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FIRE SAFETY IN GREEN BUILDINGS

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Abstract

This project was sponsored by the National Association of State Fire Marshals to address the issue of fire safety in green buildings. We researched design characteristics of green buildings, awareness of fire safety, awareness of green building practices, and the ways that green building can promote or hinder fire safety. From this we developed recommendations focused on education of the fire services, as well as increased communication between fire officials and those involved in promoting the practice of green building.

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Executive Summary

All across the U.S. local and state governments are adopting green design criteria for both public and private buildings (VanBuskirk, 2007). Green buildings differ from traditional buildings in that they are designed to efficiently use resources such as water and energy, and in doing so lessen the building's impact on the environment. This efficient use of resources, while more expensive during construction, has been shown to lower operating costs upon the building's completion (Kozlowski, 2006). Building green is becoming the new trend for many developers and construction firms, a number of which have already begun implementing the Leadership in Energy and Environmental Design (LEED) rating system into their projects.

Given that building owners are willing to invest their money in building green in order to obtain the benefits, it is crucial to ensure that fire safety is not compromised in the pursuit of "green", and also to find ways in which fire safety can be incorporated. The goal of our project was to provide our sponsor, the National Association of State Fire Marshals (NASFM) with a list of recommendations that will craft a definition of "green" that incorporates fire safety, in order to move this issue forward with the various organizations promulgating green building designs. Addressing ways to incorporate fire safety into green building is of value to NASFM because it will help them get one step closer to their primary mission of protecting life, property, and the environment from fire and related hazards.

The majority of our project data was gathered through interviews with professionals in both the green building and fire safety fields, but we also used archival

research, conducted a survey, and attended a fire protection symposium. Based on data we collected, we determined that there were three major points that our project needed to address innovative materials and design, education and awareness, and fire code acceptance. These points also shaped our results as well as our recommendations.

The materials and design of a green building were found to have a great impact on its fire safety. There is an emphasis on using recycled materials, which we found can be dangerous because the materials may not have an adequate fire rating. Also, we discovered that alternative roof designs, such as installing photovoltaic panels and vegetated roofs, could hinder firefighters when attempting to suppress a fire in the structure. By educating the fire service personnel about green buildings, they would be able to fight fires in green buildings more effectively, as well as to help ensure that green building designs are compatible with fire safety needs.

Education and awareness were also found to be a key issue that could impact its fire safety in green buildings. Both interested parties, green advocates and fire safety professionals, were found to have inadequate knowledge of the issues of the other party; that is, green advocates were unaware of many aspects of fire safety, and vice versa. By increasing communication among all parties involved in construction of a green building, and introducing education programs, we believe that many potential conflicts between green building and fire safety could be avoided.

We also determined that the fire code adoption process could lead to conflicts between green builders and existing fire safety codes. Because codes take two years or more be fully adopted, green technologies are steadily outpacing them, which can lead to conflicts during a building's permitting process. While we cannot change the code

adoption process, if the codes were more “green” conscious, many potential conflicts would no longer be an issue.

1 Introduction

Fire protection uses studies of factors such as fire's behavior, humans behavior, compartmentalization, suppression and investigation to identify fire hazards and develop safety techniques that often make their way into building and fire codes. Building owners are responsible for including the local building and fire codes in their design, and for also maintaining the current fire code once the building is complete. All buildings must meet the minimum fire codes, but the National Association of State Fire Marshals (NASFM), the sponsor of our project, is interested in helping to ensure that green building designs and materials do not compromise fire safety.

While buildings have a positive impact on how we live by providing a comfortable environment and protecting us from nature, they also can have a negative impact on our health and on the environment. As we learn more about these negative impacts, more effort is being put towards building "green." Building green is a process that aims to increase the efficiency of the use of water, energy, and other natural resources, while removing materials that harm either the building's occupants or the environment (Kozlowski, 2006). In an ideal world, buildings would use designs and materials that are fire safe and have little or no environmental impact. In order to achieve this the NASFM has decided that a major review of requirements emerging from green building rating systems and code efforts is needed, to ensure that fire safety does not get ignored.

Since this topic is relatively new, there are a number of issues that NASFM needs to be address. First and foremost, characteristics of green buildings that are potential fire

hazards need to be determined. Research has shown that there are certain design aspects and materials used in green buildings that could cause problems with fire. W.K. Chow, a professor of architectural science and fire engineering at the Hong Kong Polytechnic University, has been able to identify some of the fire hazards that have been common in green buildings, but like many other researchers, he has had trouble finding out effective ways to address them.

Second, NASFM needs to determine the level of awareness of fire safety in green buildings among architects, fire marshals, code officials, officials involved in green building rating systems, and firefighters. This topic is important because it can help determine whether fire safety is being compromised from flaws in materials and design, or from a lack of awareness of fire safety measures in green buildings.

New concepts of going green, whether they are dealing with design, construction, operation, or maintenance, are developing at a faster pace than the concepts of keeping them fire safe. Up to this point research has shown ways that buildings could be modified to become more environmentally friendly, but they may not always take fire safety into consideration. In order for green buildings to be truly safe, fire safety measures have to be incorporated. At this point, NASFM is not sure how best to address this challenge and exactly where these problems and opportunities lie.

The goal of this project was to help NASFM craft a definition of "green" that incorporates fire safety, and to develop a list of recommendations that can help move this issue forward with the various organizations promulgating green building designs. In order to make these recommendations we researched fire safety in green buildings using published papers and articles, held interviews with experts in the fields of fire and

sustainability, distributed a survey to the State Fire Marshals, and attended a symposium on sustainability challenges and fire safety. Ultimately, we hope that by using our recommendations NASFM will be able to ensure that fire safety is being incorporated into green buildings.

2 Background Chapter

The U.S. Green Building Council's (USGBC) mission is to transform the way communities are built, enabling an environmentally and socially responsible, healthy, and prosperous environment that will improve the quality of life (USGBC, 2008). However, the fire safety of these buildings is still a concern as green buildings are utilizing innovative designs and materials –and discouraging the use of certain materials- in an effort to reduce their negative impact on the environment. The National Association of State Fire Marshals (NASFM), which has as its members the most senior fire service officials in all 50 states and the District of Columbia who are responsible for fire safety code adoption and enforcement on fire protection, has developed an interest in the green building movement (NASFM, 2008). The objective of this chapter is to give a description of the green building movement and the process that goes into certifying a green building, as well as to provide a brief introduction to fire safety and the impact fires have had on the built environment.

2.1 Fire Safety

"The total cost of fire in the United States is defined to be a combination of the losses caused by fire and the money spent to prevent worse losses, by preventing fires, containing them, detecting them quickly and suppressing them effectively" (Hall, 2008). In 2005, the estimated total cost of fire was between $267-294 billion. These numbers showed a 32% decrease in costs from 1980, after adjustment using the Consumer Price Index. This decrease could be attributed to the advances in fire protection.

2.1.1 Fire Triangle

For a fire to occur, three elements must be present: air, heat and a fuel. Oxygen is required to sustain combustion and heat is required to raise the material to its ignition temperature. Fire safety, at its most basic, is based upon the principle of keeping these three elements separate to either prevent the fire from occurring in the first place, or to disrupt the interaction of the three once combustion occurs to suppress the fire (TPUB, 2008). Fuel can be naturally removed from the equation when the fuel completely burns out or it can be manually removed. Essentially, how a fire is extinguished depends on the type of fire it is (see the classification section below). The most common method of extinguishing fires is the removal of heat, which is accomplished using water or some other agent.

2.1.2 Classification of Fire

Fires are divided into four main classifications, each depending on the type of material burning (TPUB, 2008). The selection and use of extinguishing agents varies with the class of fire, its location and the extent of the fire involvement. Table 2.1, below, shows the different classifications of fire based on the materials involved.

Table 2.1: Classes of Fire (TPUB, 2008)

CLASSES OF FIRE	TYPES OF MATERIALS INVOLVED
A	Wood and wood products, cloth, textiles and fibrous materials, and paper and paper products.
B	Flammable liquids, such as gasoline, diesel fuel (F-76), jet fuels, hydraulic fluid, and lube oil. Also, involves flammable gases.
C	Energized electrical fires.
D	Combustible metals, such as magnesium and titanium.

2.1.3 Fire Safety Tactics

Fire safety has five main tactics: prevention, communication, escape, extinguishment and containment (Stollard, 1996). Fire prevention involves the use of materials that are flame-resistant, either naturally or through the use of special treatment, as well as the reduction of fire hazards, by ensuring ignition sources are separate from heating sources through design or education. If fire prevention is successful, a fire does not occur; therefore, the other tactics of fire safety are not necessary.

However, if a fire does occur, the other components become very important in the way they work together. The next important tactic is communication (Stollard, 1996). Communication involves the notification of building's occupants and emergency

responders of a fire. Fire alarm systems, public intercoms, or telephones are used to notify the building's occupants, as well as local fire departments.

The next steps, escape, extinguishment and containment, may take place simultaneously. Escape, which may also be referred to as evacuation, mainly depends on the design of the building and human behavior. Escape routes have five main stages (Yiu, 2006). Stages one through three represent high-risk situations. However, as the occupant moves down the stages, the level of risk decreases.

- Stage 1: escape from the room or area of fire origin
- Stage 2: escape from the compartment of origin by the circulation route to a final exit or entry to a protected stair or to an adjoining compartment
- Stage 3: escape from the floor of origin to the ground level
- Stage 4: final escape at ground level
- Stage 5: moving far away from the origin

Design factors in buildings that facilitate escape include well-lit, marked exits and fire-proof stairwells, as well as their number and locations. Fire drills and signs can also influence how people react to fires. They ensure that the building occupants have the knowledge of the best route to use in high-risk situations.

Containment ensures that fires do not spread from the origin to the rest of the building. Elements in the structure of the building come into play in the containment of a fire. These include the fire rating of the inside and outside walls, windows and fire doors. Smoke control systems like smoke vents, ventilation systems and smoke barriers ensure that the smoke does not spread to other areas of occupancy in the building.

Extinguishment can be achieved through manual fire-fighting equipment, auto suppression systems, or the fire department. Manual fire-fighting equipment includes hoses and fire extinguishers. The most common type of automatic suppression system is the sprinkler system, in which sprinkler heads are placed throughout a structure with pipes going back to a main source of water, be it a reserve tank or the structure's local water supply. Access to a building and its water supplies influence the ability of the firefighters to extinguish the fire.

These five tactics are not mutually exclusive; they may overlap in an attempt to reduce the risk of the fire. Fire-resistant materials could be used to prevent the start of a fire as well as ensure the fire does not spread. Sprinkler systems can contain the fire in its place of origin as well as extinguish the fire. Figure 2.1, below, shows how the different tactics work together. For example, if a fire is prevented it ensures lives and property is saved. If prevention fails, then the occupants have to be notified of the presence of the fire. Depending on how containment, extinguishment and escape proceed, loss of lives or property may be alleviated or increased.

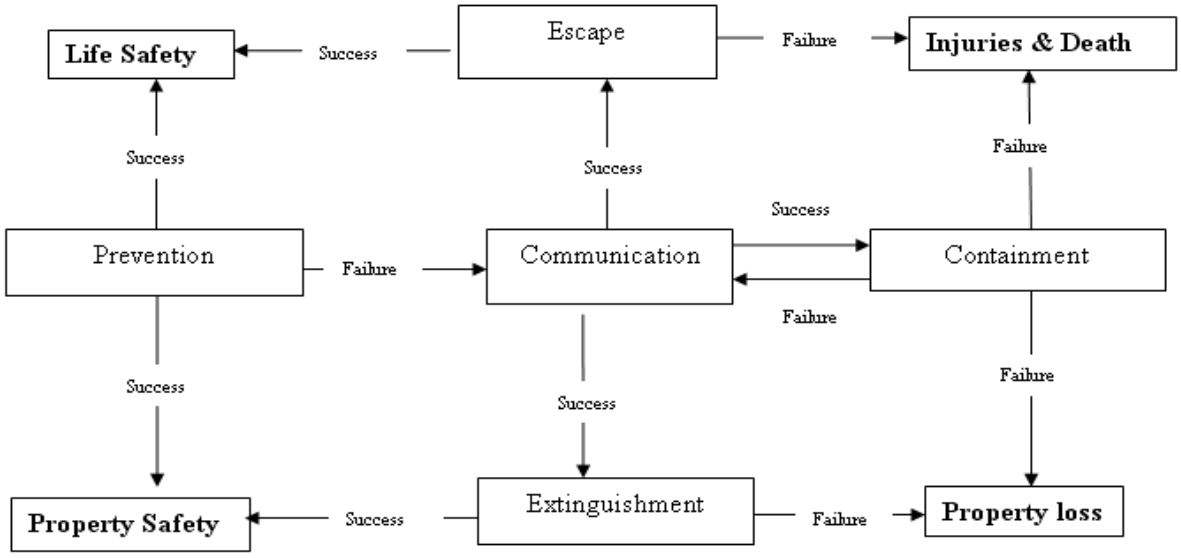

Figure 2.1: Fire Safety Tactics (Stollard, 2006, p.5)

2.1.4 Environmental Threat of Fire

Aside from the obvious threats to life safety from a fire, there are also environmental threats from fires. Groundwater runoff from water used to extinguish the fire may contain toxins and debris. This runoff may pollute water bodies nearby. "In November, 1986, 30 tons of toxic material were washed into the Rhine River by water used by the public fire department to extinguish a fire at the Sandoz chemical plant and storage facility near Basel, Switzerland. A toxic chemical slick 40 km (25 miles) long was created, resulting in widespread destruction of aquatic life, which only began recovering more than a year after the incident" (Harrington, 2006, p. 4).

Fire also affects the surrounding air. Smoke released in a fire contains toxins as a result of materials being burned. Materials releasing these toxins include cleaning agents, plastics, electric appliances and insulation materials (NASFM, 2002). Another harmful effect is the accumulation of debris on-site, which causes land pollution. Hazardous

wastes from cleaning agents and electrical appliances, which include refrigerants, used oil and mercury, must be disposed of carefully. Non-hazardous waste, including building materials, furnishings and other contents, are hauled to landfills where they are recycled.

2.1.5 Code and Standards for the Built Environment

"A code is a law or regulation that sets forth minimum requirements and, in particular, a building code is a law or regulation that sets forth minimum requirements for the design and construction of buildings and structures" (Grant & Cote, 2006, p.53). Codes are established to ensure the health and safety of the society. There are two types of codes: performance codes and specification (otherwise known as prescriptive) codes. "Specification codes spell out in detail what materials can be used, building size, and how components should be assembled. Performance codes detail the objective to be met and establish criteria for determining if the objective has been reached" (Grant & Cote, 2006, p.53). Performance codes borrow from specification codes, but provisions exist for substitution to an alternate method if they can be proven to be adequate.

More than half of the modern building codes usually refer in some way to fire protection (Grant & Cote, 2006). Some of the requirements that relate to fire protection are provisions of exits for evacuation of occupants and enclosure of vertical openings such as stair and elevator shafts. Exit requirements in most building codes are based on requirements in NFPA 101, Life Safety Code.

Standards are requirements published by nationally recognized organizations (Grant & Cote, 2006). Codes use these standards as a basis for their requirements. These organizations include standards-making organizations, professional engineering societies

and federal agencies. Some of the organizations involved in the standard development process are represented in Table 2.2.

Table 2.2: Role of Organizations in the Standard Developing Process (Grant C.C. & Cote A.E., 2006)

Types of Organizations	**Function in Standard Development Process**
American National Standards Institute (ANSI)	It coordinates and harmonizes private-sector standards activity. It also represents the United States in some of its international standardization activities
Standard-Developing Organizations (SDOs)	They have the development of codes and standards as one of their central activities of missions. E.g., National Fire Protection Association
Scientific and Professional Societies	Their memberships comprise professionals in specific fields particularly engineering. E.g., American Society of Mechanical Engineers

2.1.5.1 Enforcement of Codes and Standards Nationally

Regulations relating to safety are determined and enforced by different levels of government (Grant & Cote, 2006). Model safety codes, such as building and fire codes, are developed through consensus-based processes by code development organizations, but they do not become laws until they are adopted by states and municipalities

Federal and state laws generally govern those areas that cannot be regulated at the local level. Federal agencies have the authority to promulgate these regulations only if granted authority by a specific act of Congress. Some of the U.S. govenment agencies involved in fire safety are the U.S. Fire Administration, U.S. Consumer Protection Safety Commission (CPSC), and the Occupational Safety and Health Administration (OSHA), but these agencies do not regulate building safety.

2.1.5.2 Enforcement of Codes and Standards by State and Local Governments

The regulation of building construction for the health and safety of the public is within the power of the state; however it is usually delegated to the local governments (Grant & Cote, 2006). Building codes mostly apply to new construction and major renovations. In most states, where they recognize the principal fire official as the State Fire Marshal, the State Fire Marshal charged by law with the responsibility for the enforcement of state laws relating to life safety and property safety in regard to fire.

The adoption of building and fire regulations varies at the local level in different regions (Grant & Cote, 2006). Local governments may have their own codes or may adopt state codes. In some states, the state has already set mandatory minimum requirements, which the local government cannot go below, whereas in other states, the local government has to adopt the state codes as they are. There is a minimum of a two-year cycle from the time that the model codes are drawn up at the national level to the time they are adopted locally.

2.1.6 Impact of Fires on Codes

The building codes are usually based on known material properties, hazards and lessons from past experiences, like fires and natural disasters (Grant & Cote, 2006). Throughout history, fires have changed the way buildings are built and maintained. Huge, deadly fires over the history of the United States have resulted in the development of and improvements to building and fire codes (Crowley, 2008). Investigation of major fires has led to possible solutions to some of the fire challenges being faced today.

In 1903, Iroquois Theatre, in Chicago, caught fire (Arnold, 2005, April). The fire resulted in 603 deaths, making it the deadliest single-building fire in U.S. history. The source of the fire was a short circuit in the footlights, which ignited the stage draperies. The fire burned for 15 minutes and was extinguished in 30 minutes. Most people were killed by smoke and trampling. It was later found that there were no extinguishers or fire hoses available, and some of the exits were either unmarked or blocked. This led to new limits on audience capacities. There were modifications made to the fire detection and fire suppression systems, exit standards and illumination as well as fire equipment.

A fire in New York City that occurred in 1911 at the Triangle Shirtwaist Factory killed 146 and injured 70. The building was a non-sprinklered, high-rise, garment factory. The fire burned through the building in less than 20 minutes. This tragedy led to the enforcement of fire codes for compulsory fire drills for buildings lacking sprinklers as well as mandatory sprinkler installation in factories (Arnold, 2005, April). The development of NFPA 101, Life Safety Code was another outcome of this fire.

In 1942, 492 people were killed in a fire that occurred at the Cocoanut Grove Night Club in Boston. Two hundred people died in front of two revolving doors; another 100 died, in front of the new Broadway Lounge exit (Arnold, 2005, April). Bodies were stacked on the doorways, preventing firefighter entrance for either rescue or fire suppression. Subsequent changes to codes required outward opening, hinged doors be installed to supplement revolving doors. The new codes required that exit signs be visible at all times and banned inward-swinging doors.

The Winecoff Hotel in Atlanta burned down in 1946 leading to the deaths of 120 people. There was only one staircase in the 15-story building. The internal location of the

stairwell allowed the fire to spread rapidly throughout the building (Arnold J., 2005, April). There were no fire detection, suppression systems, or fire escapes. This tragedy led to establishment and upgrade of safety codes across the country, which included requirements for fire escapes and sprinkler systems.

A fire occurred in Our Lady of Angels Grade School in Chicago in 1958. It resulted in 95 deaths. The stairwell had no fire doors, which led to spread of dense smoke to the corridors (Arnold, 2005, April). There was no sprinkler system. Illinois subsequently changed school fire code to require fire alarms directly linked to fire departments, automatic sprinkler systems, 1-hour enclosed stairwells and monthly fire drills. Eventually fire codes nationwide were changed to require sprinkler systems in schools.

In 1977, the fire at Beverly Hills Supper Club in Kentucky led to an overhaul of state fire code enforcement. Aluminum wiring was banned in places where it was not already prohibited (Arnold, 2005, April). The fire at Dupont Plaza Hotel in Puerto Rico in 1986 resulted in upgrades in lodging safety codes to address flammable furnishings, inadequate fire barriers, lack of automatic sprinklers, insufficient exits, faulty electric grounding and failure of alarms.

On February 20, 2003, a fire at the Station Nightclub in Rhode Island caused 100 deaths and more than 200 injuries (NFPA, 2008b). It became the fourth deadliest fire in U.S. history. The fire resulted in changes to NFPA 101, the Life Safety Code; existing night clubs with greater than 100 persons occupant load were required to install automatic sprinklers (Crowley, 2008). The International Building Code was also

modified to require automatic sprinklers in restaurants and night clubs with more than 100 occupants.

Currently the deadliest fire in U.S. history occurred at the World Trade Center on September 11th, 2001 (NFPA, 2008a). It resulted in 2,666 deaths and a loss of 39.2 billion dollars. The collapse of the World Trade Center towers led to a broad investigation into the design, construction, use and maintenance of buildings especially in reference to major fires and explosions (NIST, 2005, September). The National Institute of Science and Technology (NIST) issued an extensive report and recommendations as a result of their investigation of the fire. One of the modifications made to NFPA 101 required wider stairs in high-rise buildings or buildings with an occupancy of 2,000 people or more using the exiting system (Crowley, 2008). This allows for a two-directional flow system, which allows for responders moving upwards and occupants exiting downwards. The International Code Council's (ICC) Task Force for Terrorism in Buildings passed a code change that required a third stair in high-rise buildings exceeding 130 meters to allow firefighters to use the stair without impacting egress of occupants. This will be part of the 2009 International Building Code (IBC).

A fire that occurred in 2007 in an office building at 9343 North Loop East, Houston, Texas, led to the adoption of an ordinance requiring sprinklers to be installed in both new and existing mid-rise buildings up to six stories in height with atria (Crowley, 2008). The fire claimed 3 lives and caused many injuries including that of firefighters (Stiles & Lezon, 2007). The main concern was that fires in atria are difficult to control and could spread from floor to floor easily. The solution proposes containing the fire at its origin, because when it spreads to the atrium, it becomes almost impossible to stop.

These examples show that major fires have had a large impact on building design and construction. Our research takes a different approach to the fire problem; it involves investigating ways that new building technologies, specifically green design, impact fire safety, so that fires can be prevented before large-loss tragedies occur.

2.2 Green Building

Green building is a practice that uses designs and materials to make efficient use of natural resources, protect occupant health and improve employee productivity, and reduce waste, pollution and environmental degradation (US EPA, 2008). Buildings accomplish this by reducing energy and water consumption as well as by using recycled or recyclable materials that are non-toxic and have low toxic emissions.

The building environment has a large impact on the environment. According to the EPA, buildings account for 39% of total energy use, 12 % of the total water consumption, 68% of total electricity consumption and 38% of the carbon dioxide emissions. As a result, green buildings are becoming more marketable as they become increasingly efficient in all of these areas.

Many local authorities in the United States have passed laws that encourage the movement towards green buildings. Washington, D.C.'s, Green Building Act of 2006, which went in to effect on March 8, 2007, establishes new standards for "green building," applicable to both private and public projects in the nation's capital (Karush, 2006). The act requires compliance with the Leadership in Energy and Environmental Design (LEED), the US Green Building Council's (USGBC) rating system for green buildings. New York City's green building law, which went into effect on January 1, 2007, requires that capital projects with an estimated construction cost of $2 million or more, including

new construction and major renovations, comply with the LEED green building rating system.

There are numerous green building rating systems that provide a standard by which the performance of a green building can be measured (Fowler & Rauch 2006, July). Many types of rating systems worldwide focus on different areas in sustainable development; some of these rating systems include:

- Building Research Establishment's Environmental Assessment Method (BREEAM)
- Comprehensive Assessment System for Building Environmental Efficiency (CASBEE)
- GB Tool
- Green Globes
- Leadership in Environmental and Energy Design (LEED)

Currently, only two rating systems have a US-specific version, Green Globes US and LEED (Fowler & Rauch 2006, July). According to a study done by the University of Minnesota, the two rating systems have many similarities; each is based on four levels of achievement along performance categories that closely match at first view (Smith et al., 2006, September). However, there are some significant differences. The LEED system tends to be more stringent and focuses more on materials, whereas the Green Globes system is more flexible, and its main focus is on energy systems. Due to the fact that Green Globes is relatively new and has a smaller market penetration (Fowler & Rauch, 2006, July), our study will mainly focus on the more popular LEED system.

2.2.1.1 Green Globes Rating System

Green Globes US was adapted from Green Globes Canada in 2004. The system is owned and operated by the Green Building Initiative (GBI) (Green Globes, 2008). GBI

is an accredited standards developer under the American National Standards Institute (ANSI) and has begun the process to establish Green Globes as an official ANSI standard. GBI was originally modeled after the National Association of Home Builders' (NAHB) Model Green Home Building Guidelines as a way to make residential green buildings more mainstream (GBI, 2008). However, after GBI's adoption of the Green Globes system, they have been able to widen its scope to include commercial buildings. By 2006, four buildings had received Green Globes certification, and 63 buildings had been registered (Fowler & Rauch 2006, July). Certified green building are those that have achieved certification from a rating system to signify that they are green, while registered buildings are those hoping to achieve certification.

2.2.1.2 LEED Rating System

The LEED Green Building System, which is owned by the USGBC, was introduced in 1998. The LEED system provides a standard by which the sustainability of a green building's design can be measured. It is currently the most dominant rating system in the United States and is used as the green building standard by many local authorities. The US General Services Administration (GSA) requires all new GSA construction (federal buildings) to seek LEED silver status (USGBC, 2008). By 2006, there were a total of 3,356 LEED registered buildings in the US (Green Buildings BC, 2006, March).

LEED is used in many different types of construction, which can be seen in figure 2.2, below (USGBC, 2008). The USGBC makes this system available publicly on its

website through documents that provide guidelines to follow to achieve a sustainable design (Yudelson, 2008).

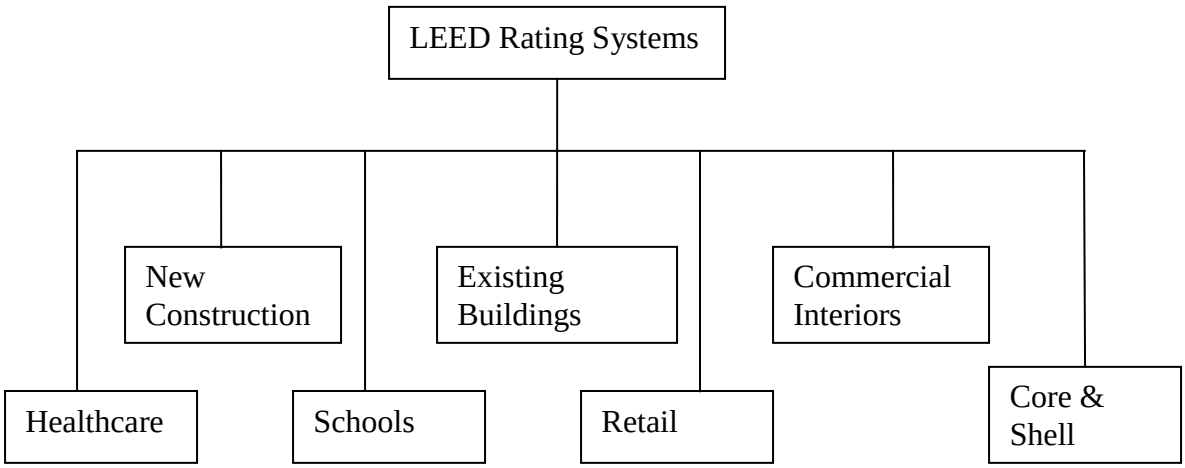

Figure 2.2: LEED Rating Systems (USGBC, 2008)

LEED is divided into five main categories, which include: sustainable sites, water efficiency, energy and atmosphere, materials and resources, and indoor environmental quality (USGBC, 2003, November). Each category contains a particular number of credits, and each credit carries a specific number of points. For the complete checklist of LEED allocation of points refer to Appendix 7.6.

Table 2.3: Distribution of points in LEED for New Construction (USGBC, 2003, November, p.10)

Category	Possible Points	% of total
Sustainable sites	14	20%
Water Efficiency	5	7%
Energy/ atmosphere	17	25%
Materials/ resources	13	19%
Indoor Environmental Quality	15	22%
Innovation	4	6%
Accredited professional	1	1%
Total	**69**	**100%**

Table 2.3, above, shows how points are distributed among categories. The sustainable site category mainly focuses on the location of a building (USGBC, 2003, November). This is in reference to the land use of the site, proximity to public transportation, preferred parking for carpool vehicles, limiting site disturbance, implementing a storm-water management plan, and installing vegetated roofs.

The water efficiency category calls for reduction of water consumption by 50% in the water efficiency portion (USGBC, 2003, November). It also gives points for treating wastewater and using captured rain or gray water for irrigation.

The energy and atmosphere section requires that all designs comply with standards put forth by the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) or a more stringent local code (USGBC, 2003, November). Another pre-requisite is zero use of CFC-based refrigerants in heating ventilation, air conditioning and refrigeration (HVACR) systems. Points are given for

reducing energy costs, installing HVACR and fire-suppression systems that contain no hydrochloroflourocarbons (HCFCs) or halons, and providing 50% of electricity from renewable sources over a two-year contract.

The materials and resources section allocates points for using 5% or 10% of salvaged or reused materials from the demolition site, using 5% or 10% of total value of reused materials and products and materials from post-consumer recycled content as well as 20% to 50% of materials that are manufactured within 500 miles of the area (USGBC, 2003, November).

The building must meet ASHRAE requirements in the Indoor Environmental Quality section (USGBC, 2003, November). Smoking is prohibited, but ventilated smoking rooms verified by tracer gas testing can be provided as an alternative. Points are awarded for installing permanent carbon dioxide monitoring system, using low-VOC (volatile organic compound) adhesives, sealants and paints, and achieving a Daylight Factor of 2% in 75% or 90% of all space occupied for critical tasks.

The points are then summed up and the total the building receives determines the level of certification (USGBC, 2003, November). The four levels of LEED certification are Certified, Silver, Gold and Platinum. The table below gives the certification levels of New Construction and their respective points.

Table 2.4: LEED Certification Levels (USGBC, 2003, p.8)

Rating	**Earned Points**
Certified	26-32
Silver	33-38
Gold	39-51
Platinum	52-69

2.2.2 Green Roof

A green roof system is an extension of the existing roof consisting of vegetation and soil, or a growing medium, planted over a water-proof membrane (US EPA, 2008c). Other layers that may be included are a root repellant system, and an irrigation and drainage system. Proponents of green roofs say they have many applications and benefits, which include storm water management, aesthetic value, energy savings on heating and cooling costs, and minimizing the urban island heat effect.

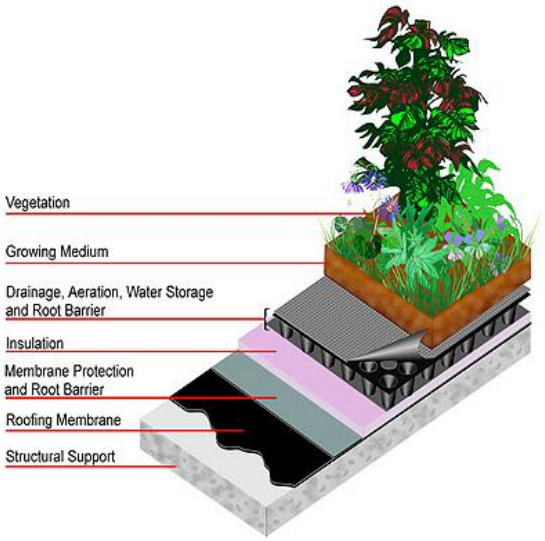

Figure 2.3: Layers of a Green Roof (LIDC, 2007)

Countries like Germany, France and Switzerland have made a great investment in to green roofs. For example, in Germany, 13.5 million square meters of green roofs were constructed in 2001, compared to 9 million square meters in 1994. However, this technology is not as widespread in the US.

2.2.3 Atrium

Atrium is a term that refers to an enclosed multi-storied space that is open vertically to multiple spaces (WBDG, 2005). Designers use them to incorporate several green attributes (Stauder, 2008). Advocates of atria in green buildings say that because atria bring in more natural daylight, they save on energy (WBDG, 2005). They say that atria also improve the quality of the indoor environment because they have a high aesthetic value, and they provide a connection to the outside environment.

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2.2.4 Case Study: An Example of a LEED Accredited Green Building

Clark University located in Worcester, Massachusetts, provides an example of a green building that has attained LEED accreditation (USGBC, 2007). The University's Lasry Center for Bioscience earned Gold Certification. The Center was designed to use 34% less energy than its equivalent conventional building (p.1). It has a triangular shape that maximizes southern exposure, and sun shades that enhance day lighting. The electric lights dim automatically when there is sufficient daylight, thereby cutting down on energy costs.

The Lasry Center also contains extra insulation and high performance operable windows that are used to maintain an optimum temperature in the building during the cold and warm seasons (USGBC, 2007). These materials are specifically selected for their environmental attributes. Eighty-seven percent of the wood used in the project met the Forest Stewardship Council standards for sustainable harvesting. All the paint used in the building met the Green Seal's standards for low volatile chemical content and all

carpeting met the Carpet & Rug Institute's Green label emissions criteria. In order to conserve water, the building reduced its use of potable water by 31%. It contains waterless urinals and low-flow bathroom and laboratory faucets.

The label below shows how the LEED points were awarded to each specific focus and how the certification was achieved.

Table 2.5: Clark University Lasry Center for Bioscience LEED Label (U.S. Green Building Council, 2007, p. 1)

2.3 Summary

It can be concluded that green building is fairly new to the building industry. It is also a technology that is quickly becoming mainstream and therefore inevitable. Fire safety is an important component of buildings to ensure the safety of the occupants as well as the property. Therefore, as the green building industry grows, the fire safety of these buildings needs to be researched in great detail.

3 Methodology

As stated earlier, one of the goals of this project was to provide the National Association of State Fire Marshals (NASFM) with recommendations to incorporate fire safety into green buildings. This chapter outlines the methods that were used in researching topics related to our project. In our research we used case studies, archival research, interviews, a survey, attendance at a symposium, and visits to green buildings to gather information on all of these topics. The following sections of this chapter will explain in detail our process of gathering information to ultimately make quality recommendations.

3.1 Awareness of Green Buildings by Fire Service Officials

Using contacts from the National Association of State Fire Marshals (NASFM), we sent out a survey questionnaire to State Fire Marshals. By contacting the State Fire Marshals, we wanted to determine their awareness of green buildings, if their approach had changed when dealing with green buildings versus conventional buildings, and if there were any aspects of green buildings that might help or hurt firefighters when trying to accomplish their jobs.

The survey questionnaire was designed to be brief, to encourage responses, but also contained open-ended questions to encourage them to share their experiences. Questions in the survey were focused on their experiences with green buildings and their concerns about dealing with them. The survey and the responses that we received can be seen in appendix C.

In addition to the survey, we spoke to the State Fire Marshals from California and Washington D.C. In these interviews we were able to probe further into their experiences

with green buildings. More specifically, our questions were focused on determining if there were any aspects of green buildings that could either help or hinder fire safety.

3.2 Role of Fire Safety in Green Buildings

A major part of our project was to determine the effect on fire safety of the designs and materials used in green buildings. In order to determine these effects, we gathered information from articles in magazines and from online databases, we interviewed experts in the field of fire protection, we visited local green buildings, and we attended a Fire Protection Research Foundation Symposium.

We contacted a professor at the Hong Kong Polytechnic University by the name of W.K. Chow who had written numerous papers on various designs in green buildings related to fire safety. While many of his papers were kept confidential by the Chinese government, he was able to give us a few of them. After reading these papers, we were able to identify some of the design aspects of a green building that are potentially dangerous in the case of a fire.

Semi-structured interviews were held with experts across the field of fire protection in order to determine the effects on fire safety of the designs and materials used in green buildings. Table 3.1 provides a list of our interviewees and their connection to the fire protection field. In these interviews we asked if they had any experience with green buildings. Based on the area of expertise of each fire safety expert, we then asked more specific questions that focused on either sustainable design or sustainable materials.

Table 3.1: Fire Safety Experts Interviewed in this Project

Name	**Date of Interview**	**Organization**	**Position**
Dr. Vahid Motavelli	November 6, 2008	George Washington University	Professor, Civil Engineering
Dr. Steven Spivak	November 11, 2008	Fire Protection Engineering, University of Maryland	Professor Emeritus
Dr. Jack Watts	November 12, 2008	Fire Safety Institute	Fire Protection Engineer, specialty in preservation of historic buildings
Dr. William Grosshandler	November 13, 2008	National Institute of Standard Technology	Deputy Director, Bldg. and Fire Research Laboratory
Dr. Margaret Simonson McNamee	November 18, 2008	SP Technical Research Group of Sweden	Research Manager
Philip Schaenman	November 20, 2008	TriData Corporation	Director

As a third approach in our research on the fire safety rules being used in green buildings, we examined green buildings first-hand. We visited several local green buildings in Washington D.C., listed in Table 3.2, to examine what fire safety techniques were being applied. During these visits, we were able to ask questions to our tour guides regarding the fire safety aspects incorporated into the designs.

Table 3.2: Green Building Visits

Name	***Date visited***	***Location***	***LEED rating***
Nusta Spa Services	November 6th, 2008	1129 20th St. NW Washington, D.C. 20036	Gold
Sidwell Friend's Middle School	November 7th, 2008	3825 Wisconsin Avenue, NW Washington, D.C. 20016	Platinum
American Society of Landscape Architects	December 4th, 2008	3636 I St. NW Washington, D.C. 20010	Green Roof (No rating)
United States Green Building Council Headquarters	December 11th, 2008	1800 Massachusetts Avenue, NW, Suite 300 Washington, D.C.	Platinum

As another approach in determining effects of green buildings on fire safety we attended the Fire Protection Research Foundation (FPRF) Symposium, entitled "Fire Protection and Safety: Preparing for the Next 25 Years," on November 17-18, 2008, at the Ronald Reagan Building in Washington, D.C. Panel sessions at the symposium dealt with environmental trends, sustainability challenges, and fire safety. Panelists included state and local fire officials, fire protection engineers, industry representatives, and sustainability experts from all around the world. Panelists discussed the future of fire protection, and brought up multiple questions involving green buildings and sustainability that will eventually need to be answered. The discussion and questions by these panelists displayed a general level of knowledge of sustainability that we used to determine their awareness.

Finally, we interviewed sustainability architects and assessed green building rating systems. We conducted interviews with a sustainability architect, and a sustainable building project manager, shown in Table 3.3, to determine the priority of fire safety during the design process of a green building. Our questions focused on fire safety techniques that they were incorporating into their buildings. These interviews, which can be seen in Appendix B, were used to identify any conflicts that they have had in their designs when dealing with fire officials.

Table 3.3: Green Building Interviews

Name	***Date of Interview***	***Organization***	***Position***
Robert S. Phinney	November 10, 2008	Wisnewski Blair & Associates, AIA, LEED	Director of Sustainable Design
Fulya Kocak	December 2, 2008	Davis Construction Corporation	Assistant Project Manager

Not only is the role of fire safety in green building design important to our project, but also the role of fire safety in green building rating systems, most notably the Leadership in Energy and Environmental Design (LEED) rating system. To determine fire safety's role in LEED we had to identify points that affected fire safety, and we had to determine if fire safety was adequately covered. Presentations from the Fire Protection Research Foundation Symposium were most helpful in answering these questions. Panel session 3, "Tomorrow's Sustainability Challenges and Fire Safety," discussed the role of fire safety in the LEED rating system.

3.3 Role of Model Building Codes

An important aspect of our project was to research model building codes, which are sets of recommended codes that a town or city can adopt as requirements in their jurisdictions to suit their needs. The model building codes are critical to the design of a building from both a cost and fire safety point of view, among other things. When we started this project, we had very little knowledge of how these codes were formed, who was involved, and how codes fit into the big picture, so we used interviews in order to fill this gap.

We conducted an interview with Ms. Allison Crowley, who is on the National Association of State Fire Marshals (NASFM) staff, and is responsible for coordinating NASFM's response to code development activities by the International Code Council and other code-making bodies. She was able to give us an overview of how codes are developed.

3.4 Summary

Our methodology describes the steps we took in researching awareness of green buildings by fire service officials, the role of fire safety in green buildings, and the role of model building codes. In our research we used case studies, archival research, interviews, a survey, attendance at a symposium, and visits to green buildings to come up with results about the aforementioned topics.

4 Results and Analysis

In this chapter we present our results, which include ways that green buildings successfully integrate fire safety, areas in which green buildings can conflict with fire safety codes, and the underlying reasons why these conflicts may arise. These results became basis for our conclusions and recommendations for the National Association of State Fire Marshals.

4.1 Materials Suited for Fire Safe Green Building

From our research we found that materials used in construction are a vital component of any building, and even more so for green buildings because of the desire to maintain a minimum impact on the environment. While many materials may have a high level of fire safety, they may be detrimental to the environment, and the converse can also be true. There are some materials, however, that can strike a balance between green building concepts and fire safety standards that are currently used in construction.

4.1.1 Insulated Concrete Forms

Insulated Concrete Forms (ICFs) are a simple system of forming the walls of a structure that are becoming more common in construction, an example of which can be seen in Figure 4.1. Because the foam forms remains in place after construction ICFs provide a high R-value, or insulation value, to the building, generally between R-17 andR-26. This pleases the green building movement, since more insulation translates into less energy used to heat or cool the structure. While some fire safety officials have expressed concern over having foam exposed to flame, many manufacturers have addressed this problem by either creating new foams that are flame resistant or covering

the forms in gypsum board, thus creating a suitable barrier from flame. Once these changes have been applied to the ICFs, the building is at least as fire safe as traditional construction.

Figure 4.1: Insulated Concrete Form

4.1.2 Straw Bale Construction

Straw bale construction is a method of building houses that has been used for thousands of years in almost all areas of the world, and the green building movement has also recognized the environmental benefits of building from straw. Since straw is a product that generally goes to waste, recycling it for use house construction would certainly be considered "green". The insulation properties of straw are also equal to or better than fiberglass insulation used in traditional construction. To achieve this, however, the walls must be considerably thicker than traditional construction, around 12", rather than 5-6" in traditionally built homes.

While most people do not think of straw as a fire safe material, it has been shown in experiments (Earth Times, 1994) that when properly coated with plaster, as done in construction, the straw is just as fire safe as a lumber and gypsum wall found in most buildings. It is vital, however, that the walls be properly coated with plaster, as seen in figure 4.2, otherwise flames could enter the wall itself and compromise the structure. Straw bale construction is not likely to be seen in large-scale building projects, but for a single-family residence it is a viable option that can be both green and fire safe.

Figure 4.2: Straw Bales coated with plaster

4.1.3 Timber Construction

With the increased use of new materials and designs in green building, it would seem that traditional construction methods are being pushed aside. New materials are said to be more energy efficient or less environmentally harmful, and so they are gaining more attention. Traditional construction practices are, however, still a viable option, which, if done properly, can be both environmentally friendly and fire safe.

Timber is still a commonly used construction material, more so in residential construction than commercial or high-rise buildings. Traditionally timber has been harvested by clear-cutting large areas of forest, which is not an acceptable method from

an environmental point of view. Today, however, timber is being harvested from sustainable sites, and there is a certification process to show that certain timber was harvested in a sustainable method, thus allowing it to be used in LEED-certified projects.

Timber is also a fire safe building material, due to its charring properties; if the outside of a piece of timber is in contact with flames, it will char and in effect insulate the interior of the piece, allowing it to maintain much of its structural integrity. This charring is generally a last resort during fire, since timber used for construction is covered by either gypsum or plaster, which acts as an additional fire barrier.

4.2 Sprinklers and Water Conservation

Fire sprinkler systems are a common form of fire suppression. According to the Home Fire Sprinkler Coalition, when sprinklers are used in conjunction with smoke alarms they can reduce deaths in homes by 82% (ARA, 2002). Many fire protection engineers argue that sprinklers are the most effective fire suppression systems available, and there has recently been a push to make them mandatory in all new homes. We did discover, however, that there are concerns with sprinklers related to water conservation.

During our interview with Robert Phinney, an architect and LEED specialist, the possibility of using gray water in fire sprinkler systems was mentioned as a way to recycle water. Gray water is non-potable water recycled from a building, usually from water used in sinks or washing machines that is used in some sustainable homes for watering gardens or other non-drinking water needs. He did mention that there could be problems with microbiologically influenced corrosion (MIC) or sediment buildup, both of which could shorten the life expectancy of the system and render it unable to suppress

a fire. Filtration is an option to remove the sediment and microbial life, but we found no system currently in use that can do the filtration needed.

Upon further researching the potential problems with a gray water suppression system, we discovered another issue related to water pressure: for a sprinkler system to be effective, it must have an adequate supply of water in order to maintain pressure throughout the system. Without enough pressure, the performance of the sprinklers will be severely compromised, thus compromising the structure in the event of a fire. If the sprinkler system's water supply was solely from gray water reclamation, it is possible that there would not always be enough water to maintain the needed pressure, especially after the system was flushed for routine maintenance.

After seeing the numerous problems that can occur in a gray water suppression system, we turned our research to traditional sprinkler systems fed off of the building's potable water supply. At a symposium we attended hosted by the Fire Protection Research Foundation, the idea of a traditional sprinkler system actually being green, despite its use of potable water, came up multiple times. It was stated that if a sprinkler system were not installed in the building, the building would likely burn down, thus releasing carbon and toxins into the environment. Even if the building did not burn down, it would likely take thousands of gallons of water for firefighters to extinguish the fire.

This statement is in line with a Scottsdale study, which concluded that on a single fire a sprinkler system would use an estimated 341 gallons of water, compared to a firefighter's hose, which would use about 2,935 gallons of water (ARA, 2002). Sprinklers most often contain and even extinguish a fire within minutes. Putting out a fire this

quickly avoids toxic off-gassing often associated with materials being burned, which in turn avoids the building having a large "carbon footprint." It can also avoid large amounts of materials that would end up in a landfill had the fire gotten the chance to expand.

4.3 Awareness of Fire Safety Community

Sustainable and green building practices have become increasingly popular in the past few years, a trend that will almost undoubtedly continue in the future. Because the concepts of green building are relatively new, most people have very little experience dealing with them. Based on our interviews with State Fire Marshals, it is clear that there is a lack of knowledge about green building in the fire safety community that needs to be addressed. This lack of knowledge is due to the fact that many fire officials have yet to deal with green buildings in their work, a point enforced by the results of a survey we sent out to the 50 State Fire Marshals pertaining to their interactions with green buildings.

This lack of knowledge is not to be thought of as one-sided, however. We found that the green community, for the most part, did not have an awareness of fire safety aside from the basics, such as sprinklers being mandatory in commercial buildings. The reasons for the lack of awareness are similar. Many LEED specialists do not deal with fire codes in their everyday work, so they are not familiar with fire safety issues. If there were increased communication between fire officials and the green building community, lack of familiarity would become less of an issue, and potentially there would be fewer conflicts during construction of sustainable buildings.

4.3.1 Definition of Green

We feel that there are several reasons for this knowledge gap, but we found that the most important was the definition of green. The definition of green can be altered to suit anyone's needs, so it becomes hard for fire officials, or anyone else interested, to find a solid working definition from which to base their research and education. This problem can best be seen by looking into the LEED rating system, the most common green building rating system in the US which gives points to different sustainable parts of the building. Since a building can gain points from a number of different features, the designs and materials used can vary greatly, and with them the definition of green.

4.3.2 Firefighting Practice and Green Buildings

In our research, we did not find any records of green building fires in the United States, so the application of traditional firefighting techniques is of concern to State Fire Marshals we have interviewed. Large atria can cause problems with the spread of fire, while green roofs and photovoltaic roofs can cause problems with venting. The Washington, D.C., Fire Marshal said that since all construction follows the same codes, the D.C. fire department has not changed its standard operating procedure to suit green building fires, but he admitted that they are not sure what to expect, and they plan to err on the side of caution until they have gained experience.

Being cautious at first is an essential step in the learning process, but we think that education of the fire service on the design and material characteristics of green buildings will prepare them to fight potential fires more effectively. Even though green buildings can vary greatly from one to another, an education program could still be developed that gave an overview of what makes green buildings different, and if need be, the course

could be altered to fit the needs of a specific fire service. We learned in our interview with the California State Fire Marshal that they are already educating the local fire services on the potential risks that photovoltaic roofs pose to firefighters. If courses like this were implemented across the United States, firefighters would know how to deal with green buildings in the event of a fire and therefore would still be able to work effectively.

4.4 Green Design and Conflicts with Fire Safety

From Section 4.1, it is clear that certain aspects of green buildings can, in fact, be compatible with fire safety without any increased impact on the environment. There are areas of green design, however, that have the potential to conflict with fire safety. These conflicts can be found in several different aspects of a green building, from its architectural design to the materials chosen for construction. While these issues are not always present in a green building, with the increased prevalence of green buildings it is more likely that these problems will arise more often, and they need to be addressed before they result in destruction of property during a fire.

4.4.1 Increased Use of Recycled Materials

As part of their effort to reduce the environmental impact of a building, many green architects and designers try to incorporate recycled materials into buildings, for both structural elements and finishing materials. If done properly, the incorporation of recycled materials should have no negative effects on the fire safety of a structure and also should not conflict with any codes. Concrete, for example, is common to almost any building project, namely for the foundation, but it can also compose the majority of the structure. Concrete is also a commonly recycled product, and has been so since before

the green movement called for recycling of materials. Once the concrete is recycled it still maintains its original properties and can be used on a new project, thus reducing the potential impact on the environment.

Other materials, however, may not maintain their original properties after being recycled, and this could affect the fire safety of a structure. From our interviews with Dr. Margaret Simonson McNamee, a research manager at the Technical Research Institute of Sweden, and Fulya Kocak, a project manager for Davis Construction, we learned that there is some concern about certain plastics being recycled; the question is whether these plastics, once recycled, maintain their original fire ratings, or are they severely degraded. If these materials are given a fire rating based on the original product (before it was recycled), this rating may not be correct, and therefore may not meet a jurisdiction's codes and present an unreasonable hazard in a fire.

Dr. Simonson McNamee also expressed concern over the uniformity of recycled materials; when some materials, such as plastic, are recycled, they are mixed with other types of plastic that may not have the same properties. This could affect their performance under fire, specifically by reducing the actual fire rating of the material. Even if a material is tested prior to its use in a building, there is no guarantee that the sample will have the same properties as the final product, again because of the mixing of different materials during recycling.

It is easy to see that recycling can have positive effects on the environment, but it can also do so for construction; by eliminating the need to collect more resources, the cost of production will go down, which in turn could lower the price of the material on the market. If the use of recycled materials is to continue, however, more stringent

testing, and also a closer inspection of their manufacturing must be done to insure that these products do, in fact, meet the requirements for safe installation in a building.

4.4.2 Removal of Flame Retardants

Flame retardants have been used for many years in both the structure of a building as well as in the furnishings, such as sofas. The introduction of flame retardants to a building greatly reduces the risk of a fire occurring, and in the event a fire does break out, they reduce the risk of flame spread throughout the structure. There have, however, been studies that show that some of the chemicals used in flame retardants can have a negative impact on health and the environment, leading some groups to call for the phasing out of these retardants.

The removal of flame retardants from buildings is of great concern to fire protection engineers and fire safety officials, because by removing the flame retardants it increases the fuel load in the building in the event of a fire. This concern was echoed during our interviews with Dr. Spivak and Dr. Simonson McNamee, both members of the NASFM Science Advisory Committee, who said that removing flame retardants is one of the biggest, if not the biggest, fire safety issue pertaining to green buildings. We also learned during our research that the LEED rating system prohibits the use of certain types of fire retardants, specifically those containing CFCs and HCFCs, in any construction that is trying to become LEED certified.

While it is clear that flame retardants do have benefits, their negative effect of certain chemicals on health and the environment also cannot be denied. There is, however, a point to be made for their continued use in structures; by preventing the outbreak of fire by using flame retardants, the negative environmental impact of a

structure fire and the resources used to rebuild can be avoided. This issue seems to be one where an agreement can be reached, simply by showing green advocates that while flame retardants may not be entirely green, the alternative of having a building burn down is certainly much less so. NASFM has called for additional research into the development of flame retardants and other ways of making products and materials more fire resistant without the negative impacts to health and the environment.

4.4.3 Effects of Roof Design

As discussed in Section 2.2.2 some green buildings have moved away from traditional roofing practices, opting instead to cover the roof in photovoltaic (PV) cells or installing a vegetated roof. While these new roofing methods are energy efficient and environmentally friendly, we learned from the Washington, D.C., and California State Fire Marshals that they pose potential problems with respect to fire safety, specifically access to the roof by firefighters. The standard operating procedure for many fire companies during a fire in a low-rise building is to cut ventilation holes in the roof for smoke removal. If the roof of a green building is covered in PV cells, it can be difficult for firefighters to safely move around on the roof, due to the slick surface of the cells. These cells may also make it more difficult for firefighters to effectively vent the structure. The cells, while used to create electricity for the building, should not pose an electrical threat to firefighters, because as we learned, in almost all cases firefighters shut off power to a building before attempting to do anything to fight the fire.

A green roof is typically about 6” thicker than traditional residential roof designs, but in commercial buildings the roof can be covered in several feet of gravel under the vegetation, which can pose difficulties for firefighters when attempting to vent the roof to

allow the release of built-up heat and smoke, permitting the firefighters to find and attack the fire. Green roofs may also pose additional hazards during a fire due to their structural integrity. While the roof would be designed to hold the additional weight of the soil and some water, this may not be adequate under fire conditions; firefighters spray thousands of gallons of water onto a structure, and with the soil being able to absorb much of this, it could add thousands of pounds to the loading on the roof. This increased weight could lead to a collapse much earlier than expected in traditional construction, potentially injuring firefighters inside the building.

Figure 4.3: Green Roof

4.4.4 Risks Associated with Atria

Atria are a common design element incorporated into building designs with the purpose of making use of natural lighting, creating open space, and allowing natural ventilation in a structure. Atria have been used in buildings for thousands of years and are now becoming increasingly popular in green buildings because the aforementioned benefits help to reduce energy costs. While these benefits help reduce the cost of a building's operation, there are certain risks associated with atria in a fire situation.

The main problem with atria is control of smoke during a fire since the high ceiling, as seen in figure 4.4, can act like a chimney, drawing smoke upwards and collecting it in the atria's upper region. This can be a hazard for several reasons; first among them, the smoke will hinder the vision of both those evacuating the building and firefighters coming in. There is also the issue of heat, since the high ceiling will create a chimney effect. It can also be hard to suppress fire in atria because the high ceilings can make it difficult to mount and maintain a sprinkler system.

Figure 4.4: Atrium

Using large ventilation fans mounted on the roof traditionally solved the problem of smoke, but this has become a problem with green buildings. To make use of natural light, many green buildings will incorporate skylights or light wells in their atria, thus limiting any mounting space for the fans. Also, these fans will consume large amounts of power, which could conflict with some building owners' idea of what "green" means.

4.5 Code Development Process

One issue that we found that could lead to conflicts between fire safety and green building practices is the fire code development process. From several of our interviews, we learned that there are several code developing bodies, with most of the development being done by the International Code Council (ICC) and the National Fire Protection Association (NFPA). As outlined in our background chapter, these code bodies create what are known as model codes, which are then modified by states and local jurisdictions to suit the needs of their communities. This period of modification, however, can take years to complete, with codes not being fully in use until at least two years after their publication. For example, we learned that Virginia is currently using the ICC 2006 codes, even though a new set of codes became available in 2008.

This delay in code development and adoption can have quite an effect on green building, particularly when incorporating new technologies and materials into construction. Technology is advancing so quickly that what may have been allowed in the 2006 codes has most likely been replaced by something new. This can become an issue during a building's inspection because the codes are prescriptive; that is, if the building does not incorporate what is written in the codes, it will not pass. These issues can be resolved using performance-based testing to show that the new materials meet or exceed the current standards, but this requires extra time and money, two vital resources in any building's construction.

4.6 Integrated Design Process

From our interviews with Robert Phinney and Fulya Kocak, a LEED architect and project manager respectively, as well as through archival research, we learned that the potential conflict between green building practices and fire safety could be avoided if the project team adopted an integrated design process. In an integrated design process, all parties involved in the construction of a building sit down in the initial design stages, look at the building plans together and voice their concerns over any aspects of the building. By pointing out possible conflicts before construction has even began, there is time to make the necessary changes to the plans and avoid wasted time and money during the actual construction of the building.

There are examples of projects in which an integrated design process was used, and in doing so a fire safe green building was achieved. The most notable example of this is the Genzyme Corporate Headquarters in Cambridge, MA. This building achieved a LEED platinum rating, the highest rating available, includes a 12-story atrium and still had no issues in code compliance because everyone was involved from the building's initial design. The fire code allowed for only a three-story atrium, but since Rolf Jensen & Associates were involved from the building's initial design phase, they were able to create a unique system of smoke shutters that would only close in an emergency. This was deemed to be within the code and still allowed the building to function as intended.

Another example of successful use of integrated design that we discovered is the Hearst Corporation Tower in New York City, a LEED gold-rated building. This building also made use of a large atrium, in this case seven stories. To achieve a fire-safe environment despite this large atrium, the Hearst Corporation consulted FM Global, an

insurance company, in the design stages of the building. FM Global pushed for the installation of twice as many sprinkler heads as required by code, simply because of the large area that needed to be covered. There was also concern over diesel generators, a common component of any high-rise building, specifically in relation to the risk of fire due to the large amount of diesel fuel available. To address this issue, a foam suppression system was installed along the fuel lines that would put out a fuel fire much more effectively than the standard water sprinklers.

4.7 Vision 20/20

In order to develop a comprehensive national strategy for fire prevention, the U.S. Department of Homeland Security awarded the Institution of Fire Engineers US Branch a Fire Prevention and Safety grant. The Institution of Fire Engineers US Branch used this grant to conduct research and then to produce a final report entitled, "Vision 20/20 National Strategies for Fire Loss Prevention."

Vision 20/20 contains five main strategy areas that were addressed. All five of these areas then have action items associated with them. These action items are proposed methods of the main strategy areas. While these strategy areas encompass a wide range of issues dealing with fire safety, a few of them in particular can be connected to fire safety in green buildings.

Strategy 1: "Increase Advocacy for Fire Prevention," deals with educating a increasing the awareness of the fire community. The fifth action item listed proposes the idea of developing an online clearinghouse for prevention activities, resources, and best practices. The clearinghouse would provide a place where advocates could go to view

programs that incorporate evidence based assessment that can establish effectiveness. Advocates would also be able to educate themselves on topics such a green buildings.

Strategy 5: "Refine and Improve the Application of Codes and Standards that Enhance Public and Firefighter Safety and Preserve Community Assets," deals with changes in codes, and fire safety in relation to the environment. Action item 5 under this strategy suggests the idea of promoting fire codes within sustainable structures and "green buildings." In order to achieve this, action item 5 calls for collaboration with green rating officials to ensure compatibility with fire codes, and also to clarify that sustainable building design cannot conflict with the goals and intent of the fire code.

4.8 LEED and Fire Safety

As noted in our background chapter, the LEED rating system has become the most popular standard for green buildings, especially in government organizations like the General Service Administration. As states adopt LEED as the standard for green buildings, it is necessary for fire officials to closely analyze the LEED rating system. From our interviews with green building architects and building contractors, it became apparent that LEED does not offer any incentives for fire safety. Therefore, green buildings only meet the basic building and fire code requirements. However, Fulya Kocak, a green building project manager pointed out that building and fire codes take precedence, if a particular aspect of green design does not meet the code requirements.

During the Fire Protection Research Foundation (FPRF) Symposium, Jonathan Hall from FM Global noted the fact that LEED has 27 credits that pertain to fire safety.

One-third of them coincidentally promote fire safety and the other two thirds have possible conflicts but can improve fire safety if properly applied.

4.8.1 Environmental Tobacco Smoke (ETS) Control Required

One of the requirements of LEED in the Indoor Environmental Quality category is the prohibition of smoking in the building or provision for a space that is well ventilated as specified by the rating system (USGBC, 2005, October). The intent of this credit is to minimize exposure of occupants to smoke. Prohibition of smoking in a building is a step towards fire safety, as it eliminates cigarettes, a common ignition source.

4.8.2 Enhanced Refrigerant Management

The Energy and Atmosphere Credit 4, Enhanced Refrigerant Management prohibits the use of fire suppression systems containing ozone-depleting materials (CFCs, HCFCs and Halons) (USGBC, 2005, October). The fire suppression industry has supported this measure for years by offering a variety of "clean agent" systems in addition to the more common water, foam and carbon dioxide fire suppression systems (VanBuskirk, 2006). From the FPRF Symposium's panel session on "Tomorrow's Sustainability Challenges and Fire Safety," we noted that the fire safety community has been conducting research on fire suppression systems that are environmentally friendly. In this way both aspects of green and fire safety can be synchronized while constructing a building.

4.9 Summary

This chapter outlines what we have found in our research of fire safety in green buildings. Using our results concerning designs and materials used in green buildings, sprinklers, awareness of the fire safety community, green building rating systems, and fire and building codes, we then made conclusions and recommendations, discussed in the next chapter, to the National Association of State Fire Marshals (NASFM).

5 Conclusions and Recommendations

Through review of information we gathered from our interviews with professionals involved in the green building movement, as well as fire officials and fire protection engineers, we have identified potential problems and opportunities with fire safety in green buildings, as outlined in Chapter 4. This chapter contains our conclusions based on these results, as well as a list of recommendations we have drafted for the National Association of State Fire Marshals.

5.1 Conclusions

By reviewing our results, we came to several conclusions about the different aspects of fire safety in green buildings. These conclusions are grouped into four major categories that we feel need to be addressed, as reflected in our recommendations.

Fire Safety and Green Design

- Fire prevention can be considered "green" due to the natural resources saved by preventing a fire.
- LEED offers no incentives to incorporate fire safety, allowing the bare minimum to be incorporated.
- The increased use of recycled materials could cause issues in the future, specifically in relation to the materials' fire rating.

Education and Awareness

- Green experts have a lack of knowledge concerning fire safety, due to a lack of involvement in the code process.
- Fire officials and firefighters are unaware of what makes green buildings different, due to a lack of interaction and experience with green buildings.
- There are jurisdictions educating firefighters about the potential hazards of green buildings, but no effort has been made to make these programs national.
- There is no solid definition for what makes a green building, which could lead to confusion from the side of fire officials.
- There is no mechanism for capturing incident data to indentify fires that may occur in green buildings.

Integrated Design Process

- Integrated design has been proven effective in designing a fire safe green building.
- By using integrated design, there is increased communication among involved parties, leading to fewer conflicts.

Code Acceptance

- The slow process of code adoption renders many codes outdated by the time they are fully adopted in all jurisdictions.
- Green technology is evolving rapidly, and is steadily outpacing the codes.

- This problem is a reality that needs to be worked with, as the process of code modification for local jurisdictions is necessary to ensure fire safety.

5.2 Recommendations

In order to promote fire safety in green buildings we formulated several recommendations for the NASFM. Based on our conclusions we recommend that the NASFM needs to focus on educating the entire fire community about green buildings, and the entire green building community about fire safety. The following section describes ways to do this.

Recommendation 1: That NASFM adopt a definition of green building as "a practice that reduces a building's negative impact on the environment and human health through reduced use of natural resources, as well as ensuring adequate fire safety so as to create a truly sustainable site".

This definition of green differs from the existing definitions by including the aspect of fire safety. As we discovered in our research, a building burning down has a tremendous impact on the environment, from both wasted natural resources and harmful emissions such as carbon monoxide. Because of this it is safe to say that fire safety is a green practice, and should be recognized as such.

Recommendation 2: Have fire officials collaborate with green rating officials to ensure that fire safety is incorporated in green building rating systems.

Fire safety can be incorporated into green building rating systems in two different ways. They can add a new section that awards points for fire safety measures, or review

points that have previously been awarded to make sure that they do not conflict with fire safety.

Recommendation 3: Educate fire experts and the fire service about green buildings and the potential conflicts of fire safety in the buildings that they might come across.

One way the NASFM can educate fire experts and the fire service is to support action item 5 of strategy 1 in the Vision 20/20 National Strategies for Fire Loss Prevention, which is mentioned in Section 4.7. Using a clearinghouse for fire safety in green buildings would help educate everyone in the fire community. Using the clearinghouse, firefighters would know how to approach a fire in a green building, and fire protection engineers would be able to effectively incorporate fire safety into them. This education can also be done through a nationwide training program for fire departments, in which the application of traditional firefighting methods to green buildings can be evaluated, as well as training for state and local code enforcement officials.

Recommendation 4: Green building construction implements an integrated design process.

The integrated design process has proven effective in building a fire safe green building. By using integrated design conflicts between sustainability and fire safety can be resolved successfully, provided a code official or fire marshal who is educated to the problems and opportunities of fire safety in green buildings is involved.

Recommendation 5: Incorporate green building designs and materials in building and fire codes.

While it may not be feasible to speed up the code process so that it could incorporate green building designs and materials immediately, it would be helpful if they were incorporated as quickly as possible. This could happen by setting up a group in the code formulation process to track developments in green design. Also, it would be helpful if local governments could adopt the most recent model building and fire codes available as developed by the International Code Council or other code developing body.

Recommendation 6: Develop a system through which State Fire Marshals can track fires in green buildings.

As of now there are no documented fires in green buildings. This may be because they are more fire safe, or because they make up such a small percentage of buildings in the United States, or because the advent of green buildings is still so recent that there have not been opportunities for fires to occur in these buildings yet. Green building is growing, however, and it will continue to do so into the future. By incorporating a way to track fires in green buildings into existing fire incident data collection systems, fire officials will be able to look at the number of fires in green buildings over the course of several years, and will be able to see if the trend of fires occurring in green buildings is more so than that in traditional buildings, indicating a fire safety issue with green building practices.

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Appendices

Appendix A: National Association of State Fire Marshals

The National Association of State Fire Marshals (NASFM) is a private, not-for-profit organization made of senior fire officials from all 50 states. Their mission is to protect human life, property and the environment from fire, and also to improve the efficiency and effectiveness of State Fire Marshals' operations (NASFM, 2008, Mission). The issue of fire safety is of great importance in the United States, with fire claiming 3000 lives annually.

State fire marshals are senior fire officials in their respective states, generally having worked their way up from the rank of firefighter. The duties may vary slightly from state to state, but a fire marshal's main job is the enforcement of fire codes. This enforcement is done through building and fire inspections, of both existing buildings and new construction.

While there are voting members in the NASFM, the overall governing body is its Board of Directors. The current board positions are president, vice president, past president, secretary/treasurer, and 4 general board members. This Board of Directors, along with every member of the NASFM, has several resources to get their message out to the general public. The first and most simple method is public education. The NASFM helps educate the public about fire safety through newsletters, pamphlets, and other print resources.

The NASFM also has several subcommittees, one of which is the Science Advisory Committee (SAC). The SAC works with the NASFM by "formulating positions and making political decisions by providing sound scientific and technical

background and advice on issues as requested" (NASFM, 2008, Science Advisory Committee). The SAC is composed of professionals from both the public and private sectors who have an area of expertise, such as fire protection engineering or risk assessment. These professionals serve three-year terms on the SAC, during which they work on projects assigned by the NASFM Board of Directors. These projects all focus on the issue of fire safety but can be quite different in their goal, with projects covering such broad topics as fire safety of cigarettes to quality control of automatic sprinkler systems.

Appendix B: Interviews

Interviewee: Prof. Vahid Motavelli, Prof. Civil Engineering- George Washington University

Date: 11/06/08

Time: 9:00 PM

Location: Residence Inn Lounge

This was an informal conversation between our project team, Prof. Motavelli, and Prof Pahlavahn.

Motavelli: The first thing to keep in mind for fire safety of any structure is the fire triangle; for a fire to occur there must be fuel, and oxidant, and a source of ignition. Common sources of ignition in a building can be wiring, cooking, smoking, etc.

We then discussed different methods of fire detection.

Motavelli: There are many different types of smoke detectors; there are ionization, light scattering, diffused infrared, and aspiration detection systems all of which can be applied to most buildings. All of these can be applied to an atrium in a green building, even though there is a high ceiling.

The conversation turned to fire suppression.

Motavelli: For a building to be green, it certainly wouldn't use Halon1301 or carbon dioxide for fire suppression, seeing as these gases are harmful to the ozone layer. Fire sprinklers should still be used, but with a dry pipe system. Another alternative being

used frequently is a mist system, which uses much less water than traditional sprinkler systems.

Diana: Do you know of anyone we should contact who may be able to help with our research?

Motavelli: The National Institute of Standards and Technology has a whole division for building fire safety, so they should be able to help. Also the Society of Fire Protection Engineers should give you access o a lot of literature on the subject. Also Jim Milke, a professor at the University of Maryland in the FPE department would be very interested in your project.

The meeting concluded with Prof. Motavelli telling us that green design was not just one step in a process, but should be considered at every step in construction of a building.

Interviewee: Robert Phinney AIA, LEED- Wisnewski, Blair and Associates

Date: 11/10/08

Time: 9:00 AM

Location: Wisnewski, Bair and Associates- Alexandria, VA

Diana: Have there been any major setbacks in getting the fire safety community to accept green building design?

Robert: There aren't any major points of conflict, the fire safety industry has been accepting of green designs and are very open-minded towards new ideas. There are however, conflicts with the fire marshals, because they see the codes as either black or white; there is no middle ground.

The biggest issue is the lag from when new codes are written to when the state (Virginia) puts them into practice. We are currently using the USBC 2006 codes, even though there was a new set written this year. This lag makes it hard to use new technologies, such as new roof coatings that have been recently developed.

Lyle: Are you aware of any instances where green building design increased the fire safety of the structure?

Robert: I don't know of any specific buildings that have increased fire safety, but many aspects of green building can increase the fire safety of a structure. The most important factor is what materials are used in construction. Some green construction makes use of ICF's, or insulated concrete formworks. Since concrete burns at a much higher temperature than traditional timber frame construction, it is obviously safer in a fire.

Another fire safe material that is not as obvious is the use of straw bales in construction. When done correctly straw bale construction has a high insulation value and also a high fire rating. Straw bale construction is becoming more common for "do it yourself" sustainability.

Diana: Have you run into any problems in the use of gray water fire suppression systems?

Robert: The use of sprinkler systems in commercial structures is certainly critical to fire safety, even though it can come into conflict with the idea of sustainability. As they are used now, sprinkler systems use too much potable water, which is why gray water is becoming an alternative for these systems. If gray water is used, however, it must be filtered to reduce the risk of corrosion or sediment build up. One possible was to reduce the risk of pipe corrosion would be to use a dry pipe suppression system, again using filtration before the water goes into the pipes.

Sean: Are you aware of the green model codes that are currently being developed?

Robert: Yes, we are aware that there are new codes being developed for sustainable sites. I haven't seen anything specific form them yet, so I don't know how well they are going to work. One concern is that codes are the bare minimum; developers will do just what the codes say, but not go any further in order to save money. Ultimately its up to the manufacturers to make their components to a higher standard than what the codes seek, so then developers will have to use those products.

The interview then became semi-structured, covering topics we hadn't initially planned to cover.

Lyle: What are some components of current construction that go against the idea of sustainability?

Robert: One of the biggest problems still found in many buildings, particularly server or computer rooms, is the use of Halon1301 for fire suppression. It is a gas known to deplete the ozone layer and is currently being phased out by law, but the government standards are too lax. Buildings continue to install these systems under variances, saying that they don't have a viable alternative for fire suppression in these buildings.

Also, many buildings are still using oil-based paints. Even though these paints aren't manufactured anymore, painting contractors can still purchase them form warehouses that have a large stockpile of these paints in storage.

Diana: Why do you think it is that Europe is so far ahead of the U.S in terms of building sustainably?

Robert: The U.S. uses 25% of the world's natural resources each year, and it just seems that people think we have an unlimited supply of these resources, and see no need to conserve. In Europe, and in most of the world, people just don't see it that way. They have been reusing old buildings and materials for centuries, long before ideas of sustainability became mainstream. In America people tend to not worry about the long term; we have enough resources for now, so they see no need to spend extra money to save resources for tomorrow.

There are also regional differences within the U.S.; California, for example, has been building sustainably for years. This is due somewhat to Title 24, an energy conservation bill, but also due to the mentality of those living in California. They seem to be more willing to try new technologies, whereas other regions of the U.S. tend to hold onto old practices.

Sustainability is a long term plan, so communities that have a high turnover rate in population, such as Washington D.C., tend to have a harder time getting residents to build green. D.C. seems to be an exception to the rule, but for the most part if someone is living in a house for only a few years they don't see the reason to put in a system that may not payback for 12-15 years, such as photovoltaic cells.

Lyle: How easy is it to keep communication open between all the entities involved in sustainable construction?

Robert: Keeping communication open is key, since it will save time and money in the long run. If the architect, building owner, and engineer can all sit down in the initial design process, it will save any confusion during construction and also prevent anyone from having to redraft plans multiple times because of conflicts that come up.

It also helps if the architect is knowledgeable in the construction process as a whole; if they know about codes and the engineering behind a building, they can design their part around it, making it easier down the line for each other person involved.

Sean: What are some topics that tend to be avoided during planning of sustainable sites?

Robert: Cost is usually a topic you don't want to bring up, because people have an idea that sustainable building costs much more than traditional construction. The truth is that most buildings can be built to a LEED certified level with no extra cost incurred to any party. Problems of cost arise when there is poor communication on the site, and the same tasks need to be done and then redone. If communication is kept open, there are no extra costs for basic sustainability. To gain a higher level of certification will cost more money, but those interested in that certification generally know about the costs beforehand.

Diana: How do you promote ideas of sustainability to town officials that may be unsure about making the change?

Robert: There are two strategies that I have found to work well, the first of which is education. If the municipality can commit to a certain goal, we can educate them on how to achieve it. This approach eliminates any confusion on their part about exactly what is involved in building sustainable structures.

The second approach is by going through the waiver process; if a new material or design is being sued that may not comply with the current codes, it is good to sit down with the officials and show them that while it may not fit exactly with the code, it meets or surpasses the guidelines already on paper. The officials know that there are better materials and methods of construction out there; they just want to know why they are better. Once they understand the facts behind it, they will generally change the codes.

At this point the interview ended, and we asked if he knew anyone else we could contact. The list included a commissioning agent, an MEP engineer, and several county officials.

Interviewee: Dr. Steven Spivak, Professor Emeritus, University of Maryland- Fire Protection Engineering Department

Date: 11/11/08

Time: 2:30 PM

Location: Phone Interview

This was a discussion about our progress on the project, as well as possible sources of information

Spivak: I was the former department head of Fire Protection Engineering at the University of Maryland, with a concentration in clothing and furnishing flammability. It's a little outside the scope of your project, but there may be some application in respect to how green buildings are furnished (i.e. recycled furniture/materials). I've also been a consultant in the cleaning industry for many years, and there has been a recent surge in interest towards environmentally friendly cleaning practices, which is certainly something that the owners of LEED certified buildings would have interest in. The U.S. General Service Administration, which runs all aspects of green buildings, has also been taking an environmentally friendly approach to cleaning all of their buildings.

Green Flame, a certification program ran by Margaret Simonson, has been testing materials that are both environmentally friendly and fire safe. It would be interesting for you to look into what they've done so far, as it may be applicable to your research.

Another issue that has come up recently is the environmental impact of fire retardants; while they may cause long-term environmental harm upon breaking down, they prevent fire in the short-term. There are people who feel strongly on both sides of

the issue, and both sides have validity behind what they say. What really needs to be done is to create flame-retardants that cause little to no environmental impact.

Diana: Could you provide us with a list of potential contacts?

Spivak: I think some good companies and organization to contact would be Green Guard Environmental Certification, the International Code Council, and Rolf- Jensen and Associates. Also, contacting the NFPA and NIST would be helpful. Any colleges in the area that have schools of Architecture may have professors who specialize in sustainability, and they would be willing to talk to students about their work.

The interview concluded with Dr. Spivak giving us several contact in the aforementioned agencies.

Interviewee: Allison Crowley, National Association of State Fire Marshals

Date: 11/12/2008

Time: 1:30 PM

Location: NASFM Office

This was a basic overview of the code process

Allison: One of the biggest issues with code development and adoption is the fact that it takes a while. The model codes are developed by the ICC or another organization, and then passed down to each state. The states can then make task forces to reconcile any issues they see within the codes, either to make them more stringent or to alter them altogether. This process of modifying the codes varies from state to state, but in general after it is modified at the state level, it is passed to the local jurisdictions that can make further changes as they see fit. Because all of these changes to the codes take time, the codes may already be 2 or 3 years old when they are finally adopted and put into law.

Currently the ICC is developing set of codes for green buildings, but I don't know any specifics of it yet. I do know, however, that they are working in conjunction with LEED and the National Association of Home Builders to develop these codes.

Two of the biggest potential issues I can see in green buildings are the lack of flame retardant and green roofs. Flame-retardants are being removed because they are not environmentally friendly, but doing so increases the risk of fire in the structure. And

as for green roofs, it isn't known how they will perform under fire conditions; that is, will the vegetation act as an extra fuel load, will the soil cause the roof to collapse, etc. If the green codes address these two aspects properly, any potential risks could be eliminated.

Interviewee: Dr. John Watts, Director- Fire Safety Institute
Date: 11/12/08
Time: 2:30 PM
Location: Phone interview

Lyle: Is the green movement affecting fire safety?

Watts: As of now I don't think it is affecting fire safety too much, but as the green movement continues to grow its impact will certainly increase. Fire safety and its affect on the environment wasn't an issue until about 20 years ago, when there was large fire at a chemical plant in Germany. The chemicals stored there, as well as those used to douse the fire, ran off into the Rhine River, causing a large fish kill. There was also a warehouse fire in New Jersey around that time that brought more attention to the environmental impact fire can have.

The interaction between fire safety and green building design, however, is pretty new. There hasn't been too much research into the field, although the Fire Protection Research Foundation did do a study that looked at LEED designed buildings and how they would perform in fires from a structural engineering point of view. There really hasn't been a true integration of green building and fire safety as of yet.

Lyle: Do you know of anyone documenting the potential problems of green building fire safety?

Watts: There was a paper published that voiced some concerns about sustainable architecture not taking fire safety into account. A good example of this would be straw bale construction; if done properly it will be as safe as traditional construction, but if the walls aren't sealed adequately it is a huge fire risk. There is also research into the

environmental impact of certain materials burning, but this research isn't specific to green building materials.

Also, there was research done on prevention of fires in historic buildings due to the potential for harmful chemicals in an old structure (lead paint, etc). Again, this is not specific to green buildings, but to fire safety in general.

Diana: Do you know of any good introduction to fire safety books that we could use for research?

Watts: The library the National Institute of Standards and Technology would certainly be a useful place to find books on fire safety, both basic and advanced.

The interview concluded with Dr. Watts giving us the names of two contacts at the National Fire Protection Agency.

Interviewee: Gary Palmer

Date: 11/13/08

Time: 3:45 PM

Location: Washington D.C. Fire Marshal Office

We started by giving an overview of what our project entails and some additional background information

Palmer: The influence of the fire marshal on Washington DC has mainly to do with permitting of buildings. We come in early during the building process and make sure that fire codes are being followed. After that we also come in for routine building inspections, but again we only focus on the fire codes.

Lyle: Have you had any experience with green buildings in the DC area?

Palmer: We haven't dealt with any buildings that were "green" to our knowledge, but since we deal with any new construction we probably dealt with them without even knowing they were "green". We'll certainly be dealing with green buildings more in the future though, since it's becoming quite a hot topic today.

We haven't run into any conflicts with green buildings and fire safety, since all construction follows the same codes, be it a green building or not. Overall, a balance must be met in which the environmental impact is reduced but the occupants are still safe. Two areas of potential conflict that I know of are the phasing out of fire retardants, and

also green roofs. We don't know how a green roof will perform under fire, and it may be a hazard to firefighters inside the building.

Fire marshals aren't involved at all in the green building process; we just go to a building and evaluate it regardless of if the building is green.

Lyle: Is the fire service as a whole aware of the green building movement?

Palmer: In DC we haven't had any issues with green buildings yet, so we haven't changed our education programs yet. The fire service is aware of the green movement however; we are currently in the process of "greening" several of our firehouses by installing new lighting and conserving water.

Diana: Do you think there is a lack of communication between engineers, architects, and fire safety officials during the building process?

Palmer: there are definitely times when more communication is needed. Most conflicts during construction occur simply because there isn't enough communication between all the parties involved. If there were occasional meetings between engineers and fire officials, not for any specific building, it could help eliminate any conflicts before construction even started.

Sean: Have you seen an increased use in mist sprinkler systems in an effort to conserve water?

Palmer: Water mist systems are a touchy subject for a lot of people. Some advocate them for water conservation, but others just want to put fires out with traditional higher

volume sprinklers. I think that they would be fine to use in residential buildings, that is one or two family dwellings, but in high rises traditional sprinklers are still preferred.

Interviewee: Dr. William Grosshandler, Deputy Director, Building and Fire Research Laboratory, National Institute of Standards and Technology

Date: 11/14/08

Time: 11:00 AM

Location: National Institute of Standards and Technology (NIST)

Lyle: Are there any flaws that you know of present in green buildings?

Grosshandler: A big issue with green buildings has to do with their furnishing and finished materials, since those involved in green building want to remove fire retardants for environmental reasons. Other materials used may also pose problems, such as cellulose insulation, since it isn't fire safe and may increase the fuel load during a fire greatly. They are also replacing fluorocarbon HVAC fluids with new hydrocarbon alternatives, which again increases the fire hazard in the building.

Diana: Are there any fire suppression systems being developed that are both effective and "green"?

Grosshandler: There is an alternative to Halon1301 called FM200, which has much lower risk for ozone depletion. Sprinkler systems are also environmentally friendly, since they reduce the risk of a building burning down and releasing toxins into the environment. Water mist systems, while difficult to design, can be effective in confined spaces, such as around machinery, or in places where there is liquid fuel present.

Lyle: Have you looked into the possible effects of a grey water fire suppression system?

Grosshandler: There is the risk for corrosion of the pipes due to MIC, but these can be solved with proper engineering. The problem is that the green designers don't take the time to do this engineering, which results in issues later on.

Sean: Are there any positive effects green building has on fire safety?

Grosshandler: Green building doesn't affect fire safety negatively too much, since codes must still be adhered to. Aside from removing fire retardants from furniture, there aren't any real issues. Green roofs may actually have a positive effect on fire safety, in that it could hinder the spread of fire from one building to those adjacent to it.

Lyle: Does there need to be a change in the way firefighters handle fires to get around issues associated with PV and green roofs?

Grosshandler: Fires don't need to be fought from the roof down; it can be done in other ways. Fire officials can change their standard operating procedure if need be, they just choose not to. If green roofs and PV roofs really catch on, they will eventually change their procedures and still fight fires just as effectively.

Interviewee: Fulya Kocak, Project Manager, LEED AP, James G. Davis Construction Company

Date: 12/03/08

Time: 12:30 PM

Location: Davis Construction Office, Rockville, MD

Diana: Have there been any setbacks in getting the fire safety community to accept green building?

Fulya: There are certain aspects of fire safety that don't fit into line with green building, such as the use of HCFC's and CFC's in fire suppression systems. Currently, the green building movement isn't really concerned with fire safety, because under the LEED rating system no extra points are available for incorporating fire safety measures.

One product being used that satisfies both the green building movement and fire safety is the use of low VOC adhesives; they are better for the workers and residents of the building because they emit less harmful toxins, and also release less of these toxins during a fire, which is better for the firefighters. From a construction side, however, these adhesives aren't as effective as those traditionally used.

Lyle: When constructing a green building, are there any conflicts with the existing building codes?

Fulya: As I said before, green buildings tend to not focus on fire safety, but hey are still built to the jurisdiction's codes; for example, all commercial construction in the D.C. area

must be fitted with sprinklers. As long as the codes are followed, we shouldn't have any conflicts.

There are conflicts in some cases where new technologies are being incorporated into a building, be it something large or something hardly noticeable. An example of a small conflict happened in one of our projects; we were installing two flush toilets, and the code official had never seen on, so he was wary. Conflicts like these, however, are easily fixed by showing the official that the new technology is effective.

Sean: Are you aware of any problems with vegetated or photovoltaic roofs related to fire safety?

Fulya: There shouldn't be any issues under fire conditions; it would be comparable to a traditional roof. The roofs are designed to withstand the extra weight of soil or the solar cells, and there are always walkways (in our projects) incorporated onto the roof. Firefighters would still be able to move around on the roof if they had to. Also, there are drains in a vegetated roof, so waster drainage from firefighting shouldn't become and issue either.

Lyle: Is the green movement becoming more generally accepted today?

Fulya: Green building practices are definitely more accepted today than just a few years ago. Many areas are now requiring sustainable building practices, not necessarily LEED building practices, but just more energy efficient homes and less environmental impact.

Sean: With other rating systems available, why has LEED become the most popular?

Fulya: LEED has become so popular because it was successfully marketed, and it also covers more aspects of the building process than other rating systems do. Even LEED at first wasn't very popular, but it caught on, becoming more and more popular.

Diana: Are code officials becoming more interested in the green movement?

Fulya: I have been to meeting about green building where code officials were present and interested in what was being said, but I think for the most part they will be forced into learning. If a jurisdiction mandates sustainable building practices, the officials will have to learn what sustainable building is in order to do their job successfully.

Diana: Do you see any issues with the green movement that could affect fire safety?

Fulya: The increased use of recycled materials could become a fir safety issue, because with a lot of materials you don't really know what you are getting. If the materials have been processed in the recycling, they may have lost their original properties. It is clear that a lot of people care more about the recycled content than the fire safety of a product.

Sean: Are there benefits to using an integrated design approach in a project?

Fulya: Integrated design definitely makes it easier to get everyone involved on the same page, especially when it comes to what materials are going to be used and why. With large construction like we do, however, it is hard for this to occur because of the bidding process. Most projects are already somewhat set in their plans by the time we enter, but we can advise changes that we see fit.

Lyle: Why are building owners becoming more willing to send extra money to make their building green?

Fulya: I think that most building owners are going green simply for marketing; if someone wants a green home or office, they would be willing to pay more for it since there aren't as many. There are building owners who do care about the environment, but again its mostly for marketing to their tenants.

Interviewee: Margaret Simonson, NASFM Science Advisory Committee Chair

Date: 12/05/08

Time: 3:00 PM

Location: Phone Interview

We began by giving some background about ourselves, and the progress of our project

Lyle: Have you had much success with the Green Flame certification program?

Margaret: Green Flame was a certification system originally developed by the International Consortium for Fire Safety, Health and the Environment. The programs goal was to look for fire safe green products. It wasn't really well marketed, however, and not many people are applying to have their products certified. Also, many companies don't seem interested in being both green and fire safe; they tend to pick one of those aspects and focus on that specifically. We have tested several products, but as for ones that may have failed, the testing is confidential and can't be released.

Lyle: Are there any other programs that you have been involved with that relate to fire safety and its environmental impact?

Margaret: There was a life cycle assessment of products that we conducted, which looked at the environmental impact of a material from the cradle to the grave; that is, we looked at the manufacture, installation, removal, disposal, and recycling of a product. Our assessment was unique in that we included fire retardants in the products. While many believe that thee retardants are negative to the environment, they don't look at the

amount of fires that can be avoided by their use, which would cut down on harmful chemical emissions.

Lyle: Are there any risks associated with materials used in green building?

Margaret: The use of recycled materials can certainly be a risk, because it is hard to ensure the quality of recycled materials; for example, how do fire retardants used in materials hold up after being recycled or reclaimed? Also, plastics are being mixed in he recycling process, and this could have an effect on the fire safety of the finished product.

Even though products are tested before being used on a building project, the tested material may not always be representative of what the final product may be, due to the fact that recycled materials will vary greatly in their quality. Because of this, the fire rating of a recycled material may not always be entirely accurate, or in some cases it may not even be truly known, and this could have great effects on the fire safety of a building, whether its green or not.

Appendix C: Survey

We are three students from Worcester Polytechnic Institute currently taking part in a 7-week internship program with the National Association of State Fire Marshals, working on a research project titled *Fire Safety in Green Buildings*. This project focuses on the potential fire risks associated with the new wave of "green" construction, "green" meaning a building with little environmental impact. This lessened impact is achieved through using recycled materials, reducing water usage, making architectural changes to allow for better ventilation and natural lighting, and several other criteria.

Our project is looking into what, if any, effects these new materials and techniques have on the fire safety of a building, and also the awareness the fire community has towards this topic. If you would be able to complete this short survey, it would be a great help to us in furthering our understanding of the topic. Thank you.

1) Have you had any experience dealing with any issues pertaining to green buildings? If yes, what specific issues are you facing, and how are you resolving them?
2) Do you know of any aspects of green building that conflict with fire safety? If so, what are these issues?
3) Can you provide any examples of buildings that have been built by "green" standards and also meet fire safety standards?
4) Can you provide the names and contact information of anyone in your state that is addressing the issue of fire safety in green buildings?
5) Further comments?

Constant Contact Survey Results

Survey Name: Fire Safety and Green Buildings - NASFM
Response Status: Partial & Completed
Filter: None
Nov 25, 2008 10:54:23 AM

1. Have you ever had any experience dealing with any issues pertaining to green buildings?

	Number of Response(s)	Response Ratio
Yes	4	28.5%
No	10	71.4%
No Responses	0	0.0%
Total	14	100%

3 Comment(s)

2. If you answered "Yes" to question 1, what specific issues are you facing, and how are you addressing them?

3 Response(s)

3. Can you provide us with the names and locations of any buildings that have been built by "green" standards that also meet fire safety standards?

3 Response(s)

4. Would you provide the names and contact information of anyone you may know of in your state who is addressing the issue of fire safety in green buildings?

5 Response(s)

5. Can you comment on the compatibility of fire safety and green building design.

12 Response(s)

6. Please enter the information indicated below.

First Name	12
Last Name	12
Job Title	11
Company Name	12
Work Phone	11
City	11
State/Province (US/Canada)	12

Constant Contact Survey Results

Survey Name: Fire Safety and Green Buildings - NASFM
Response Status: Partial & Completed
Filter: None
Nov 25, 2008 10:54:23 AM

1. Have you ever had any experience dealing with any issues pertaining to green buildings? - Comments

Answer	Respondent
This office reviews submittals as required by state law for federal energy code requirements . See our website (lasfm.org)	thevjbella@aol.com
In some of the buildings we regulate there are energency effeciency requirements.	Anonymous
inspection of heating units on a periodic basis can improve fire safety and prevent carbon monoxide poison as well as improve effieciency of the unit,	Anonymous

2. If you answered "Yes" to question 1, what specific issues are you facing, and how are you addressing them? - Responses

Answer	Respondent
We insure that lighting, building materials and mechanical equipment meet current fire codes, whether they are considered "green" or not	john.falgione@sfm.ne
N/A	Anonymous
The use of native lumber is becoming popular. We are requiring that lumber that is harvested and milled locally be certified.	Anonymous

3. Can you provide us with the names and locations of any buildings that have been built by "green" standards that also meet fire safety standards? - Responses

Answer	Respondent
There have been many, but all of the new structures at the University of Nebraska-Lincoln have been designed "green"	john.falgione@sfm.ne
We are currently reviewing three schools that are registered for LEED	Anonymous
The Ohio State University, 4H Building, located on Fred Taylor Drive is the only "green building" that has received a LEED certification that this office is aware of.	Anonymous

4. Would you provide the names and contact information of anyone you may know of in your state who is addressing the issue of fire safety in green buildings? - Responses

Answer	Respondent
The Louisiana Department of Natural Resources could be consulted .	thevjbella@aol.com
John Bryan, Baltimore County 410-887-3985 John Picco, Frederick County 301-600-1083	wbarnard@mdsp.org
Mark Wassom, PE Colorado Division of Fire Safety (720)852-6735 mark.wassom@cdps.state.co.us	Anonymous
Not aware of any.	Anonymous
Carl Wren,Chief Fire Protection Engineer City of Austin, Fire Departemnt 512-496-2099	Anonymous

5. Can you comment on the compatibility of fire safety and green building design. - Responses

Answer	Respondent
Not at this time.	firemar1@fire.state.ok
laws are being re-drafted	john.blaschik@po.stat
At this point, it is being reviewed to ascertain if there are any significant hurdles to cross. At this point, I think green building requirements are compatible with existing fire safety standards.	les.hallman@fldfs.com
See our website for various codes that are mandated for buildings(green or otherwise)built in Louisiana .	thevjbella@aol.com
In my opinion sprinklers are the most important issue in a "Green Building." If the building is sprinklered there will be less smoke if there is a fire, less water will be used for suppression and there will be less run off of waste water into the public drainage which could run into important waterways.	wbarnard@mdsp.org
I haven't really encountered any difficulties with "green" design in regard to fire codes.	john.falgione@sfm.ne.
We haven't had any problems	Anonymous
The green building mentioned above met the design requirements of the Ohio Building Code and passed all acceptance inspections. No fire safety issues were noted during the inspections.	Anonymous
NO	Anonymous
In some casees the renewable products used will not have any type of fire resistance rating. An industrial building that is designed to have live vegetation groing on the roof. It may work in some warm climates where the plants are green year round. In cold climates vegetation becomes dry and adds to the fire loading in the winter.	Anonymous
No, not at the present time as I have not had any dealings with any fire safety issues in green buildings.	Anonymous
problems - contactors, in their attempt to use more insulation do not follow code requirements for use, such as providing a thermal barrier for foam plastic insulation... HVAC attempt to use alternative fuel boilers that do not meet ASME manufacturing standards...	Anonymous

LEED for New Construction v 2.2

Registered Project Checklist

Project Name: _____

Project Address: _____

Yes	?	No	Project Totals (Pre-Certification Estimates)	69 Points
			Certified: 26-32 points **Silver**: 33-38 points **Gold**: 39-51 points **Platinum**: 52-69 points	

Yes	?	No	Sustainable Sites	14 Points
Yes			Prereq 1 **Construction Activity Pollution Prevention**	Required
			Credit 1 **Site Selection**	1
			Credit 2 **Development Density & Community Connectivity**	1
			Credit 3 **Brownfield Redevelopment**	1
			Credit 4.1 **Alternative Transportation**, Public Transportation	1
			Credit 4.2 **Alternative Transportation**, Bicycle Storage & Changing Rooms	1
			Credit 4.3 **Alternative Transportation**, Low-Emitting & Fuel Efficient Vehicles	1
			Credit 4.4 **Alternative Transportation**, Parking Capacity	1
			Credit 5.1 **Site Development**, Protect or Restore Habitat	1
			Credit 5.2 **Site Development**, Maximize Open Space	1
			Credit 6.1 **Stormwater Design**, Quantity Control	1
			Credit 6.2 **Stormwater Design**, Quality Control	1
			Credit 7.1 **Heat Island Effect**, Non-Roof	1
			Credit 7.2 **Heat Island Effect**, Roof	1
			Credit 8 **Light Pollution Reduction**	1

Yes	?	No	Water Efficiency	5 Points
			Credit 1.1 **Water Efficient Landscaping**, Reduce by 50%	1
			Credit 1.2 **Water Efficient Landscaping**, No Potable Use or No Irrigation	1
			Credit 2 **Innovative Wastewater Technologies**	1
			Credit 3.1 **Water Use Reduction**, 20% Reduction	1
			Credit 3.2 **Water Use Reduction**, 30% Reduction	1

LEED for New Construction v 2.2
Registered Project Checklist

Yes	?	No			
			Energy & Atmosphere		**17 Points**
Yes			Prereq 1	**Fundamental Commissioning of the Building Energy Systems**	Required
Yes			Prereq 1	**Minimum Energy Performance**	Required
Yes			Prereq 1	**Fundamental Refrigerant Management**	Required

***Note for EAc1:** All LEED for New Construction projects registered after June 26, 2007 are required to achieve at least two (2) points.

			Credit 1	**Optimize Energy Performance**	1 to 10
			Credit 1.1	10.5% New Buildings / 3.5% Existing Building Renovations	1
			Credit 1.2	14% New Buildings / 7% Existing Building Renovations	2
			Credit 1.3	17.5% New Buildings / 10.5% Existing Building Renovations	3
			Credit 1.4	21% New Buildings / 14% Existing Building Renovations	4
			Credit 1.5	24.5% New Buildings / 17.5% Existing Building Renovations	5
			Credit 1.6	28% New Buildings / 21% Existing Building Renovations	6
			Credit 1.7	31.5% New Buildings / 24.5% Existing Building Renovations	7
			Credit 1.8	35% New Buildings / 28% Existing Building Renovations	8
			Credit 1.9	38.5% New Buildings / 31.5% Existing Building Renovations	9
			Credit 1.10	42% New Buildings / 35% Existing Building Renovations	10
			Credit 2	**On-Site Renewable Energy**	1 to 3
			Credit 2.1	2.5% Renewable Energy	1
			Credit 2.2	7.5% Renewable Energy	2
			Credit 2.3	12.5% Renewable Energy	3
			Credit 3	**Enhanced Commissioning**	1
			Credit 4	**Enhanced Refrigerant Management**	1
			Credit 5	**Measurement & Verification**	1
			Credit 6	**Green Power**	1

LEED for New Construction v 2.2
Registered Project Checklist

Yes	?	No	Materials & Resources	13 Points

Yes					
			Prereq 1	**Storage & Collection of Recyclables**	Required
			Credit 1.1	**Building Reuse,** Maintain 75% of Existing Walls, Floors & Roof	1
			Credit 1.2	**Building Reuse,** Maintain 95% of Existing Walls, Floors & Roof	1
			Credit 1.3	**Building Reuse,** Maintain 50% of Interior Non-Structural Elements	1
			Credit 2.1	**Construction Waste Management**, Divert 50% from Disposal	1
			Credit 2.2	**Construction Waste Management**, Divert 75% from Disposal	1
			Credit 3.1	**Materials Reuse**, 5%	1
			Credit 3.2	**Materials Reuse**, 10%	1
			Credit 4.1	**Recycled Content**, 10% (post-consumer + 1/2 pre-consumer)	1
			Credit 4.2	**Recycled Content**, 20% (post-consumer + 1/2 pre-consumer)	1
			Credit 5.1	**Regional Materials**, 10% Extracted, Processed & Manufactured	1
			Credit 5.2	**Regional Materials**, 20% Extracted, Processed & Manufactured	1
			Credit 6	**Rapidly Renewable Materials**	1
			Credit 7	**Certified Wood**	1

Yes	?	No	Indoor Environmental Quality	15 Points

Yes					
Yes			Prereq 1	**Minimum IAQ Performance**	Required
			Prereq 2	**Environmental Tobacco Smoke (ETS) Control**	Required
			Credit 1	**Outdoor Air Delivery Monitoring**	1
			Credit 2	**Increased Ventilation**	1
			Credit 3.1	**Construction IAQ Management Plan,** During Construction	1
			Credit 3.2	**Construction IAQ Management Plan**, Before Occupancy	1
			Credit 4.1	**Low-Emitting Materials**, Adhesives & Sealants	1
			Credit 4.2	**Low-Emitting Materials**, Paints & Coatings	1
			Credit 4.3	**Low-Emitting Materials**, Carpet Systems	1
			Credit 4.4	**Low-Emitting Materials**, Composite Wood & Agrifiber Products	1
			Credit 5	**Indoor Chemical & Pollutant Source Control**	1
			Credit 6.1	**Controllability of Systems**, Lighting	1
			Credit 6.2	**Controllability of Systems**, Thermal Comfort	1
			Credit 7.1	**Thermal Comfort,** Design	1
			Credit 7.2	**Thermal Comfort,** Verification	1
			Credit 8.1	**Daylight & Views,** Daylight 75% of Spaces	1
			Credit 8.2	**Daylight & Views,** Views for 90% of Spaces	1

LEED for New Construction v 2.2
Registered Project Checklist

Yes	?	No			
			Innovation & Design Process		**5 Points**
			Credit 1.1	**Innovation in Design:**	1
			Credit 1.2	**Innovation in Design:**	1
			Credit 1.3	**Innovation in Design:**	1
			Credit 1.4	**Innovation in Design:**	1
			Credit 2	**LEED® Accredited Professional**	1