloom carpeting, which is the most popular amongst residential floors, is usually made of Styrene Butadiene Latex (SB Latex). SB Latex is a known emitter of 4-

phenylcyclohexene (4 PC), which is a VOC that has received much attention by the carpet industry and scientific community in the last ten years for its potential impacts on human health, as well as its cause of a new carpet's smell (Bowyer & Pleil).

In addition to off-gassing of VOCs and other particulates from carpet material or adhesives, many carpeting manufacturers use antimicrobials to make their product more resistant to mold and bacteria growth. Although the Healthy Building Network (HBN) opposes the use of antimicrobials in carpeting for fear of their effects on human health, there is uncertainty in the carpet industry and scientific community as to whether or not antimicrobials in carpeting come in toxic concentrations. Some companies utilize the precautionary principle and refuse to use antimicrobials, while others are convinced that their use of antimicrobials offer more benefits to building occupants. Thus, the industry is split on the issue. Nevertheless, with this critical knowledge on how carpeting has the potential to off-gas VOC's and other particulates into the air, the next steps to avoiding or alleviating its impact on indoor environmental health rests in the hands of installers and proper supervision by building managers or occupants during installation.

Installation

There are two key measures during carpet installation that can lessen the amount of VOC and various other particulates from off-gassing into a home. Both measures are simple, but to reiterate the point that this information may be unknown or overlooked by many building managers and occupants, studies on indoor environmental health have linked the chemical off-gassing of particulates from carpeting to Sick Building Syndrome as a result of installation. The first measure is a pre-installation task, and calls for new carpeting to be aired out before it is installed. That is, letting new carpeting lay unrolled

outside before it is placed indoors. The recommended amount of time to air out new carpeting before installation is 48-72 hours (National Park 2005). This is thought to enable many odors due to VOCs, which decrease in emissions during the first three months of new carpeting with intense ventilation, to be released outdoors instead of inside a home (Sobbatka and Thriene 1996). Some studies, however, show that the Total Volatile Organic Compounds (TVOCs) are released in heavier amounts after installation as opposed to pre-installation (Citizens). Contrary to both of these claims, one study, which used a carpet-specific test with lab mice to determine the potential effects that toxic chemicals found in carpet fibers have on humans, indicates that no toxicity resulting from carpeting was found in the mice (Stadler and Kennedy 1996). However, this study only looked at carpeting as a general floor surface, and did not focus on the health effects of toxic chemicals specifically after carpet installation. Although there is inconsistency in the scientific community on the best method for removing VOCs and other particulates from carpeting prior to installation, airing out carpeting remains a precautionary measure recommended by most government health agencies and NGOs across the nation.

The second important measure during installation calls for the use of metal fasteners rather than adhesives to secure carpeting to the floor of an indoor space. Like SB Latex, many adhesives used on carpeting emit VOCs (Vermont 2005). Fasteners however, such as staples, do not emit VOCs or other particulates that threaten the health of building occupants. Fasteners are also generally just as effective as adhesives in securing carpeting to the floor. Both measures become even more critical when indoor air quality is subject to poorer conditions due to inadequate ventilation. Therefore it is the combined responsibility of installers, building managers, and occupants to be aware of

the impacts that installation of carpeting can have on indoor air quality, and to take appropriate measures to alleviate them.

Carpeting As A Sink

Although there is no clear evidence that carpet fibers are a direct cause of environmental health problems, the characteristics of carpeting are known to create unhealthy indoor environments that can lead to asthma attacks, skin and eye irritability, and nausea. One way to understand this kind of environment is to imagine carpeting as a sink. Due to the tightly packed nature of carpet fibers, particulates and moisture easily get trapped between the fibers. One study, for example, examined this characteristic and determined that carpet surface area along with fluorocarbon-fiber treatments have the highest impact on cat allergen retention (Lewis and Breysse 2000). Like a sink, the build-up of particulates continues until carpeting's holding capacity for matter between the fibers is reached. When this happens in a sink, for example, fluid either overflows out of the sink or gets released through a drain. With carpeting, particulates can enter the air by almost any kind of disruption, such as footsteps or a vacuum cleaner. However, like a sink, some particulates do not get picked-up by ordinary cleaning methods (i.e. vacuuming). Thus, years of particulate build-up in carpeting can occur. Common particulates found in carpeting over time are dust, dirt, pet-dander, and even lead paint (Cheong and Neumeister-Kemp 2005). All of these are linked to dust-mite allergies, pet allergies, and lead poisoning respectively. Therefore the very nature of carpeting increases the potential for poor indoor air quality. This critical information ought to be considered by flooring decision-makers whenever deciding between carpeting and other

flooring materials. In addition, knowing the sink-like characteristic could help carpet users better understand the potential health risks of living with carpet.

Moisture Retention

In connection with the sink characteristic, moisture retention in carpeting is one of the largest health problems because it has a high probability of leading to mold growth. Even the smallest spill can lead to mold growth if not cleaned up promptly and properly. The other issue with moisture in carpeting is that it is difficult to extract from the material's tightly packed fibers and stiff backing. Nevertheless it is important to clean-up 100% of spills as soon as possible. Numerous studies on carpeting maintenance recommend cleaning spills within 24 hours of their occurrence to prevent mold growth, and others recommend total removal of the moistened area (Yates 2006). Aside from spills there are other pathways that moisture can take to come into contact with carpeting. Shoes can track in mud, rain, and snow from outside. Leaky roofs and open windows can permit storm water to leach indoors. Even high humidity levels in the air can moisten carpeting (Vermont). Thus, carpeting can get exposed to moisture in a variety of ways. However, moisture is difficult to extract fully from carpeting due to its sink-like characteristic. This greatly increases the potential for mold growth, which further impacts indoor environmental health.

As described, the natural characteristics of carpeting create indoor environments that likely increase occupant exposure to build-up of dust, pet dander, mold, and toxic particulates such as lead. These conditions are particularly not suitable for people with indoor allergies or asthma. However, the indoor conditions described thus far can be alleviated, if not avoided entirely, with proper maintenance techniques.

Maintenance

With consistent effort carpeting can be kept in a state that does not foster mold growth or provoke allergies. There are various cleaning methods and precautions that building occupants can take in order to live with carpeting and maintain a healthy indoor environment. The first level of maintenance calls for vacuuming on a regular schedule (Amr et. al 2003). Vacuuming, with its rapid back-and-forth motion of bristles, has been said to disrupt carpet fibers with intense vibrations, and consequently displace particulates into the air (Cheong). However, vacuum cleaning technology underwent an incredible progression during the last half of the twentieth century, and continues to improve to the point where it is more effective at sucking up particulates instead displacing them into the air. Vacuuming more than one time each week is often recommended as an effective measure for keeping particulate levels in carpeting down. Wall-to-wall carpeting is also discouraged in homes in order to prevent organic matter and moisture from accumulating in carpet fibers near doorways and windows, which is where they are most likely to accumulate (National Park). One solution to this problem is to leave a hard-surface floor space or implement mats and grates in these areas because they can be cleaned easier than carpeting. In addition to removing dry particulates on a regular basis, the parts of carpeting with spills (as mentioned previously) should be cleaned-up and dried as soon as possible.

Due to the high amount of petrochemicals often used in manufacturing modern carpet, intense cleaning procedures are sometimes required (Roberts). Deep cleaning, such as shampooing carpet, is an effective intensive cleaning method for carpeting that is known to remove a large amount of particulates from the material (Yin et. al 2008). This

however, can create additional problems if done incorrectly. For example, if a shampooing job is not properly completed, moisture may be left in the carpet, which can result in mold growth (Kennedy 2007). One study even warns carpet-cleaning companies and asthmatics to take safety precautions during intensive carpet cleanings after looking into the case of a 42 year old woman who suffered from acute asthma attacks, seizures, and unconsciousness immediately after a carpet cleaning and deodorizing job was completed in her home (Lynch 2000). The woman had been exposed to high amounts of sodium tripolyphosphate and multiple VOCs. Another precaution to take is to change the water collected by a carpet shampooer during the cleaning process. If the dirty water is not replaced with clean water during the cleaning process, the carpet can be left dirtier than it was before the cleaning commenced. Thus, it is important to use deep carpet cleaning machines properly so that they do not add to or create unhealthy indoor environments.

Last, there are many carpet cleaning supplies in the marketplace that include toxic chemicals and can ultimately create new dangers in a home. One reason that these supplies exist is due to the difficulty of properly maintaining carpet. To combat this issue, powerful cleaning supplies enable carpet users to extract tough stains or add a fresh smell to their carpeting. This is proven to be a risky cleaning method because some carpet cleaning supplies are very hazardous to users due to the amount of toxic chemicals in them, and there is also a risk of consumers using these products incorrectly. Based on these observations, it can be determined that the safest cleaning measures to take with carpeting are to clean it frequently with a vacuum cleaner and reduce moisture contact with it s much as possible. There are also environmentally friendly carpet cleaning

supplies on the market that use less toxic chemicals and are proven to be just as effective as ordinary cleaners.

Flooring decision-makers and building occupants ought to be aware of how synthetic carpet material and its characteristics can create poor indoor environments. Carpeting, including all of the poor quality indoor environments that it can create, has been linked to a variety of illnesses and indoor health problems. This knowledge is an important aspect to consider in the decisions that building managers make on flooring material, and is covered in the next chapter.

References:

Amr Sania, Bollinger Mary E., Myers Monica, Hamilton Robert G., Weiss Sheila R., Rossman Maura, Osborne Lisette, Timmins Sidey, Kimes Daniel S., Levine Elissa R., Blaisdell Carol J., "Environmental allergens and asthma in urban elementary schools," *Annals of Allergy, Asthma and Immunology*, 90 (2003): 34-40.

Bowyer, James R., Pleil, Joachim D., "Comparison of supercritical fluid extraction and Soxhlet extraction of organic compounds from carpet samples," *Journal of Chromatography*, 787 (1997): 171-179.

Carpet and Rug Institute (CRI). *The Carpet and Rug Industry*. 2008. The Carpet and Rug Institute. 4 August 2007. <http://www.carpet-rug.org/carpet-and-rug-industry/>

Cheong Cedric D., Neumeister-Kemp Dr. Heike G., "Reducing airborne indoor fungi and fine particulates in carpeted Australian homes using intensive, high efficiency HEPA vacuuming," *Journal of Environmental Health Research*, 4 (2005): 3-16.

Citizens for a Safe Learning Environment. *Carpets in Schools?* 2003. Citizens for a Safe Learning Environment, 16 December 2007. <http://www.chebucto.ns.ca/Education/CASLE/carpet4.html>

Environmental Protection Agency (EPA). *Basic Information: Organic Gases (Volatile Organic Compounds-VOCs)*. 2007. EPA. 9 April 2008. < http://www.epa.gov/iaq/voc.html>

Kennedy, Mike, "Breathing in Comfort," *American School & University*, (2007): 39.

Lewis, Roger D., Breysse, Patrick N., “Carpet Properties that affect the retention of cat allergen, *Annals of Allergy, Asthma and Immunology*, 84 (2000): 31-36.

Lynch, Richard M., “Modeling of Exposure to Carpet-Cleaning Chemicals Preceding Irritant-Induced Asthma in One Patient,” *Environmental Health Perspectives*, 108 (2000): 911-913.

National Park Service, “*Environmentally Responsible Carpet Choices: Carpet Choices with Environmental Attributes*,” Pacific West Region, (2005) 1-9.

Natural Home Design Center. “*Chemicals commonly used in the manufacture of synthetic carpeting,”* and “*Symptoms associated with exposure to the previous chemical*.”2008. Natural Home Design Center. 16 December 2007. http://www.naturalhomeproducts.com/1430chemicals.html>

Neil C. Hawkins, Alan E. Luedtke, Carey R. Mitchell, Joseph A. LoMenzo, Marilyn S. Black, “Effects of Selected Process Parameters on Emission Rates of Volatile Organic Chemicals From Carpet,” *American Industrial Hygiene Association Journal*, 53 (1992): 275-282.

Roberts Tristan, “Making Carpet Environmentally Friendly,” *Environmental Business News*, (2007): 1-12.

Sobbatka Armin, Thriene Bernd, “Sanitation programmes for living spaces and health risks involved,” *Toxicology Letters*, 88 (1996): 365-368.

Stadler J.C., Kennedy Jr. G.L.,“Evaluation of the Sensory Irritation Potential of Volatile Organic Chemicals from Carpets-Alone and in Combination,” *Food and Chemical Toxicology*, 34 (1996):1125-1130.

Vermont Department of Environmental Health. “Carpets and Air Quality.” Vermont Department of Health. 2005. 19 April 2008.
< http://healthvermont.gov/enviro/indoor_air/Carpet.aspx>

Yates, Michael, “What you need to know about removing mold and mildew. With increased knowledge we can better protect ourselves against potential health risks,” *Metal Finishing*, 104 (2006): 82-84.

Yiin Ling-Ming, Yu Chang Ho, Ashley Peter, Rhoads George, “Cleaning Efficacy of High-Efficiency Particulate Air Filtered Vacuuming and “Dry Steam” Cleaning on Carpet, *Journal of Occupation and Environmental Hygiene*, 5 (2008): 94-99.

Carpeting Related Illnesses & Tenant Choice

Some the most common reports from medical and scientific communities on carpeting have addressed indoor environmental conditions that are conducive to asthma and allergy triggers for building occupants. Although the experiments conducted in these studies, and consequently the results, are quite diverse, the argument that carpeting plays a significant role in decreasing the well-being of people with asthma, allergies, and exposure to certain particulates (ex. lead) is a consistent theme amongst both communities. This chapter explores a variety of specific illnesses which either resulted from direct exposure to toxins in or used on carpeting, or from exposure to poor indoor air quality due to the impacts of carpeting's many characteristics. With this knowledge, flooring decision-makers can better take into account the high potential for external costs, such as medical bills, when choosing carpeting for a flooring material.

Asthma and Allergy

As described earlier, the sink-like characteristic of carpeting is a primary cause of particulate matter build-up over time. The millions of tiny open spaces between tightly packed carpet fibers are perfect for dust collection, and consequently excellent nesting grounds for dust-mites (Strien et. al 1994). In addition, the thickness of padding beneath which hold the carpet surface layer together provides adequate conditions for moisture retention, which can easily lead to mold growth. Unfortunately, dust, dust-mites, and moisture build-up are three indoor conditions that provoke symptoms in people who suffer from asthma and other indoor allergies (Strien). There is also a strong correlation between these conditions present in the homes of poor children with asthma and other indoor allergies that live in urban areas, and the presence of carpeting (Krieger et. al

2000). One study looked into the living conditions of children with asthma who live in poverty in King County, Washington. The study reported findings on a variety of asthma triggers found in 112 households with children ages 4-12 years old. Amongst the results ranging from homes with smokers, damp conditions, water damage, and other allergens, the report found that 76.8% of surveyed homes had carpeting in the bedrooms. This was classified by the study as an environment that puts children "at substantial risk of ongoing exposure to asthma triggers" (Krieger, pg. 50).

Another study sought to find room-specific characteristics that could be predictors of indoor allergen concentrations by examining relationships between various risk factors. In addition to infrequently cleaned bedding and stuffed toys on or around bedding, one of the "high risk" factors classified in this study was wall-to-wall carpeting, which yielded high dust-mite concentrations (Perrt et. al 2006). Both of these studies are just a few among the many that classify carpeting as risk factors for children and adults with asthma and allergies. Additionally, many of these studies confirm the presence of asthma and allergy triggering conditions (i.e. build-up of dust) primarily in the homes of those living in poverty. This is a large concern for low-income renters, whose lack of choice in flooring material will be discussed later.

According to research on asthma and indoor allergies, the best way to alleviate high risk conditions for people, particularly children, with asthma and allergies that live with carpeting is to wash bedding and clean all upholstery, including their carpeting, as frequently as possible (Murray and Ferguson 1983). One New Jersey study looked into the amount of lead measured on the surface of residential carpet in 50 New Jersey homes by using two types of cleaning methods. At first half of each sampled carpet was cleaned

with a high-efficiency particulate air-filtered (HEPA) vacuum cleaner twice. The second method was cleaning the other half of each sampled carpet with a HEPA vacuum cleaner, then cleaning it with a dry-steam carpet cleaning device, and finally with the HEPA vacuum cleaner again. Results from the report showed significant decreases in the amount of lead measured on the carpet surface after both methods, and that the dry steam cleaning in addition to HEPA vacuum cleaning method reduced the amount of lead on the carpet's surface significantly more than just using the HEPA vacuum cleaner twice (Yiin et. al 2008). Hence the necessity to clean carpeting as much as possible with the intensive cleaning devices is critical to maintaining adequate indoor air quality. These sometimes expensive yet necessary cleaning methods, however, may not be an option for many people with asthma and allergies due to possible financial constraints.

Illness Through Direct Exposure to Toxins In Or Used on Carpeting

Particulate matter and moisture in carpeting are not the only risk factors that play into poor indoor environmental health. Toxic contaminates can be introduced to the indoor environment by direct or indirect application on carpeting. As described in the previous chapter, one study analyzed the case of a woman who suffered from acute asthma attacks, seizures, and unconsciousness after a carpet cleaning and deodorizing job was completed in her home (Lynch 2000). Due to an improper or incomplete cleaning job, the woman was exposed to excessive amounts of sodium tripolyphosphate and multiple VOCs. Although this is an extreme case of over-exposure to chemicals from carpet cleaning, it illustrates how delicate and hazardous the intensive carpet cleaning process can be to building occupants.

Another case study discusses one man's development of pneumoconiosis, a type of lung disease, after his diagnosis of silicotosis, another type of lung disease. The man is thought to have developed the disease from over exposure to talc through his job as a carpet installer for 15 years (Szeinuk and Wilk-Rivard 2007). Again, this is another extreme case of serious medical conditions resulting directly or indirectly from carpeting. However, the point to take away from this study is that carpeting not only raises the potential risk for poor indoor environmental conditions in living spaces, but it can also create just as high or even higher risk environments for those who work with it.

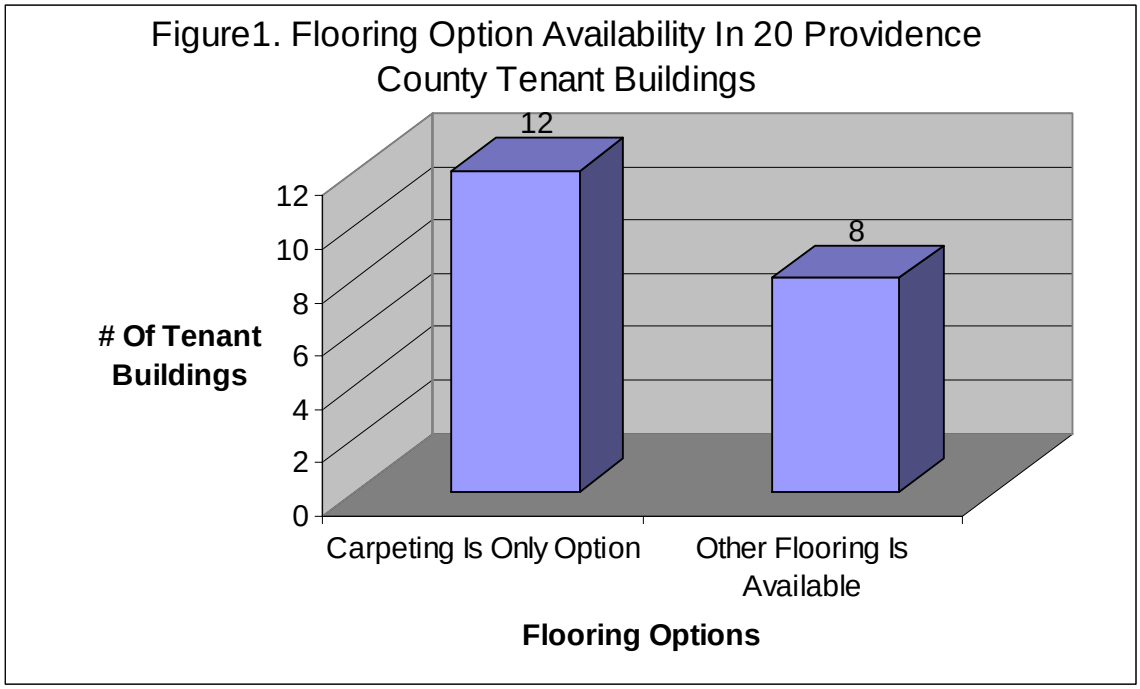
Tenant Choice

Through experiments and documented case-studies that link poor indoor environmental health to the presence of carpeting in homes, it is evident that something is wrong either with the way that many residents maintain their carpet, or with many residents' ability to live with an alternative flooring material (ex. Hardwood flooring). If the problem is the latter, there may be an environmental injustice issue surrounding carpeting in homes. Based on the evidence that carpeting increases the potential for poor indoor air quality, residents that do not have the option to live without carpeting may be placed at a higher risk for poor indoor environmental health by those who decide on their flooring material. However, not all residents can fit into this category.

Homeowners, for example, have the right (although not always the financial means) to change their flooring material at their leisure. Renters, on the other hand, may not always have that ability. Consequently, renters may need to live with carpeting as a result of their building manager's requirements. Considering the high percentage of interior floors that are covered by carpeting in the U.S., this may not be an unlikely

circumstance. As discussed, however, carpeting requires frequent and intensive cleaning processes to adequately maintain a healthy indoor environment. Therefore, if there are renters of tenant housing who are not given the option to live without carpeting, their health may be indirectly compromised by the decisions or restrictions of their building's managers. The remaining section of this chapter is dedicated to this possible environmental injustice related to carpeting. Through a brief study on the prevalence of tenant housing with or without flooring options for renters, and a discussion on the reasons why these circumstances occur, the potential impacts on renters living in such conditions are addressed.

For the purposes of this study, one urban area is used to represent the choice that renters may or may not have on the flooring material they live with. The flooring choice that renters have or lack in twenty tenant buildings in Providence, Rhode Island was obtained (See Figure 1 below). As seen in Figure 1, 60% (12 buildings) sampled buildings offer carpeting and no alternative flooring option to tenants. The remaining 40% (8 buildings) offer carpeting in addition to other flooring materials, such as hardwood and linoleum. Although this sample size is not representative of the entire Providence County, it offers enough evidence to speculate the likelihood that the health of many renters in regards to carpeting is not considered a high enough priority for building managers to outweigh the cons of carpeting with the perceived positives. Again, this evidence is in line with studies which looked into the prevalence of poor indoor environmental health amongst those living with carpeting in urban areas (Krieger).



A variety of reasons exist to explain why many renters lack the option to live without carpeting. One reason is that building developers are often obligated to obey noise constraints and the implementation of carpeting into all tenant spaces of a building is an effective method for absorbing sound and limited noise from traveling across living units (Croxton 2005). As noted previously, carpeting also helps retain heat in a room. Thus, developers may utilize carpeting as a means to reduce heating costs. Carpeting may also be chosen for its aesthetic value. Many types of carpeting come in fabulous designs that developers may choose for the theme of their building. Whatever the reasons, the choice to implement carpeting and offer no alternative to tenants generates unfavorable circumstances that often lead to poor indoor environmental health and, as a result, higher external costs.

The kinds of impact on renters who live with carpeting depend highly on how well their flooring material is maintained throughout its lifespan. Frequent cleaning is

contingent on the ability of building occupants to clean their carpeting as often as possible with effective cleaning techniques (ex. using a HEPA vacuum cleaner twice a week or more). Deep-cleaning is also only sometimes offered by building management, or else it is at the discretion of building occupants to invest in. As concluded by the Yiin study, deep-cleaning is a much more effective measure for removing particulates from carpeting than ordinary vacuuming. Thus, if deep-cleaning is not offered by building management and some renters do not have the financial means to invest in it, those renters may be at a higher risk for poorer indoor environmental health than those who have access to deep-cleaning. In addition to necessary maintenance, carpet cleaning techniques and certain characteristics of carpeting, such as the sink characteristic, present various hazardous or potentially hazardous conditions to building occupants. These conditions are virtually non-existent with most alternative flooring materials.

In conclusion, the lack of choice in flooring material is central to key findings on the relationship between poor indoor environmental health and the presence of carpeting in homes. Though there is little known about the prevalence of renters who lack that choice and, as a result, live in poor indoor environmental conditions, much about the potential impacts on human health from living with carpeting is known. That knowledge can help building managers anticipate external costs that result from tenants living with carpeting, as well as prevent an environmentally unjust living condition from occurring.

References

Croxton Collaborative Architects, PC., "Acoustics (Draft): Sustainable Design Guidelines Reference Manual. WTC Redevelopment Projects," The *Port Authority of NY & NJ.*, 2005.

<http://www.panynj.gov/DoingBusinessWith/contractors/pdfs/7526/IEQ-11_Acoustics.pdf>

James W. Krieger, Lin Song, Timothy K. Takaro, and James Stout, "Asthma and the home environment of low-income urban children: Preliminary findings from the seattle-king county healthy homes project," *Journal of Urban Health*, 77, 1, (2000): 50-67.

Murray AB, Ferguson AC. "Dust-free bedrooms in the treatment of asthmatic children with house dust or house dust mite allergy: a controlled trial." *Pediatrics*, 71(1983): 418-422.

Perrt TT, Wood RA, Matsui EC, Curtan-Brosnan J, Rand C, Eggleston PA, "Room-specific characteristics of suburban homes as predictors of indoor allergen concentrations," *Annals of allergy, asthma & immunology*, 97, 5 (2006): 628-635

Richard M. Lynch, "Modeling of Exposure to Carpet-Cleaning Chemicals Preceding Irritant-Induced Asthma in One Patient," *Environmental Health Perspectives*, 108 (2000): 911-913.

Strien R.T. Van, Verhoeff A.P., Brunekreef B., Wijnen J. H. Van, "Mite antigen in house dust: relationship with different housing characteristics in the Netherlands," *Clinical & Experimental Allergy*, 24 (1994): 843-853.

Szeinuk J, Wilk-Rivard EJ, "Case report: silicatosis in a carpet installer," *Environmental Health Perspectives*, 115, 6 (2007): 932-935.

Yiin LM, Yu CH, Ashley P, Rhoads G, "Cleaning efficacy of high- efficiency particulate air-filtered vacuuming and 'dry steam' cleaning on carpet," *Journal of Occupational and Environmental Hygiene*, v.5 issue.2 (2008): 94-99.

Government & Industry Response on Health Concerns Related to Carpeting

The poor indoor environmental quality typical of carpeted homes is wide-spread across the United States. Just as the presence of lead-based paint creates an environment conducive to lead poisoning in children, carpeting has been proven to create environments that promote asthma and allergy symptoms (Norback et. al 1995). Lead-based paint, however, was outlawed in 1978 to decrease exposure to lead amongst building occupants, and ultimately prevent lead poisoning from ingestion of lead-based paint particulates. Carpeting has yet to receive the same amount of legal action even though it presents analogous health hazards to building occupants.

The question, then, of whether or not anything at all has or is being done to prevent building occupants from exposure to carpeting, and ultimately decrease the number of asthma or allergy attacks, can be raised. This chapter explores the various paths to improving indoor environmental health through recommendations and actions taken on carpeting by the U.S. government and carpet industry. The goal of providing this information is to assess how effective or not the U.S. government and industry has been on improving the indoor environmental health problems surrounding carpeting. These conclusions will then be utilized in recommendations on how to improve carpeting related health problems in the final chapter of this paper.

Government Response

The most common type of response issued by government agencies is information based. For example, indoor environmental health and carpeting are often addressed together by the U.S. National Institute of Health (NIH) under the categories of Indoor Air Quality (IAQ) and Asthma research. NIH issued documents on ssthma frequently

mention carpeting as a major factor in creating environments with high dust-mite allergen levels, which is one of the largest environmental triggers for asthma. The NIH also makes recommendations to landlords, tenants, and homeowners on proper carpet maintenance that can alleviate the affects of carpeting on asthmatics. One asthma prevention document issued by the National Institute of Environmental Health Sciences (NIEHS), a department within the NIH, makes several recommendations to tenants and landlords on how to prevent asthma triggers in homes. A section of these recommendations is dedicated to how landlords can provide cleanable surfaces, and here landlords are advised to check for damages on floor surfaces and carpet, as well as to clean the carpeting in each rental unit twice a year if possible (NIEHS 2004). The NIEHS also provides a Fact Sheet called "Asthma and Its Environmental Triggers." This document provides tenants with simple steps to reduce dust-mite allergen levels in homes. One of the steps is to vacuum and steam-clean carpet and all upholstered furniture in order to reduce dust-mite allergen levels (NIEHS 2006). Steam cleaning, however, is not always offered by landlords and many tenants may not be financially equipped to do it themselves.

The NIEHS provides further discussion on carpeting in its General Information section of Dust-Mites on its website. Here the NIEHS recalls the importance of reducing dust-mite allergens in homes of people with asthma by stressing the link between reducing dust-mite allergen levels and removing carpeting. One of the strategies for preventing high dust-mite allergen levels states "If possible, replace wall-to-wall carpets in bedrooms with bare floors (linoleum, tile or wood) and remove fabric curtains and upholstered furniture" (NIEHS 2007). In another document titled "Thinking About Asthma: A Developer's Guide to Building a Healthy Home," a set of recommendations

for building developers to take when building healthy homes and keeping people with asthma in mind are provided. One of these recommendations states “Properly ventilated homes and the use of flooring (rather than carpeting) goes a long way to create healthy environments that reduce asthma triggers” (* NIEHS 2004).

The US Environmental Protection Agency (EPA) also makes effectives recommendations on how to reduce mold in homes, which it links to carpeting and indoor environmental health. In one document titled “A Brief Guide to Mold, Moisture, and Your Home,” the EPA states that a common hiding place for mold, among wallpaper, ceiling tiles, and other home accessories, is on the underside of carpet and padding. The document also states that carpeting is one of many materials that may need to be discarded if mold is discovered on it, and that a specialist in carpet cleaning is recommended for the removal of mold from carpet. This indicates that the EPA, in addition to the NIH, has an adequate understanding of the impacts that carpeting has on indoor environmental health.

Therefore multiple information outreach efforts from different government agencies exist and are directed toward residents and building managers. Such outreach programs provide information on the impacts of carpeting on human health, as well as on how to properly maintain carpeting to alleviate these impacts. How effective the above mentioned government agencies have distributed this information to residents and building managers remains, however, unclear. In addition, there is no clear indication that the U.S. government has exercised its legal power on carpeting as it relates to indoor environmental health other than a ban on polybrominated diphenyethers (PBDE’s), which are chemicals used as fire retardants in carpeting and many other household products that

the EPA believes can negatively affect human health (Science Daily 2007). The recommendations on flooring provided by government agencies also often require maintenance, however many residents may not have the financial means to invest in such consistent upkeep. Furthermore, these recommendations are accessible through the internet, but whether or not they are made accessible to residents who do not have access to the internet is unclear. Thus, government efforts to educate residents on the impacts of carpeting on indoor environmental health and legal efforts are, for the time being, minimal.

Industry Response

In contrast to the government's response, the carpet industry is actively involved in responding to public concern over how carpeting impacts indoor environmental health. Many carpet manufacturers have taken great initiative in the last ten years to initiate programs and promote new products that reduce the growing image that "carpeting is bad." An example of one such attempt is Milliken, which is one of the largest carpet manufacturers in the country. Milliken promotes a variety of information on the environmental programs it is involved in, as well as the sustainable products it offers. In a document titled "More Than a Century of Stewardship and Respect for the Earth," Milliken attempts to create a sustainable and caring image of itself by informing the public about all the green initiatives it took part in throughout its history. The document lists more than 20 sustainable programs, products, or commitments Milliken has made. Among them are Milliken's "TractionBack" coating, which is used for carpet backing and enables the company to install carpeting without the use of adhesives. Also promoted in the document and by Milliken in general is "Millitron," the company's carpet dyeing

technology that has increased its environmentally friendly carpet dyes and water recycling. Although these products, programs, and commitments do not focus on carpet maintenance or allergies, the company is improving a major feature of carpeting that the government barely addresses. That feature is the negative impact that solvents in carpeting and VOC's from adhesives used in installation has on indoor environmental health.

Interface is another large carpeting manufacturer which has put considerable effort into decreasing the impacts that its carpeting has on indoor environmental health. Since Interface Founder Ray Anderson announced in 1994 that his company will become responsible for its impact on the environment, Interface has been dedicated to using ingredients in its products that are not toxic to or harmful in any way to human health and the environment (Rosenberg 2005)**.** Interface also focuses on the environmental impact that waste generated from its manufacturing process has on the environment. The company's "Mission Zero" program is a "promise to eliminate any negative impact" it may have "on the environment by the year 2020" (Interface 2008). In addition to Interface, The Mohawk Group is another carpet manufacturing leader in products and programs that focus on decreasing carpeting's impact on indoor environmental health. Mohawk uses a variety of sustainable methods to accomplish this, including using less petroleum based materials, using a higher percentage of recycled materials, and using less material overall in its production processes (Mohawk 2007). Like Interface, Mohawk also takes part in recycling programs used in the manufacturing process, as well as in reclamation/waste diversion initiatives.

In conclusion the distinction between government and industry response on how carpeting affects indoor environment health is clear. The government spends resources on information campaigns for people with asthma and allergies, which establish the link between carpeting and poor indoor air quality. Many in the carpet industry, on the other hand, focus a great deal on how the public perceives it through taking part in environmental initiatives that lower its carbon footprint and clean-up or preserve the environment. More importantly, many companies now provide products that do not negatively impact indoor environmental health. Therefore, the two most influential factors in poor indoor environmental health as a result of carpeting are being addressed through the government and industry combined. Again, those two factors are difficult maintenance and direct exposure to toxins in carpeting. Yet, there seems to be a disconnect between the responses to carpeting's impact on indoor environmental health issued by government agencies and the industry, and the rising number of residents who suffer from illnesses related to the presence of carpeting in their homes. Perhaps the responses by government and industry are not strong enough. However, considering the potential environmental health risk similarities between carpeting and lead-based paint, a more likely explanation is that enough legal action does not yet exist to significantly decrease the amount exposure by building occupants to the harmful environmental health conditions that carpeting presents.

References

Interface, "Our Goals: Mission Statement," Interface Inc., 2008, retrieved from the world wide web on 20 April, 2008.
<http://www.interfaceinc.com/goals/mission.html>

National Institute of Environmental Health Sciences, "Preventing Asthma: A Landlord's Guide to Property Maintenance for Healthy Homes," *University of Michigan Law School Legal Assistance for Urban Communities Clinic*, 2004.

* National Institute of Environmental Health Sciences, "Thinking About Asthma: A Developer's Guide to Building a Healthy Home," *University of Michigan Law School Legal Assistance for Urban Communities Clinic*, 2004.

National Institute of Environmental Health Sciences, "Asthma and Its Environmental Triggers," *U.S. Department of Health & Human Services, National Institute of Health*, 2006.

National Institute of Environmental Health Sciences, "Dust Mites: Preventative Strategies," *National Institute of Health*, 2007, retrieved from the world wide web on 4 February 2008.
<http://www.niehs.nih.gov/health/topics/conditions/asthma/dustmites.cfm>

Norback D., Bjornsson E., Janson C., Widstrom J., Boman G., "Asthmatic symptoms and volatile organic compounds, formaldehyde, and carbon dioxide in dwellings," *Occupational & Environmental Medicine*, 52 (1995): 388-395.

Rosenberg Beth, ScD MPH, "Case study of Interface Carpet and Fabric Company," *Tufts University School of Medicine, Department of Public Health and Family Medicine*, 2005.

Science Daily, "Tracking Fire Retardants In Humans And Environment," *ScienceDaily*, 2007.

The Mohawk Group, "Mohawk Greenworks," *Mohawk Industries*, 2007, retrieved from the world wide web on 5 February 2008.
<http://www.mohawkgreenworks.com/>

Government and Industry Response to Carpet in the Waste-stream

Carpeting not only affects indoor environmental health, but it also has considerable impacts on the environment to which it is disposed. That is, carpeting is one of many materials to get discarded into landfills that usually do not biodegrade, which results in it accounting for 1% of municipal solid waste in U.S. landfills (Fishbein 2001). In 2007, an estimated 5.3 billion pounds of carpet were projected for disposal into landfills. Of that, only 4.6%, or less than 250 million pounds, were expected to be recycled (SF Carpet 2007). The troubling reality of this situation is that for every 10 million pounds of recycled carpet, 50 thousand cubic yards of landfill space are saved. For those 10 million pounds of recycled carpet, 70 million pounds of Green House Gas (GHG) emissions can be avoided (CO_2 equivalents) (CARE 2006 Annual Report).

To combat these issues, the U.S. government and carpet Industry have introduced large-scale programs to divert the growing number of post-consumer carpet from landfills and to recycle that material into new carpeting or other useful products. In addition, many manufacturers have been improving their production processes in order to receive and use more recycled carpet material each year, as well as to produce recyclable carpeting (Fishbein). Thus, the problem with carpeting in the waste-stream has greatly improved over the past ten years. However, the rising amount of carpeting still disposed into landfills contradicts these efforts. According to the CARE 2006 Annual Report, total carpet discards in 2006 amounted to approximately 5.26 billion pounds, which was up from approximately 5.03 billion pounds in 2005, even though the amount of carpet diverted increased by 16% and the amount of carpet recycled increased by 23% from 2005 to 2006 (CARE 2006 Annual Report). Therefore this chapter explores the programs

and initiatives in place by the government and carpet industry in an effort to understand why the amount of carpeting in landfills continues to rise. Additionally, the role of building managers in deciding what kind of carpeting to use (recyclable or not) and how to dispose of old carpeting is considered.

Government Response

In 2002 a joint effort between the U.S. government and carpet industry was established to put forth a formal program to decrease the amount of post consumer (PC) carpet in landfills and increase the amount that is recycled. Primarily funded by the carpet industry, this program was created under the Memorandum of Understanding for Carpet Stewardship (MOU) and called the "Carpet America Recovery Effort," or "CARE" for short (CARE 2008). The MOU & CARE program launched with two official goals: The first goal is to increase the amount of recycling and reuse of post-consumer carpet and the second goal is to decrease the amount of post consumer carpet that goes to landfills. CARE's primary method for accomplishing these goals is to focus on market based solutions for recycling and reusing carpet. The first CARE Annual Report for 2002 stated that the parties involved dedicated themselves to diverting 40% of carpet from U.S. landfills by the year 2012. According to the 2006 CARE Annual Report, the program is on track to meet its 2012 carpet waste diversion goal.

Criticism about the CARE program mainly comes from its ambitious goals. However, CARE is responsible for diverting 484 million pounds of post-consumer carpet from landfills and has significantly increased the number of carpet reclamation sites in the country (Environmental 2007). To date, CARE has partnered with 55 reclamation facilities across the nation, which is up from 37 facilities in 2006, and just 5 facilities in

2002. Also, the number of carpet manufacturers that accept post-consumer carpet for reuse and the number of carpet recycling plants continues to grow, making it easier for more reclamation facilities to open. This has also undergone criticism because not all carpet is reusable or recyclable yet, and therefore certain kinds of carpet are very difficult to break down for any kind of reuse. Residential carpet, however, "provides much better yields and productivity per square yard" for manufacturers (CARE 2006). Residential carpet also accounts for approximately two thirds of all carpet sold in the U.S. (Roberts 2007).

CARE plans to continue partnering with carpet reclamation facilities and expand outreach efforts to inform carpet users about them. To aid this effort, CARE provides a free reclamation facility locator on its website that allows users to find the nearest facility. Today, CARE also has the growing support of carpet manufacturers that understand the economic benefits of reusing post-consumer carpet. The 2006 CARE annual report states that a major driver behind this interest is the rising price of oil. At oil costing over $100 per barrel in 2008, producing synthetic/petroleum-based carpeting from scratch is not as attractive as it used to be and can be more costly than utilizing recycled carpet material (Fishbein). CARE also discusses the dramatic population growth projections for China & India and how indoor spaces in each country are being planned out. This growth is expected to have tremendous effects on the carpet industry and CARE because oil prices are projected to keep rising with along with an increasing demand for carpet in the indoor floor market in these two countries. Consequently, the demand for reclaimable carpet will also increase and both CARE and the industry will need to work together to meet those demands.

Industry Response

In the past ten years the carpet industry has been responsible for devising new kinds of carpet that can be reused and more easily. Each year, the amount of post-consumer carpet that is accepted through take-back, buy-back, or waste diversion programs by carpet manufacturers is growing. Post-consumer carpet can now be recycled through a variety of methods in order to reuse it in the manufacturing of carpet (Simpson 2000). As mentioned, some manufacturers use take-back or buy-back programs to retrieve post-consumer carpet. This enables them to be responsible for the carpet they introduce to the environment and allows them to streamline their manufacturing processes to specific kinds of post-consumer carpet that they reuse (Fishbein).

For example, BASF, a chemical company, launched a closed loop recycling program called "6ix Again," allowing the company to reclaim self certified Zeftron Nylon 6 carpet (BASF 2002). Milliken & Company, another carpet manufacturer, and DuPont chemical company also recycle post-consumer carpet fiber and backing and down-cycle the materials into reusable carpet products. Some companies even use a mixture of methods. For example, Interface utilizes a "ReEntry" program that lets it recycle carpet nylon into carpet and other floor coverings, and down-cycles carpet backing into products ranging from industrial matting to auto parts.

With a wide variety of carpet reclamation, recycling, and reuse programs in use today by multiple manufacturers, the prospect of diverting more carpet from landfills in future years looks positive. These efforts also provide a large amount of help to the growing and successful CARE program in meeting its 40% carpet waste diversion goal in 2012. However, the explanation of the fact that total discards of carpet into landfills

increased by 223 million pounds from 2005 to 2006 remains unclear. Additionally, data on how much of the total discards that can be recycled but are not due to poor disposal decisions, as oppose to how much of the total discards that can not be recycled due to make-up of the material, is unavailable. Therefore this study can not state whether or not building managers who purchase un-recyclable carpet or building managers who do not properly dispose of recyclable carpet play a significant role in the increase of carpeting discards into landfills, though both are possibilities.

References:

BASF The Chemical Company, "Partnership yields improvements in design and environment," *Northwest Georgia Trade & Convention Center, J & J Industries, BASF Corporation*, 2002, retrieved from the world wide web on 16 October 2007.
< http://www.basf.com/corporate/news2002/news_partnershipimprove_022702.html>

Carpet America Recovery Effort (CARE), "Memorandum of Understanding for Carpet Stewardship," *Carpet America Recovery Effort*, 2008, retrieved from the world wide web on 15 October 2007.
<http://www.carpetrecovery.org/mou.php>

CARE 2006 Annual Report, *Carpet America Recovery Effort*, 2007, retrieved from the world wide web on 15 October 2007.
<http://www.carpetrecovery.org/reading.php>

Environmental Division Newsletter, "Highlights of GPEC 2007: 2007 Environmental Award Winners," *Environmental Division, Society of Plastics Engineers*, 2007, retrieved from the world wide web on 14 April 2008.
<http://www.4spe.org/communities/divisions/d40_0705.pdf>

Fishbein Bette K., "Carpet take-back: EPR American Style," *Environmental Quality Management*, 10 (2001) 25-36.

Roberts Tristan, "Making Carpet Environmentally Friendly," *Environmental Business News*, (2007): 1-12.

SF Carpet Recycling, "About The Process: Make A Difference," *SF Carpet Recycling*, 2007, retrieved from the world wide web on 3 March 2008.
<http://www.sfcarpetrecycling.com/html/process.htm>

Simpson Robert, “Used Carpet Recycling: An Industry Poised for Vast Growth,” *Flooring Magazine*, 2000.

Alternative Flooring Options to Carpeting

Many alternative flooring materials with little to no negative impacts on indoor environmental health or the environment have increasingly gained attention by flooring decision makers over the past twenty years. Today there are more than ten established alternative flooring options to carpeting that builders can choose from. Each alternative flooring material differs from carpeting in a unique way and many can be financially advantageous to building managers during the lifetime of a building, as well as healthier for occupants. One of the ways to determine whether or not an alternative flooring material meets these criteria is to compare it to carpeting through a sustainable lens. For the purposes of this study, using a "sustainable lens" means that flooring decision-makers consider the financial impacts of their decisions throughout the entire occupancy of a tenant and lifetime of a building, as oppose to only considering the initial costs of flooring material and installation. In considering these impacts through a sustainable lens the decision-maker must take into account any external costs, such as medical expenses resulting from carpeting related illness on behalf of the building occupants, as well as internal costs, like maintenance and replacement expenses. The sustainable lens is a key aspect of the flooring decision-making process because it enables decision makers to weigh both the internal *and* external costs and benefits of implementing and maintaining alternative flooring materials to carpeting. However, there seems to be an under-utilization of the sustainable lens by flooring decision-makers as a whole. This is evident in the fact that most alternative flooring materials are financially advantageous over carpeting for builders and building managers over the lifetime of a building, and are relatively harmless to building occupants compared to carpeting (resulting in fewer

external costs), yet approximately 70% of U.S. interior floors are still surfaced with carpeting (Goddin).

A percentage of U.S. flooring decision-makers do, however, choose alternative flooring options to carpeting and reap the financial benefits from them. Unlike carpeting, other hard-surface flooring materials such as tile are relatively easy to clean. These materials are hard, flat, smooth, and have fewer pores than carpeting to allow moisture retention and build-up of particulate matter (Ellis). As a result, external maintenance costs, such as costs from carpet shampooing, are reduced over the lifetime of a building. Each alternative flooring material also has its disadvantages. For example, hardwood and ceramic tile flooring are often more costly to purchase and install than carpeting. However, these flooring materials are more durable and have a longer lifespan than carpeting. Consequently, the total amount of money spent on these flooring materials throughout the lifetime of a building can easily be less than that of carpeting due to fewer replacements costs.

In this chapter, nine alternative flooring materials are compared to carpeting through a sustainable lens in order to consider the financial benefits to building managers and the health benefits to building occupants. Although a complete life-cycle study on each of these flooring materials would factor in all internal and external costs throughout their lifespan, for the purposes of this study a comparison analysis between the major factors that ought to go into a building manager's flooring decision is all that was analyzed. However, it is important to note that such life-cycle studies have been completed and are comparable to the comparison study discussed here (Goddin).

In place of an in-depth life-cycle study, a comparison of the up-front and major external costs for carpeting and alternative flooring materials is offered in the form of a scenario. Estimations on average low and high prices for carpeting and alternative flooring materials are used in line with each flooring material's approximate maximum lifespan to compare the replacement costs for each flooring option (See Table 1). Each flooring material's maximum lifespan is used under the assumption that building managers want to make their flooring last as long as possible, and minimum installation cost is used under the assumption that building managers seek out the least costly installation available to them. Availability of installation and maintenance costs also differ greatly by flooring option, and therefore not every flooring option's replacement costs are adjusted for installation or maintenance. Finally, a 700 square foot apartment and a 100 year building lifetime are used to compare the estimated total costs of carpeting and alternative flooring materials throughout the lifetime of a building.

Table 1. Approximate Maximum Lifespan and Average Low & High Costs of Carpeting and Alternative Flooring Materials

Flooring Material (residential)	Approximate Maximum Lifespan (yrs)	Estimated Average Cost of Flooring Material in Lower Price Range (U.S. dollars/sq.ft.)	Estimated Average Cost of Flooring Material in Upper Price Range (U.S. dollars/sq.ft.)
Carpeting *	11	$1.50/sq.ft	$8.00/sq.ft.
Hardwood Flooring	50	$3.50/sq.ft	$11.00/sq.ft
Ceramic Tile Flooring	Lifetime	$1.50/sq.ft.	$7.50/sq.ft.
Linoleum Flooring	40	$3.50/sq.ft.	$5.00/sq.ft.
Cork Flooring	50	$3.00/sq.ft.	$5.50/sq.ft.
Rubber Flooring	30	$5.00/sq.ft.	$20.00/sq.ft.
Concrete Flooring	25	$2.50/sq.ft.	$9.50/sq.ft.
Natural Stone Flooring	Lifetime	$4.00/sq.ft.	$23.00/sq.ft.
Laminate Flooring	30	1.50/sq.ft.	$5.00/sq.ft.

Porcelain Flooring	Lifetime	$2.00/sq.ft.	$12.50/sq.ft.

* Broadloom or tile carpeting

Carpeting

Carpeting, like other flooring materials, comes in many different varieties. Amongst residential carpeting broadloom is the most popular, but carpet tiles are gaining a reputation as well because they enable users to replace individual tiles instead of an entire carpet if damaged (INFORM). As a whole, residential carpeting can cost anywhere from $1.00 per square foot to $70.00 per square foot. Based on information from carpeting manufacturers and retailers the average low cost of carpeting in the U.S. is an estimated $1.50 per square foot, and the estimated average high cost of carpeting is $8.00 per square foot, as shown in Table 1. The adjustment for installation costs is approximately $1.00 per square foot, and the approximate maximum lifespan for carpeting is 11 years.

Given an area of 700 square feet, the estimated average low replacement cost is $1,050, or $1,750 when adjusting for installation. The estimated average high replacement cost is $5,600 or $6,300 after installation. With an 11 year maximum replacement rate in a building that can last up to100 years, the estimated total low cost for carpeting in a 700 square foot apartment is $9,450 or $15,750 after installation. The estimated total high cost is $50,400 or $56,700 after installation. These estimates assume a maximum of 9 installations (8 replacements) for a total of 99 years. In addition, deep-cleaning costs for carpeting can vary greatly and are not always absorbed by building managers. In fact, it is unclear as to who absorbs these internal costs more (building managers or occupants). The frequency of deep-cleaning is also dependent on the up-

keep by its users and recommendation of the manufacturer (INFORM). External costs, such as those spent on medical bills due to illnesses caused or promoted by carpeting, also vary greatly and are absorbed by building occupants.

Table 2. Estimated Average & Total Costs for Carpeting

Flooring Material	Area of Apartment ($ft.^2$)	Building Life (yrs)	Total # of Replacements	Estimated Average Low Replacement Cost (U.S. Dollars)	Estimated Average High Replacement Cost (U.S. Dollars)	Estimated Total Low Cost (U.S. Dollars)	Estimated Total High Cost (U.S. Dollars)
Carpeting	700 $ft.^2$	100	9	$1,750*	$6,300*	$15,750*	$56,700*

* After Installation

Hardwood Flooring

According to the National Wood Flooring Association [NWFA], hardwood flooring offers a wide range of benefits to building occupants that carpeting can not. Compared to carpeting, hardwood flooring is easier for occupants to keep clean and free of dust, dirt, pet dander, and moisture. Hardwood flooring's non-porous and smooth surface generally requires sweeping on a regular basis, but vacuum cleaners can also often be used to clean it. In addition, the hardwood flooring industry has transformed into a large set of ecologically friendly flooring manufacturers due to public concern over deforestation and waste (NWFA). Today, many hardwood floors can be purchased from manufacturers that harvest their wood in sustainably grown forests, as well as from manufacturers that use reclaimed wood. On the other hand, hardwood floors have some drawbacks that carpeting definitely compensates for. The largest of these disadvantages are sound and softness. Walking and moving objects on hardwood floors creates a lot

more noise than these actions do on carpeting. In addition, the make-up of carpeting provides a much softer floor surface to walk, crawl, and sit on than hardwood flooring.

Compared to carpeting, however, hardwood flooring is financially advantageous for building managers. As displayed in Table 1, the estimated average low cost for hardwood flooring in the U.S. is $3.50 per square foot, and the estimated average high cost is $11.00 per square foot. The adjustment for installation costs is approximately $2.00 per square foot, and the approximate maximum lifespan for hardwood flooring is 50 years. Given an area of 700 square feet, the estimated average low replacement cost for hardwood flooring is $2,450 or $3,850 after installation, and the estimated average high replacement cost is $7,700 or $9,100 after installation. With a 50 year maximum replacement rate in a building that can last up to100 years, the estimated total low cost for hardwood flooring in a 700 square foot apartment is $4,900 or $7,700 after installation. The estimated total high cost is $15,400 or $18,200 after installation. These estimates assume a maximum of 2 installations, or 1 replacement, for a total of 100 years. The comparison of total low and high costs between hardwood flooring and carpeting is displayed in Table 3 below.

Table 3. Estimated Average & Total Costs for Hardwood Flooring & Carpeting

Flooring Material	Area of Apartment ($ft.^2$)	Building Life (yrs)	Total # of Replacements	Estimated Average Low Replacement Cost (U.S. Dollars)	Estimated Average High Replacement Cost (U.S. Dollars)	Estimated Total Low Cost (U.S. Dollars)	Estimated Total High Cost (U.S. Dollars)
Hardwood Flooring	700 $ft.^2$	100	1	$3,850*	$9,100*	$7,700*	$18,200*
Carpeting	700 $ft.^2$	100	9	$1,750*	$6,300*	$15,750*	$56,700*

* After Installation

As shown, the estimated average low cost for an initial installation of hardwood flooring is a little more than twice the amount of the estimated average low cost for an initial installation of carpeting. The estimated average high cost for an initial installation of hardwood flooring is almost $3,000 more than the estimated average high cost for an initial installation of carpeting. However, over the lifetime of the building, the estimated total low cost of hardwood flooring is nearly half of the estimated total low cost of carpeting. In addition, the estimated total high cost of hardwood flooring is less than 30% of the estimated total high cost of carpeting. Considering the ease of maintaining hardwood flooring relative to carpeting, and therefore reducing internal and external costs, on the assumption that building managers want to replace flooring as infrequently as possible, this scenario offers a realistic view on how hardwood flooring is better for both building managers throughout the lifetime of a building and for occupants throughout their occupancy.

Ceramic Tile

Like hardwood flooring, ceramic tile is a practical hard-surface flooring option for anyone who wants an easy to clean and very durable floor covering. Unlike carpeting, ceramic tile is produced with all natural ingredients, mainly clay and water. According to the World Floor Covering Association (WFCA), ceramic tile flooring often comes glazed, which gives it a protective coating that helps it resist moisture, dirt, and other particulate matter. Ceramic tile flooring is also fire resistant, an attractive safety feature that neither carpeting nor hardwood flooring possess. When comparing ceramic tile to carpeting, however, the cons stand out. Like hardwood flooring, ceramic tile is not nearly

as soft to walk, crawl, or sit on, and it provides little to no sound absorption. In addition, this flooring type is not slip resistant, whereas carpeting provides more friction for protection against slipping (Hanson et. al).

When considering costs, however, ceramic tile flooring can easily be one of the most attractive flooring materials for building managers. Its approximate lifespan equals the lifetime of a person, and therefore its replacement costs can be as little as zero. As seen in Table 4, the estimated average low cost of installation for ceramic tile flooring is $1,050, and the estimated average high cost of installation is $5,250. Both of these estimates do not include installation costs. During a 100 year lifetime of a building, however, ceramic tile flooring may not need to be replaced. Therefore the estimated total low and high costs could equal the installation costs, or at most be double the low and high costs respectively. In either case, these costs are dwarfed by the estimated total average low and high costs of carpeting, making ceramic tile flooring one of the most financially advantageous flooring materials for building managers. With no costly maintenance necessary as well, ceramic tile flooring offers building managers and occupants the opportunity to keep their floors clean and moisture free with relative ease compared to carpeting, and therefore maintain good quality indoor environmental health during the time of their occupancy. Thus, compared to carpeting, internal and external costs are reduced for building managers and occupants with ceramic tile flooring.

Table 4. Estimated Average & Total Costs for Ceramic Tile Flooring & Carpeting							
Flooring Material	Area of Apartment ($ft.^2$)	Building Life (yrs)	Total # of Replacements	Estimated Average Low Replacement Cost (U.S. Dollars)	Estimated Average High Replacement Cost (U.S. Dollars)	Estimated Total Low Cost (U.S. Dollars)	Estimated Total High Cost (U.S. Dollars)
Ceramic Tile Flooring	700 $ft.^2$	100	0	$1,050	$5,250	$1,050	$5,250
Carpeting	700 $ft.^2$	100	9	$1,750*	$6,300*	$15,750*	$56,700*

* After Installation

Linoleum

Linoleum floors are made from all natural products. The primary ingredients are linseed oil, rosin, wood flour, cork flour, limestone, pigments, and jute (GreenFloors). Linoleum flooring is also typically recyclable and has a lifespan of approximately 25-40 years. Due to Linoleum's make-up of all natural ingredients, it can either be incinerated at the end of its lifecycle or safely put in landfills for decomposition because it is fully biodegradable. Linoleum also contains zero toxins unless installed with toxic adhesives, and therefore is not detrimental to the indoor environmental health of building occupants (GreenFloors). Like ceramic tile and hardwood flooring, linoleum flooring requires little maintenance compared to carpeting. Dry mops, brooms, and occasional water-based cleaning (wet mops) are all that is necessary to keep linoleum floors clean and free of dust, pet dander, dirt, and other particulates that are ordinarily difficult to extract from carpeting. GreenFloors, a website dedicated to "environmentally friendly flooring," also states that linoleum tiles are manufactured in accordance with the International Standards Organization (ISO) 14001 standards, and that linoleum flooring can qualify for LEED

credits if purchased locally[4]. The drawbacks to linoleum equal those of ceramic tile and hardwood flooring because linoleum flooring is another kind of hard surface material. As a result it does not absorb sound or provide as much friction as carpeting.

The financial benefits, however, mimic those of hardwood and ceramic tile flooring. Linoleum flooring can last up to half a lifetime, and with minimal maintenance necessary linoleum flooring can save building managers money throughout the lifetime of a building. Table 5 compares the estimated average low and high costs, as well as the estimated total low and high costs between linoleum flooring and carpeting. Similar to hardwood flooring and ceramic tile, linoleum flooring costs more than carpeting for each installation. These estimates use an installation cost of $5.00 per square foot, but linoleum installations can cost up to $7.00 per square foot. Nevertheless with an approximate lifespan of 50 years, and in a 700 square foot apartment with a lifetime of 100 years, only 1 replacement floor is necessary. As seen in Table 5, the estimated total low and high costs for linoleum flooring are $11,900 per square foot and $14,000 per square foot respectively. When comparing these to the estimated total low and high costs of carpeting, linoleum is the obvious money saver in the long-run. Like ceramic tile and hardwood flooring, both internal and external costs are reduced as well.

Table 5. Estimated Average & Total Costs for Linoleum Flooring & Carpeting							
Flooring Material	Area of Apartment ($ft.^2$)	Building Life (yrs)	Total # of Replacements	Estimated Average Low Replacement Cost (U.S. Dollars)	Estimated Average High Replacement Cost (U.S. Dollars)	Estimated Total Low Cost (U.S. Dollars)	Estimated Total High Cost (U.S. Dollars)
Linoleum Flooring	700 $ft.^2$	100	1	$5,950*	$7,000*	$11,900*	$14,000*
Carpeting	700 $ft.^2$	100	9	$1,750*	$6,300*	$15,750*	$56,700*

* After Installation

Cork

Cork is another alternative flooring option to carpeting but stands out in a unique way amongst the other eight alternatives under discussion here. Cork flooring is made entirely from the cork wine stopper manufacturing process, which typically harvests cork from trees approximately once every ten years (GreenFloors). The cork trees are never cut down and the bark grows back over time. Globus Cork, one of many cork flooring manufacturers, also makes the effort to use only water based adhesives and dyes to produce cork flooring with no toxins or VOC's, making this type of flooring good for indoor environmental health and recyclable or biodegradable. In addition cork flooring offers many of the same features to building occupants as carpeting. It absorbs sound better than the three previously mentioned hard-surface flooring materials, it helps prevent heat loss in a room, and cork flooring acts as a cushion to provide a semi-soft surface to walk, crawl or sit on (Globus). The reason that cork flooring can mimic most carpet-like characteristics is because of its natural structure. With a honeycomb-like structure, 90% of cork material is an air-like gas. This makes cork lightweight yet durable. Although cork flooring does not provide the very soft sponge-like feeling of

carpeting, it offers a much softer feel than linoleum, ceramic tile, and hardwood flooring, and has a longer life-span than carpeting. According to Globus, cork also has a naturally occurring substance called Suberin, which repels mold, mites, bugs, termites, and coincidentally also acts as a natural fire resistor.

Financially, cork is like all other hard surface flooring materials discussed so far. As seen in Table 6 below, the estimated average low and high replacement costs are higher than those of carpeting, but the estimated total low and high costs are three to eight times less than those of carpeting, respectively. These estimates, however, do not account for installation costs. With additional qualities such as durability, resistance to mold and fire, and a sustainable production and recycling process, cork flooring is easily one of the superior hard-surface flooring materials and far superior to carpeting when considering indoor environmental health, impact on the environment, and both internal and external costs absorbed by building managers and occupants.

Table 6. Estimated Average & Total Costs for Cork Flooring & Carpeting

Flooring Material	Area of Apartment ($ft.^2$)	Building Life (yrs)	Total # of Replacements	Estimated Average Low Replacement Cost (U.S. Dollars)	Estimated Average High Replacement Cost (U.S. Dollars)	Estimated Total Low Cost (U.S. Dollars)	Estimated Total High Cost (U.S. Dollars)
Cork Flooring	700 $ft.^2$	100	1	$2,100	$3,850	$4,200	$7,700
Carpeting	700 $ft.^2$	100	9	$1,750*	$6,300*	$15,750*	$56,700*

* After Installation

Rubber

Rubber flooring is most well known and suited for gym floors, exercise rooms, children's play areas, and other sport facilities, but it can also be used for residential home floor surfaces. According to the WFCA, rubber flooring is extremely durable. It is comparable to carpeting and cork flooring in how it absorbs sound and provides a cushioned surface to walk, crawl, and sit on. Some rubber flooring manufacturers also claim to produce 100% their product with reclaimed materials from landfills (RubberFlooring). Consequently rubber flooring can be recycled into many different products after its use as a flooring material.

Rubber flooring, like all other flooring materials, also has its drawbacks. The primary downside is that rubber flooring material is relatively expensive compared to other flooring materials. As seen in Table 7, the estimated average low and high replacement costs are $3,500 and $14,000 respectively, and these estimates are not adjusted for installation costs. Since rubber flooring has an approximate maximum lifespan of 30 years, it would need to be replaced twice for a total of three installations in a 100 year lifetime building. In a 700 square foot apartment, the estimated total low and high costs are $10,500 and $56,700 respectively. Without including installation costs rubber flooring is financially advantageous for building managers in the long-run. However, installation costs can easily make carpeting more financially attractive than rubber flooring when factored into this scenario. Nevertheless, rubber flooring does not present as many indoor environmental health concerns as carpeting, it can be produced from 100% reclaimed material, it can be recycled, its durability gives it a lifespan up to three times as long as carpeting. All of these qualities factor in to reduced internal and external costs.

Table 7. Estimated Average & Total Costs for Rubber Flooring & Carpeting							
Flooring Material	Area of Apartment ($ft.^2$)	Building Life (yrs)	Total # of Replacements	Estimated Average Low Replacement Cost (U.S. Dollars)	Estimated Average High Replacement Cost (U.S. Dollars)	Estimated Total Low Cost (U.S. Dollars)	Estimated Total High Cost (U.S. Dollars)
Rubber Flooring	700 $ft.^2$	100	2	$3,500	$14,000	$10,500	$42,000
Carpeting	700 $ft.^2$	100	9	$1,750*	$6,300*	$15,750*	$56,700*

* After Installation

Concrete

Although commonly known as the kind of ground surface material used for streets, basketball courts, and basement floors, concrete is also an option for residential interior flooring. Similar to linoleum and ceramic tile, concrete is made from all natural materials, and its characteristics are very basic when compared to cork flooring. Concrete is a very hard flooring material and offers no cushion for walking, crawling, or sitting. However, interior concrete flooring has come a long way in providing suitable flooring for residents. According to the Concrete Network, a website dedicated to the education of concrete and related networks, concrete flooring has many attributes that are also offered by other flooring types. Concrete flooring can be stained or colored with dyes to make almost any color or pattern, providing a decorative flooring surface comparable to cork, ceramic, linoleum, and carpeting. Modern concrete floors are also being grinded to provide a smooth and glossy finish that does not require the floor to be waxed or coated during its lifetime (ConcreteNetwork). These finishes make concrete flooring easy to clean with dry mops or brooms and occasional wet mopping.

In contrast to carpeting, however, concrete flooring is a terrible insulator for heat. Manufacturers, however, have devised methods of utilizing this feature of concrete and turning it into an attractive quality. For example, one can now use a “radiant heating system” with concrete flooring. With this system, heating rods can be placed within the concrete during installation, which can then radiate heat into a room. According to the Concrete Network, this type of heating system is more cost and energy efficient than a forced air system because the thermostat can be set to 4 degrees less than a forced air system and provide the same amount of heat into a room.

Concrete flooring is also financially advantageous for building managers in the long-run. Compared to carpeting, the estimated average low and high replacement costs for concrete flooring in a 700 square foot apartment are $1,750 and $6,650 respectively (See Table 8). These estimates are not adjusted for installation costs. The estimated total low and high costs of concrete flooring after 3 replacements and 4 total installations for a 100 year lifetime building are $7,000 and $26,000 respectively. Concrete, then, is a viable alternative interior flooring option to carpeting. Concrete floors can last up to three times as long as carpeting, they require less maintenance on behalf of building occupants, and are 100% recyclable. Again, this has potential over carpeting to reduce internal and external costs on behalf of building managers and occupants.

Table 8. Estimated Average & Total Costs for Concrete Flooring & Carpeting							
Flooring Material	Area of Apartment ($ft.^2$)	Building Life (yrs)	Total # of Replacements	Estimated Average Low Replacement Cost (U.S. Dollars)	Estimated Average High Replacement Cost (U.S. Dollars)	Estimated Total Low Cost (U.S. Dollars)	Estimated Total High Cost (U.S. Dollars)
Concrete Flooring	700 $ft.^2$	100	3	$1,750	$6,650	$7,000	$26,600
Carpeting*	700 $ft.^2$	100	9	$1,750	$6,300	$15,750	$56,700

* After Installation

Natural Stone

Another alternative flooring material to carpeting is stone flooring. Like concrete, natural stone flooring is made entirely of natural materials and is a hard surface flooring type. There are variations of natural stone flooring. The most popular is slate, but others, such as limestone, travertine, granite, marble, quartzite, and sandstone rank among the most established natural stone flooring materials. Natural stone flooring also resembles other hard-surface flooring materials in that its maintenance is minimal compared to carpeting. Stone flooring has a hard, smooth surface that mainly requires dry mopping or sweeping and occasional wet mopping. The major disadvantage of stone flooring is that it resembles concrete and does not have as good heat retention as carpeting. However, unlike concrete flooring, stone flooring can last a lifetime and may never need to be replaced if properly taken care of (NTMA).

Although natural stone flooring can cost up to $2,000 per square foot for materials with that go through an intense manufacturing process, such as marble and quartzite, it can also be purchased for as little as $1.50 per square foot for materials such as slate. As seen in Table 9, the estimated average low and high costs for natural stone flooring in a

700 square foot apartment are $2,800 and $16,100 respectively. These estimates do not include installation costs. However, since natural stone flooring can last a lifetime and therefore may never need to be replaced during the 100 year lifetime of a building, the estimated total low and high costs are the same as the replacement costs. This scenario is similar to that of ceramic tile flooring, except natural stone flooring costs more. Thus, in the long-run natural stone flooring lasts a very long time, so the financial advantages of fewer maintenance and replacement costs in line with the flooring's approximate non-existent negative impact on indoor environmental health make natural stone flooring another superior hard-surface flooring alternative to carpeting. This is especially apparent when considering the reduced internal and external costs absorbed by building managers and/or occupants.

Table 9. Estimated Average & Total Costs for Natural Stone Flooring & Carpeting

Flooring Material	Area of Apartment ($ft.^2$)	Building Life (yrs)	Total # of Replacements	Estimated Average Low Replacement Cost (U.S. Dollars)	Estimated Average High Replacement Cost (U.S. Dollars)	Estimated Total Low Cost (U.S. Dollars)	Estimated Total High Cost (U.S. Dollars)
Natural Stone Flooring	700 $ft.^2$	100	0	$2,800	$16,100	$2,800	$16,100
Carpeting*	700 $ft.^2$	100	9	$1,750	$6,300	$15,750	$56,700

* After Installation

Laminate

The eighth alternative flooring material to carpeting is laminate flooring. Laminate flooring is constructed in layers of "high density fiberboard" (Armstrong). The point of laminate flooring is to provide a floor surface that looks like other flooring

materials, such as hardwood or ceramic tile flooring, but is not. This is accomplished with the use of images placed onto the fiberboard that are protected by a coating, which also protects the flooring from wear and stains over time. All of this means that laminate flooring is artificial, as easy to clean and maintenance as other hard-surface flooring materials, and does not absorb sound or provide as much comfort to walk, crawl, or sit on as carpeting.

Unlike any other flooring surface material, including carpeting, laminate flooring is the cheapest on the market today. As seen in Table 1, the estimated average low and high costs of laminate flooring are $1.50 per square foot and $5.00 per square foot respectively. The low cost estimated average is the same as carpeting, but the high cost estimated average is $3.00 per square foot less than carpeting. These estimates do not include installation costs. However, laminate flooring has an approximate maximum lifespan of 30 years, which is about three times longer than that of carpeting. In a 700 square foot apartment scenario, the estimated average low and high replacement costs are $1,050 and $3,500 respectively (see Table 10). In a 100 year lifetime building the estimated total low and high costs are $3,150 and $10,500 respectively, or approximately five times less than that of carpeting. Laminate flooring is therefore the most financially attractive and advantageous flooring option for building managers when looked at through a sustainable lens. It is on average cheaper than or equal to carpeting for the initial installation and does not need to be replaced as many times as carpeting. It also offers an easy-to-maintenance floor surface to building occupants and has little, if any, impact on indoor environmental health and the waste-stream. Thus, like all alternative

flooring materials under discussion here, laminate has greater potential than carpeting to reduce internal and external costs to building managers and occupants.

Table 10. Estimated Average & Total Costs for Laminate Flooring & Carpeting

Flooring Material	Area of Apartment ($ft.^2$)	Building Life (yrs)	Total # of Replacements	Estimated Average Low Replacement Cost (U.S. Dollars)	Estimated Average High Replacement Cost (U.S. Dollars)	Estimated Total Low Cost (U.S. Dollars)	Estimated Total High Cost (U.S. Dollars)
Laminate Flooring	700 $ft.^2$	100	2	$1,050	$3,500	$3,150	$10,500
Carpeting*	700 $ft.^2$	100	9	$1,750	$6,300	$15,750	$56,700

* After Installation

Porcelain Tile

The last alternative flooring option to carpeting for discussion is porcelain tile flooring. Porcelain is actually a form of ceramic. The difference is that it is produced from finer clays and minerals, and that makes it a denser material (Shaw). Consequently, the major characteristic difference between porcelain tile flooring and ceramic tile flooring is that porcelain tiles are more water resistant due to smaller pores in the denser material. Financially though, porcelain tile flooring is sold at a slightly higher price than ceramic tile flooring. As seen in table 11, the estimated average low and high replacement costs in a 700 square foot apartment for porcelain tile flooring are $1,400 and $8,750 respectively. These estimates do not account for installation costs. Nevertheless, like every other hard-surface flooring material, porcelain can cut flooring costs significantly throughout the lifetime of a building, as well as reduce internal and external costs to building managers and occupants.

Table 11. Estimated Average & Total Costs for Porcelain Flooring & Carpeting							
Flooring Material	Area of Apartment ($ft.^2$)	Building Life (yrs)	Total # of Replacements	Estimated Average Low Replacement Cost (U.S. Dollars)	Estimated Average High Replacement Cost (U.S. Dollars)	Estimated Total Low Cost (U.S. Dollars)	Estimated Total High Cost (U.S. Dollars)
Porcelain Flooring	700 $ft.^2$	100	0	$1,400	$8,750	$1,400	$8,750
Carpeting*	700 $ft.^2$	100	9	$1,750	$6,300	$15,750	$56,700

* After Installation

There are other alternative flooring materials to carpeting, such as vinyl and bamboo, and they too should be compared to other flooring options under a common scenario to discuss their advantages or disadvantages over carpeting. For the purposes of this study, no more than ten flooring materials (carpeting included) need comparison to each other under a common scenario in order to prove the financial inefficiency of carpeting. In summary, the sustainable lens seems to be under-utilized by flooring decision-makers throughout the U.S. today. There are many established alternative flooring materials available that offer greater financial efficiency and decrease the potential for negative impacts on indoor environmental health and the outdoor environment. Some of these alternatives reduce internal and external costs to building managers and occupants more than others. Nevertheless, they are all viable alternatives to carpeting that flooring decision-makers ought to consider. It is in the best financial interest for them, as well as in the best health interests for the occupants of their buildings.

References

Armstrong. *QA Laminate Buyer's Guide: What is Laminate?* 2008. Armstrong.com. 19 April 2008.
<http://www.armstrong.com/resflram/na/home/en/us/flooring-buyers-guide-laminate-flooring.html>

Concrete Network. *Interior Concrete Floor Information*. 2008. ConcreteNetwork.com. 14 March 2008.
<http://www.concretenetwork.com/concrete/interiorfloors/>

Ellis, Tom. *Controlling IAQ Problems With Alternative Flooring*. 2001. INvironment Professional. 9 April 2008.

Globus Cork. Frequently Asked Questions: *What is Cork and Why is it so Unique?* 2008. Globus Cork. 12 March 2008.
<http://www.globuscork.com/faqs.html>

Goddin, Lesley. *TCNA Study: Ceramic Tile Is Most Economical Of All Floor Finishes.* 2006. National Tile Contractors Association. 10 April 2008.
<http://www.tileletter.com/June06/TCNAstudy.htm>

GreenFloors. *Attributes That Make Linoleum Floors "Green."* 2008. GreenFloors.com. 12 March, 2008.
<http://www.greenfloors.com/HP_Linoleum_Table_Insert.htm>

Hanson, James P., Redfern, Mark S., Mazudmar, Mainak. "Predicting slips and falls considering required and available friction." *Ergonomics* 42 (1999): 1619-1633.

INFORM. *Cleaning for Health: Best Practices*. 2006. INFORM. 14 April 2008.
<http://informinc.org/cfhbp.pdf>

INFORM. *Community Waste Prevention Toolkit: Carpet Fact Sheet*. 2008. INFORM. 14 April 2008.
<http://informinc.org/fact_CWPcarpet.php>

National Wood Flooring Association (NWFA). *Benefits of Wooden Floors*. 2007. NWFA. 12 March 2008.
<http://www.woodfloors.org/consumer/whyBenefits.aspx>

National Terrazzo and Mosaic Association Inc. (NTMA). 2008. NTMA.com. 14 April 2008.
<http://www.ntma.com>

RubberFlooring Inc. 2008. Rubberflooringinc.com. 15 April 2008.
<http://www.rubberflooringinc.com>

Shaw. *Ceramic or Porcelain?* 2008. Shawfloors.com. 9 April 2008. <http://www.shawfloors.com/ceramic-flooring>

World Floor Covering Association (WFCA). *Ceramic/Porcelain-How It's Made*. 2008. Creating Your Own Space & WFCA. 15 March 2008. <http://www.wfca.org>

Recommendations & Conclusion

Carpeting is approximately a $10 billion industry in the United States. Its presence on the majority of indoor floors helps to retain heat inside of rooms, absorb sound well enough to prevent noise from traveling across living spaces, and most notably, it provides a soft surface to walk on. Yet, due to its many characteristics, carpeting presents several indoor environmental health concerns to building occupants. Carpeting can also have significant environmental impacts on land through the waste-stream that it is most often discarded into. Furthermore, based on current usage trends, reclamation efforts, and non-toxic material initiatives from manufacturers, the impacts of carpeting on the indoor and outdoor environments seem likely to increase in the near future before they can finally taper off and decline.

Thankfully, however, these critical issues have grasped the attention of the public, the carpet industry, and in mild ways, the government in the last twenty years. The government has primarily responded to the increase in asthma and allergy related illnesses by recognizing the link between carpeting and indoor environmental health. On the other hand, the carpet industry has spent most of its efforts voluntarily responding to concerns over the impact of carpeting on the environment when it is in the waste-stream, as well as the impact of various toxic chemicals in carpeting on indoor environmental health. Again, although these efforts have decreased the potential impact on building occupants and the environment through the waste-stream, the number of indoor illnesses that carpeting contributes to and the amount of carpeting discarded into landfills continues to rise annually.

The most important characteristic of carpeting that contributes to poor indoor environmental health also happens to be the most difficult to address. This is the sink environment that results from the tightly packed fibers bound on a backing, which create a perfect environment for collecting particulate matter. Consequently, carpeting is the most difficult flooring material to keep free of particulates and properly maintain during its lifetime in a home. In addition, maintaining carpeting can be costly and, on occasion, create hazardous indoor conditions for building occupants if conducted improperly. Yet, for the very reason that carpeting is made of soft tightly packed fibers and it is cheap to purchase and install, it remains the most desirable flooring material in the U.S. Again, based on usage trends, all of carpeting's positive attributes seem to over-shadow its impact on indoor environmental health and the outdoor environment when flooring decision-makers choose it, in spite of available information on these issues.

For that reason, this document is meant to present available information on the impacts of carpeting in a way that flooring decision-makers can understand the consequences that their decisions have on indoor environmental health. Additionally, this document can be used as a starting block for policy recommendations that would improve the problem with tenant choice on flooring material, and consequently reduce carpeting's impact on indoor environmental health. Stricter policies on waste management can also act as catalysts for reducing carpeting's impact on the environment through the waste-stream. Last, government influence on flooring installation and maintenance requirements can have a dramatic effect on the improvement of indoor environmental health. Thus, the remainder of this chapter will outline recommendations for carpeting in

three areas: building occupant choice in flooring material, material requirements for lifetime impact on indoor environmental health, and waste-management.

Occupant Choice:

Though this study only provides a small set of data on an urban population of tenant buildings that provide or do not provide tenants with a flooring choice, the prevalence of indoor illnesses that are partly or directly linked to carpeting can temporarily supplement the necessary proof to show that many tenants do not have a choice of living with anything other than carpeting as a flooring material. With the aid of more research into the prevalence of this issue, as well as the impact it has on building occupant health as a whole, a strong case can be made for why tenants should be able to choose whether or not they live with carpeting. Information on carpeting's impact on indoor environmental health, particularly for people with asthma and allergies, is available through various government agencies. However, the existence of this information may be unknown to many tenants, and efforts to make sure that tenants are aware of this information are unclear. Therefore, at a minimum, tenant choice in flooring material should be enabled and protected under federal, state, or local law.

This would coincide with the federal government's recent interest in protecting indoor environmental health. For example, lead-based paint was banned by the Consumer Product Safety Commission (CPSC) for residential use in 1978. Although lead-based paint on interior walls was not the primary source of concern, lead-based paint was deemed too hazardous for building occupants because there was a risk of ingesting paint chips or breathing in dust with lead-based paint particulates. This risk was found to be significantly higher for children because they spend more time than adults on the floor of

interior spaces and that is where paint chips and particulates accumulate the most. Similarly, carpeting does not present a significant risk to building occupants from the nature of it being a flooring material. However, carpeting is difficult to maintain and keep free of particulate matter build-up, and that increases the risk of any particulate matter that could be toxic to accumulate in carpeting. Additionally, with a much higher risk for dust accumulation and mold growth due to the difficulty of maintaining carpeting, building occupants are at a higher risk for exposure to dusty and moldy indoor atmospheres. This is of particular concern for occupants with asthma and mold and dust allergies. Children are also at higher risk than adults for exposure to the accumulated particulates and fungus growth in carpeting because they spend more time on interior floors than adults do. The similarity between carpeting and lead-based paint as a high risk factor for indoor environmental health is strikingly clear and ought to be taken more seriously by public health officials. However, rather than going as far as banning carpeting from the market, the federal government can choose to issue a mandate on building managers that makes it necessary to provide tenants with a choice of living with an alternative flooring material to carpeting. Along with such a mandate, the government would need to increase its outreach efforts to make sure that all tenants are informed of the potential impacts that carpeting can have on indoor environmental health. Together, with more informed and choice bearing residents, the number or illnesses partly or directly resulting from poor indoor air quality due to carpeting can decline.

In addition to government issued policy, there exists the opportunity for voluntary action on behalf of carpeting decision-makers. In tenant buildings, where flooring choice is generally limited to building managers, both the internal and external costs of choosing

carpeting would need to be considered and weighed against the benefits. Again, this means that building managers would need to be informed of the impacts that carpeting has on indoor environmental health, as well its replacement costs and the frequency of those costs, which can result in both higher internal and external costs over the lifetime of a building. Some of the primary concerns for building managers related to this might be the long-term ability to attract and retain tenants, as well as the costs of replacing and maintaining each tenant's flooring. Giving tenants a choice on flooring, however, does not exclude potential tenants with asthma or indoor allergies, and can decrease maintenance costs if carpeting becomes the least chosen flooring material. Thus, choice in flooring material can attract and retain more tenants because a large group of tenants (people with asthma and allergies) would not be excluded from a healthy living environment. Though voluntary action is an ideal method for creating tenant choice in flooring material and decreasing carpeting's impact on occupant health, it is not guaranteed because the economic and health benefits may not always get factored into a building manager's flooring decision.

Material Requirements:

Controlling the impacts that carpeting has on indoor environmental health from the manufacturing stage can also be an effective method. This would encompass controlling the types and amounts of chemicals that are used in the creation of carpeting sold to residents. The most effective means would again call for government influence, but there remains the possibility that independent manufacturers can voluntarily improve their products so that the materials they are made of do not have any or have little affect on the health of building occupants. One reason why the government should intervene in

the manufacturing process of carpeting is that there is a national purpose to protect human health. Traditionally, the federal government has intervened on matters that reflect upon human health across the nation. A prime example is the ban on lead-based paint. Since carpeting creates indoor environments that are difficult to properly maintain, which then increases the risk of poor indoor air quality, and carpeting covers the majority of indoor floors, the government has a national purpose to protect the majority of building occupants from the high potential health risks that carpeting imposes on them.

Interestingly, independent carpet manufacturers are already taking steps to decrease or prohibit the use of toxic chemicals in their products. These actions may be the result of a bad stigma around carpeting due to several Sick Building Syndrome cases that are linked to it. On the other hand, manufacturers may have realized that fewer chemicals used in their products make it easier to recycle them later, which is what more manufacturers are motivated by today. In spite of the possible reasons why manufacturers have taken interest in this issue, the point is that they have and, as a result, more carpeting today is being manufactured without toxic chemicals that can off-gas and create poor indoor air quality. However, the number of carpeting with little or zero toxic chemicals and how much of it reaches residents remains unknown. Therefore, like occupant choice, voluntary action only has potential to improve the problem. Government action, with proper enforcement, is a much more surefire method for decreasing the risk of poor indoor air quality in homes with carpeting.

Waste Management:

Diverting carpeting from landfills and increasing recycling and reuse efforts are already being addressed by the government and carpet industry. Nevertheless, these

efforts can be improved. In addition to the CARE program, a joint government and carpet industry initiative, the government can offer incentives to manufacturers that increase their carpet recycling capacities, as well as incentives to consumers so they will buy recyclable carpet instead of non-recyclable carpet material. Similar policies have been issued by the federal government in the form of tax breaks. One example is the tax incentive to purchase a hybrid vehicle, which gives consumers an incentive to buy a vehicle that uses less gasoline than conventional internal combustion engines use, and therefore pollute less (IRS 2007). Again, this relates to the federal government's national interest in public health. Carpeting is a very large problem in landfills nationwide. The government can express exigency through policies and incentives that will speed up the process of improving this problem.

In addition to government aid, flooring decision-makers as a whole have the ability to divert carpeting from landfills and make a significant impact on this problem. The primary method for accomplishing this is to reduce the amount of carpeting purchased. As discussed, there exists plenty of alternative flooring options to carpeting that offer a variety of incentives to building managers and occupants. The first major incentive is that hard surface flooring requires little maintenance compared to carpeting, thus reducing costs for necessary deep cleaning. The second is that hard surface flooring lasts between two and five times longer than carpeting, reducing the replacement costs for flooring to building managers. The initial costs of alternative flooring to carpeting are generally higher than that of carpeting's initial costs, but as demonstrated in the cost comparison analysis of carpeting to nine alternative flooring materials, the initial cost of alternative flooring materials is usually less than the total costs of replacing carpeting

over the lifetime of a building. As appealing as the financial benefits to alternative flooring can be for building managers, they are still dependent upon an altruistic decision. This is not a promising strategy for decreasing the amount of carpeting that gets purchased and ultimately discarded into landfills. Rather, a combination of government incentives to increase carpet recycling capacities and building manager efforts to exclude carpeting from their buildings is a more promising method for decreasing the amount of carpeting in landfills.

In conclusion, carpeting has played an important role in the increasing number of indoor environmental health related illnesses for over a decade. Today, certain agencies with the U.S. government and the carpet industry as a whole recognize many health concerns that result from carpeting in residential spaces and have made several attempts to alleviate carpeting's health impacts in those areas. In addition, each of these institutions has initiated efforts to reduce the impact that carpeting has on the environment through the waste-stream. The overarching problem, however, is that the benefits to carpeting often overshadow its disadvantages, even though its negative impacts can significantly outweigh the benefits. This problem is most likely the result of habitual practices on behalf of flooring decision-makers to choose carpeting without considering alternatives or weighing the potential internal and external costs against its often appealing initial costs. Thus, carpeting remains the dominant indoor flooring material in the U.S. Yet, if efforts to improve its impact on indoor environmental health and to decrease its volume in landfills are not re-examined and increased, the number of indoor illnesses related to carpeting and the amount that gets discarded into landfills may steadily increase until it becomes a significant national health issue. This, however, can

be avoided. With more research into tenant choice on flooring material and how that relates to the impact of carpeting on indoor environmental health, as well as a reprioritization that puts the need to recycle more carpeting higher on the political agenda, the potential and definite impacts of carpeting on the indoor and outdoor environments can be alleviated, and ultimately diminished over time.

References

Internal Revenue Service (IRS). *Summary of the Credit for Qualified Hybrid Vehicles*. 2007. IRS. 1 May 2008.
< http://www.irs.gov/newsroom/article/0,,id=157557,00.html>