Bridging the Gap:
Fire Safety and Green Buildings

A Fire and Building Safety Guide to Green Construction

NATIONAL ASSOCIATION STATE FIRE MARSHALS

by Jim Tidwell
with Jack J. Murphy

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ABOUT THE AUTHORS

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Dwayne Garriss, Assistant State Fire Marshal, Georgia

Tonya Hoover, California State Fire Marshal *(Acting)*

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Finally, we want to thank Alan Shuman, President of the National Association of State Fire Marshals, and the NASFM Board of Directors for their foresight and leadership in recognizing the impact that the green movement will have on public safety and the fire service.

FOREWORD

This publication is part of a larger effort on the part of NASFM to heighten the awareness of the fire service regarding issues related to sustainable development and construction. Sustainable development practices provide substantial, meaningful benefits to our society in the form of natural resource conservation and our long-term health and welfare. The importance of this movement is such that any negative unintended consequences must be avoided to assure the momentum of the effort isn't impeded.

Because many of the organizations that are focused on sustainability are working under the belief that public safety is addressed by other codes and standards, these organizations may not always recognize the safety implications of their practices. NASFM did recognize this fact and petitioned the U.S. Department of Homeland Security, via a Fire Protection & Safety Grant, to fund a green project. Their undertaking begins to address the issue, and this publication is one component of the larger effort. *Bridging the Gap – Fire Safety and Green Buildings* will provide information to the fire service and the green community that may be used as the foundation for collaboration that will lead to higher achievements in the realm of public safety and sustainability.

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I. INTRODUCTION

A. Current Status of the Green Movement

The green movement in the United States and in most of the developed world has grown beyond a fad, into a serious effort to minimize and even reverse the damage being done to our planet. The U. S. government has implemented dozens of programs to provide incentives to individuals and businesses to save energy and reduce their negative impact on the environment through conservation. Private companies are now offering certifications, accreditations, and ratings to those who wish to show their customers and others that they are taking their environmental responsibilities seriously. These are all signs that the public is placing increased importance on reducing the human impact on our environment.

Above are just a few symbols of green components or companies.

The area of activity that seems to have garnered the most attention is that of energy conservation. With declining levels of fossil fuels, increasing energy costs, and the rise in global temperature, it seems almost everyone agrees we need to conserve energy wherever possible. And, because buildings consume 48 percent of the energy used in the United States and 76 percent of the electricity generated[1], it's only logical that a serious effort be made to find ways to reduce the amount of energy expended in them.

The green movement doesn't stop with energy consumption in buildings, however. It encompasses ways to encourage recycling building materials and waste, water conservation, and an overall reduction in any discharge that negatively affects our planet's ecosystem.

This guide and the series of checklists provided are intended to be used as a basic primer on fire safety and green construction, as well as a convenient means to access information on this subject. It will not be all-inclusive, and will need to be updated often to ensure innovations in the green construction movement are addressed. The guide will review the current status of the green movement, define green construction, and provide a description of green building components that affect fire and life safety as well as suppression activities. It will clearly highlight issues to consider when planning or responding to these facilities.

It is our desire for this guide to be utilized as a tool to begin a serious dialogue between the fire service and those involved in green construction. Through communication and collaboration, we believe that the goals for sustainable communities and fire safe communities can co-exist as well as leverage opportunities for the enhancement of both.

B. Definition of Green Construction


National Center for Appropriate Technology

Missoula, Mont. Fire Station with solar power.

As one might imagine, there are several definitions of "green" as the term relates to building construction. In order to clarify the purpose of this guide, we will use the following definition:

Green Construction: The practice of creating sustainable/high-performance structures that is a holistic approach to design, construction, and demolition so as to minimize the buildings' impact on the environment, the occupants, and the community. These buildings and processes are environmentally responsible and resource-efficient throughout a building's lifecycle from the site design to construction, operation, maintenance, and deconstruction. A "green" building practice expands and complements the classical building design concerns of economy, utility, durability, and comfort so as to reduce the overall impact of the built environment on human health and nature. Note that this definition does not include "natural construction" techniques that include using materials such as straw bale, earth-filled used tires, etc.

Based upon this definition, we will not refer to "green buildings"; rather, we will address green components of buildings. Almost every building will have some green components, i.e. high-efficiency air conditioning or increased insulation. However, because there is no widely accepted definition of a green building outside some proprietary rating systems, it would be counterproductive to limit our discussion in that fashion.

What follows is a description of building components, techniques, and materials that are considered positive innovations toward a more sustainable community. Along with a description of each item will be a general discussion of its impact on fire safety, public safety, and firefighter safety. After the descriptions of these items will be a series of checklists for commercial and residential facilities, both from a plan review perspective and an emergency response perspective.

C. Why is the Green Movement Relevant to the Fire Service?

Like any other trend that affects the manner in which our buildings are constructed, the green movement has the potential to change the work environment of firefighters everywhere. In this context, firefighters' work environment includes any building in which they must perform firefighting, rescue, or other emergency operations.

Consider the changes in building technology that brought about lightweight construction. The construction industry developed innovative techniques to solve many of their problems, such as the shortage of quality materials, and the need for consistent and precisely sized lumber (without warping or other deformation). Their goal was to construct buildings with predictable load-carrying characteristics in a more economical fashion. How the building reacted under fire conditions wasn't on the manufacturers' radar screen; now, the fire service is living with the results of millions of buildings that have been constructed with lightweight construction. This presents even more dangerous challenges for firefighters working in these buildings under fire conditions. The development of lightweight building components, without taking into account firefighter safety, occurred (at least in part) because the fire service, as a whole, was not attentive to the developments in this arena.

The green movement has the same potential to impact the safety of a firefighter's work environment at a fire scene. It's imperative that those who are developing green building techniques, regulations, and materials receive fire service input during the development of these products in order to effectively address the firefighter safety and the public safety impact of their actions. Without fire service participation in the development of codes, standards, and rating criteria for green buildings, firefighters face the possibility of being placed in the precarious position of being unable to serve their constituency as successfully as in the past. In addition, the likelihood is that the overall fire safety of buildings will take a back seat to environmentalism, an unwarranted and unintended consequence. *It is incumbent upon the fire service to provide the input necessary; no other group has the background, knowledge, and expertise to do so.*

D. The Impact of Fire on Our Environment

The terms "green" and "sustainable" are used interchangeably in virtually all mainstream literature regarding high performance buildings. So the question persists: "How sustainable is a building if it isn't fire safe?" When posing the question to those who develop codes, standards, and rating systems for different levels of green construction, the responses vary. Some will say the focus of their efforts is to reduce the overall impact on our environment, not on fire safety. Others report that, while fires have a negative impact on the environment, they are rare and isolated events, so they don't try to address the issue in their work. In reality, fire prevention is omitted from these systems for a wide variety of reasons. Green regulations and rating systems are intended to recognize high-performance buildings from an environmental perspective. As fire safety considerations are considered basic rather than high performance requirements, they haven't been recognized at this point. Our goal in this section is to quantify the benefits of fire safety as it relates to air and water pollution, thereby reducing the embodied carbons in structures. Our intent is to provide a framework for a discussion about fire safety measures that should be reasonably expected from a standard building, and what fire safety measures may be appropriate to recognize in high-performance buildings.

The body of research on this issue is relatively slim; however, FM Global has published two reports that are considered the leading edge of the research in this area. *"The Influence of Risk Factors on Sustainable Development,"* which was published in 2009, included a review of factors that impact the risk of fire to green buildings. This report provides two conclusions that should be points of focus when studying the impact of green building and our environment. First, efforts to improve sustainability solely by increasing energy efficiency (without consideration of risk) have the potential to increase the relevance of risk factors by a factor of three. Second, without effective fire protection systems, "the risk of fire increases the carbon emissions by 30-40 kg of CO_2/m^2 *(an increase of 1-2 percent) over the lifecycle of a standard office building, and can add up to 14 percent to the carbon emissions over the lifetime of a facility exposed to extensive fire hazard."*[2]

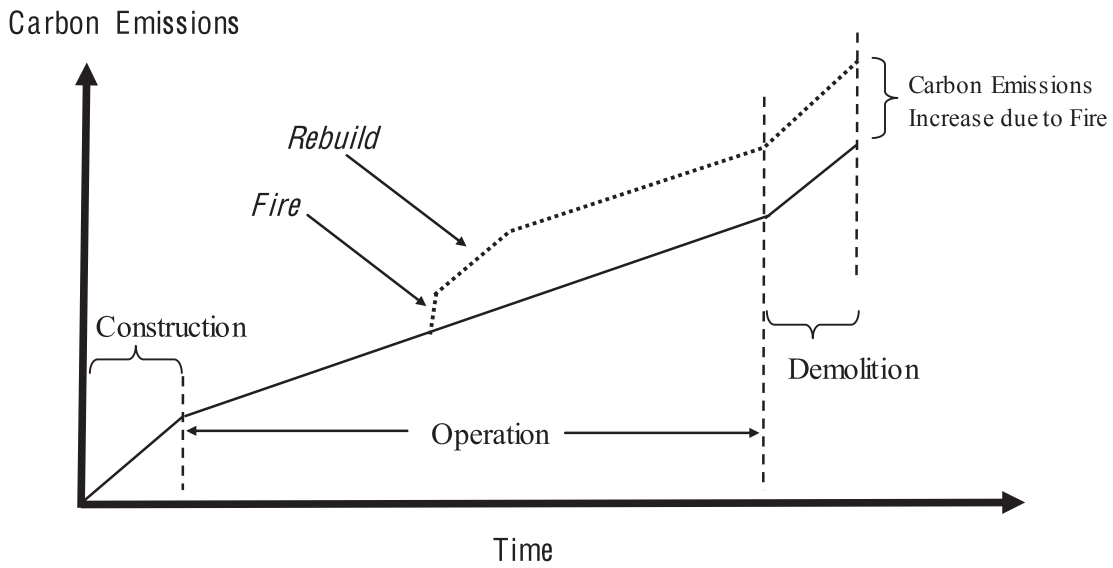


Figure 1: Contribution of risk factors to total lifecycle carbon emissions.

The other report published by FM Global in 2010, *Environmental Impact of Automatic Fire Sprinklers,*[3] focuses specifically on residential sprinklers as a method to reduce overall carbon emissions, water runoff, and other pollution sources originating from residential fires. Both studies, along with data from the National Fire Protection Association (NFPA) and other sources, provide a reasonably accurate image of the relationship between fire risk, fire protection, and environmental protection in the built environment. According to the NFPA, "there were 515,000 reported structure fires in the United States in 2008 (the latest annual statistics available at the time of this report); the damage estimate for these fires is more than $12 billion.[4] As one might imagine, the environmental impact of more than 515,000 fires is considerable.

While the second FM Global report focuses primarily on residential fires and the impact of sprinklers, it quantifies the fire impact on the environment with data and models that are appropriate to determine the impact of residential and non-residential structure fires on the ecosystem.

The data contained in the FM Global report are drawn, in part, from actual room burns conducted under controlled circumstances in FM's full-scale fire test facility. These tests compared identical rooms, identically furnished according to today's practices, with the only difference being that one room was equipped with residential sprinklers, while the other was not. According to the results published in this report, "the fire generated 794 pounds of equivalent $C0_2$ in the room without fire sprinklers, and 13 pounds of equivalent CO_2 in the room with sprinklers. The rooms were 300 square feet, so the amount of CO_2 can be stated as 2.6 and .04 pounds of CO_2 per square foot respectively."[3] While there are many variables to be considered when defining the role of fire in the environmental equations, we can see that, if each of the 515,000 fires reported in 2008 only burned a single room equivalent to the rooms FM Global used, the fires would generate 408,910,000 pounds of CO_2, the equivalent of more than 33,000 cars driven for a full year.[5] In addition, they would generate a significant amount of other polluting particulate matter and gases and would require more than two billion gallons of treated water for manual extinguishment – enough to cover more than 6,300 acres with a foot of water. Put another way, this is enough water to supply the normal daily consumption of more than 60,000 people for a year.[6]

E. Environmental Impact Reductions

Increasing the fire safety of green buildings not only decreases risk to firefighters and increases public safety, but also greatly reduces the potential impact that a building may have on the environment when a fire occurs. First, it's important to consider the water usage necessary to control or extinguish a fire in a building manually, as opposed to the amount of water used to control a fire with automatic sprinklers. The water usage from the non-sprinklered and sprinklered tests resulted in the sprinkler activation using 50 percent less water compared to the non-sprinklered test. *(Figure 31)*

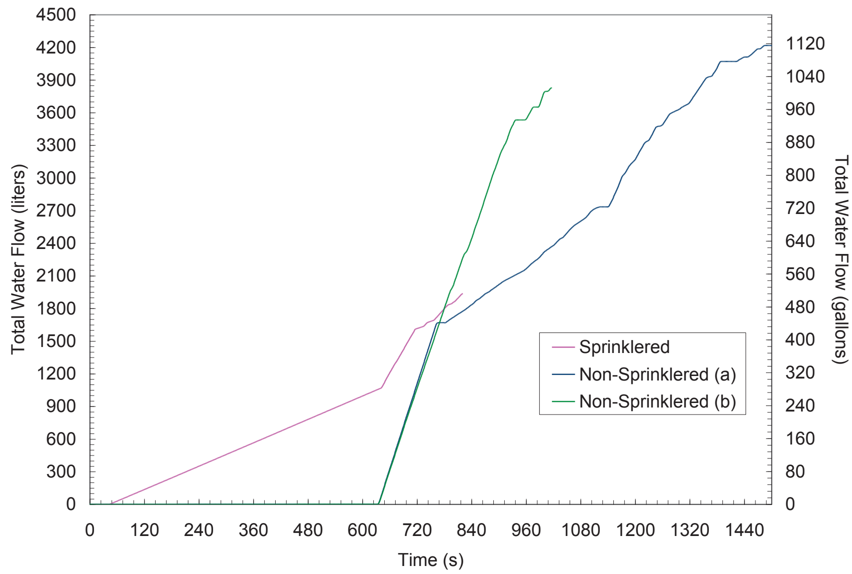


Figure 31: Total volume of water used as a function of time.

Table 13: Water Usage Results

	Sprinklered	Non-Sprinklered (a)	Non-Sprinklered (b)
Sprinkler [L (gal.)]	1393 (368)	0	0
Hose Stream [L (gal.)]	545 (144)	4221 (1115)	3835 (1013)
Total [L (gal.)]	1938 (512)	4221 (1115)	3835 (1013)
Time to Extinguishment [s]	820	1484	1017

This is a significant decrease in water use, and the fire controlled by a sprinkler system was contained to the ignition area, negating any additional impact from fire spread to other rooms.

A reduction in fire spread also means a reduction in fire size and overall release of toxins into the air. "The air emissions from these tests contained 76 different components that were analyzed. In the non-sprinkled test, Anhydrous ammonia, 1carbon tetrachloride, and ortho-xylene were detected, while in the non-sprinklered test ethanol, hydrogen chloride, isopropyl alcohol (IPA) and bromoform were detected."[3]

The data (See *Appendix F)* indicate that the total emissions from the sprinkler-controlled burn were significantly lower than the emissions from the non-sprinkler-controlled burn.

While the installation of automatic sprinklers is an obvious choice to minimize the impact of fire on the environment, it is far from the only one. The best choices are those that prevent the fire from occurring in the first place. This includes appropriate design of the building and systems (electrical, fuel, gas, etc.); education of the occupants to ensure safe practices in the use of electrical appliances, storage of combustible materials, etc; and creating an overall fire safety culture in the home and workplace.

Should a fire start, the earliest intervention provides the best outcome. Something as simple as closing an oven door, turning off the power or using an appropriate portable fire extinguisher will result in very early suppression. Also, attention should be given to emerging technologies that have the potential to reduce the effects of fire even further. Water mist suppression systems are currently available, and extinguish a fire with less water and no water runoff – a significant enhancement to traditional fire sprinklers.

Based upon the information from two FM Global Studies, NFPA, and other supporting information, the following conclusions can be drawn:

- Fires are contributing a significant volume of greenhouse gases, carbon particulate matter, and a host of other pollutants into the atmosphere.

- Manual fire suppression efforts are using millions of gallons of treated water annually, which is polluted with fire by-products and then running off into watersheds.

- Energy efficiency measures, a critical component of green construction, may increase the risk of fire substantially.

- Effective fire prevention and fire protection measures and systems have the potential to reduce the effect of fire on the environment to a point that the impact is negligible.

II. SITE SELECTION AND USE

The selection and use of a site may have the greatest potential to affect a fire department's ability to provide service to the occupants, more than any single factor of green construction. Whether it's a single building or an entire community being planned, the site and fire department access to the buildings on the site are critical factors in developing a reasonable plan for emergency response. In this phase, a collaborative planning process is vital to the success of the project and the safety of future occupants. In the past, prescriptive code requirements for fire department vehicle and personnel access were accepted as reasonable. However, with a focus on walkable communities, urban villages, ecological designs, etc., these prescriptive requirements are being challenged, and performance criteria are needed to better serve the public. Innovation and collaboration will be necessary for success; adversarial relationships will result in one or both sides of the debate suffering setbacks needlessly, and it's the public that will suffer. In the end, the public wants to reduce its overall impact on the environment without giving up safety, and the fire service must provide the best advice available to achieve its constituents' goals.

A. Fire Department Access

Firefighters must have access to sites and buildings in order to provide emergency services. Green construction and development have a myriad of issues relative to site access that must be considered to assure their needs for minimal environmental impact are met without reducing safety. For instance, heat island mitigation requires that at least 50 percent of the hardscape of a development be either shaded or permeable material. Innovation and cooperation by the regulators and the developers are important to maximize the opportunities for both to succeed.

To develop a sustainable site, it's necessary to minimize the amount of ground covered by impermeable materials such as asphalt. Roofs, roads, driveways, and concrete features may send rainwater into storm water collection systems or onto neighboring properties, with a potentially negative impact on the community and neighbors. A better concept is to manage the rainwater on site. One way to avoid runoff is to maintain as much permeable ground surface as possible. Where the fire service may be more comfortable with paved roads, drives, and fire lanes, other options include aggregate, open grid pavers, and permeable concrete. These options can be engineered to be all-weather surfaces that will support the weight of fire apparatus. Marking these types of access methods may be somewhat challenging, but there are many ways to do so. One jurisdiction requires a ground level concrete strip to be installed to mark fire department access ways where traditional markings aren't possible. Responding firefighters know that if they keep their apparatus between the concrete curbs, they're on a drivable surface. Note that in areas that receive snow or that have other events that would hide the ground-level markings, arrangements should be made to delineate the fire lanes under all conditions.

Courtesy Jim Tidwell

Permeable surface for fire department access road at a green campus. Note sign marking entrance and white markers outlining the roadway.

When an entire community is being planned, it's now the norm for developers to implement designs that encourage pedestrian traffic and discourage vehicular traffic in many areas. Enhancing pedestrian safety by controlling or eliminating vehicular traffic may restrict emergency access. Balancing pedestrian safety with fire protection requirements will call for innovative thinking, and the overall safety of the community should always be the highest priority. It's likely that a developer will want streets that are narrower than normal fire lanes; they may desire traffic calming devices (speed humps, etc.); and they may plan landscaping and furniture where we would normally see streets or access roads. Obviously, fire department vehicle access is a public safety requirement, and there are methods to achieve the developer's goals while meeting fire department access needs. Fire departments should consider roll-down curbs, drivable sidewalks, and other innovative ways to get fire apparatus to their destination. While the fire code may envision wide expanses of concrete with red stripes marking a fire truck's way to a building, this is not the only solution.

Where a large walkable community is planned, it may severely limit firefighter access to buildings' interior spaces. In these cases, consideration should be given to providing resources for firefighting within the grounds of a walkable community. Standpipes are an obvious choice, but other novel features might include staging areas for firefighters that would be pressurized rooms with substantial passive fire protection. These rooms might contain firefighter equipment such as hose, tools, and an automatic air supply to refill SCBA cylinders. By building staging area(s) within the development, the need for apparatus access is reduced.

Courtesy Scott Stookey

Firefighter breathing air replenishment system

Fire Department Concerns Include:

- Load-carrying capacity of non-traditional road surfaces. Many of these products are available in different forms for different uses. It's important, in both the planning and inspection phases of the project to assure that the fire department access roads will, in fact, support the weight of the department's apparatus in all weather conditions. Also, some surfaces require more maintenance than others, and this should be factored into the decision-making process.

- Roadway identification is important so that responding firefighters can easily discern where the drivable surface begins and ends. This is especially true where driving off the surface could result in the apparatus becoming incapacitated.

- Obstructions to access roads may be a greater problem where the surface isn't readily identifiable by the community. Where drivable sidewalks and similar solutions are found, it's important to maintain the access route free of furniture and other obstructions.

- Fire equipment staging areas within the grounds of a walkable community can alleviate long hose stretches and lugging equipment across vast open or hard-to-reach spaces.

B. Urban Villages

A green campus overlooking green space.

An urban village is a medium to high-density development of residential and commercial uses. These developments are intended to provide access to living, working, and entertainment venues without the use of an automobile. It's desirable to link multiple urban villages to each other with mass transportation facilities, such as bus or light rail, to facilitate interaction between the communities without driving. The concept is to reduce traffic jams and vehicular pollution while promoting a healthy and communal lifestyle.

Fire Department Concerns Include:

- Issues that should be considered by the fire service include the density of these developments and the restricted access. Our previous discussion on access applies to urban villages and similar developments. Because of the high density of occupants, it's likely that the call volume will be significant for these communities.

C. Building Orientation

Planning a green building or development will undoubtedly take passive and active solar energy sources into consideration. Over the years, developers and builders have developed innovative ways to guarantee that buildings have access to the sun for their expected life span. A building's orientation will affect heating and cooling costs, placement of shading structures and plants, and may have an impact on the hardscape of the project. While the cost of heating and cooling may not be of importance to the fire service, shading structures and limitations on hardscape may impact fire department access, so being involved in the earliest stages of planning a site is imperative.

A green solar deflection system at the roof line provides shade to the building.

D. Landscape

A sustainable landscape begins with an appropriate design that includes functional, cost efficient, visually pleasing, environmentally friendly, and maintainable areas. Sustainable landscape design is an attractive environment that balances native plants, recycled paving materials, pervious concrete, highly-efficient sub-surface drip irrigation, grey water irrigation, along with non-toxic amendments and materials that can be recycled in the future. This may include a green roof that can contribute to the sustainability of a landscape architecture project.

Green rating systems and codes may require planting a specific quantity of plants and trees. Because most developers will want to use as much of the lot as possible for the building, trees and other plants may be closely spaced, and may be very close to the building. The need for ladder placement on the exterior of a building, along with firefighter access to the building during an emergency, should be considered when determining the location of landscaping (including future growth). Planting a forest between the fire lane and the building is probably not a good idea.

An additional concern in areas at risk to wildland fires is the protection of the wildland-urban interface (WUI). Many states have adopted requirements for defensible space around buildings subject to this threat. In these areas, the use of plants with high moisture content, the proximity of the plants to combustible building components, and the overall landscaping scheme will need careful consideration in light of the severe threat of wildland fires.

Fire Department Concerns Include:

- Access to buildings can be severely impacted by landscaping. Plantings should not interfere with access to fire department connections for standpipes and sprinklers, and should allow for the laddering of the exterior of the building.

- Provisions should be made for plant growth. Landscaping can provide an additional avenue of fire spread if this consideration isn't taken into account during the planning stages. In areas subject to wildland fires, the issue becomes even more important.

Courtesy Jack J. Murphy

Awnings and trees provide shade for green building.

- Some mulch material has been identified as an avenue of fire spread and, in rare cases, the actual ignition source through spontaneous combustion. Mulch should not be applied adjacent to combustible building components. (*Appendix D, Case Study 1)*

III. BUILDING ENVELOPE AND DESIGN ATTRIBUTES

The design and construction of a building's exterior will have a significant impact on its ability to conserve energy, one of the hallmarks of green construction. Other factors, such as natural lighting, recycling, and overall environmental stewardship, will often be considered as well. Enhanced insulation products and techniques, high performance glazing, and vegetative roofs are a few of the building shell components that contribute to sustainability. While some have little or no effect on fire safety, others present significant challenges.

A. Insulation

As insulation techniques and products evolve, it's important to assure a reasonable level of fire safety. Most of the foam insulation products coming to the market are either polyurethane or expanded polystyrene foam, both of which are manufactured from petroleum derivatives. Untreated and exposed to elevated temperatures or flame, these foam products will burn vigorously, producing copious quantities of smoke, and spreading fire to other combustibles. Their burning characteristics require that they be manufactured with a fire retardant, be provided with a fire resistive barrier, or both. Buildings all over the world use foam finishing systems on the exterior of buildings to give them the desired appearance. If owners want their buildings to look like the Taj Mahal or the White House, a foam façade is probably the most cost-effective material to use. In addition to providing flexibility in appearance, the insulation value and low cost are very attractive to designers and owners.

Most foam insulation materials are closed cell foams. These foams are rigid, don't readily absorb water, and provide higher insulation values than open cell foams. Closed cell foams may be applied to the exterior of the building as rigid board material, they may be sprayed into cavities of buildings, where they cure as a rigid material, or they may be incorporated into some of the structural components. Rigid foam can be added to many different structural components to add strength and insulation simultaneously. Often, the rigid foam is placed between two layers of wood or metal to achieve the desired strength and insulation value. These are known as Structural Insulated Panels (SIP's). Exterior walls made of these composite panels are highly energy efficient and are structurally stable. As long as fire doesn't reach the foam core, they are as safe as any other building component. Depending upon the amount of flame retardant in the foam, however, it's possible that a fire could consume the entire foam core, leaving only the encasing material to withstand the gravity of the structure.

Open cell foam is softer, and provides no structural enhancement. The advantages of open cell foam are that it is less expensive, is lighter in weight, and uses water as a blowing agent. While open cell foam's insulation properties aren't as good as closed cell foam, it is still less expensive per insulating unit (R-Value) than closed cell foam. The fire characteristics of both types of foam are very similar, as they're both manufactured from petroleum products.

Fire Department Concerns Include:

- The burning characteristics of foam insulation are such that any installation instructions, listing criteria, or design instructions must be followed very carefully. Failure to design and install a product in strict compliance with its listing could cause the foam to be vulnerable to increased ignition hazards and fire spread, with potentially disastrous results.

- Any foam application criteria should be carefully reviewed to assure the foam has been tested and listed for the application. Foam listed for horizontal application may be inappropriate for vertical application; some foams will require a physical separation to protect it from ignition (gypsum board, etc.); still other foams will pollute the interior of a building and aren't intended for that use. In this author's opinion, few other building materials need the level of scrutiny and adherence to installation instructions and listing criteria as foam.

- In general, the International Building Code (IBC) limits the thickness of a foam insulation application to four inches unless the foam has been tested in accordance with national standards for the specific use, including thickness, seams, orientation (vertical, horizontal), etc.

- Code requirements limit the use of untreated foam in the interior of buildings. The density, geometry, and coverage are all factors in need of consideration.

- Foam facades may not be structurally sound. These materials are easily mistaken for stone or other solid materials. Firefighters should be aware that applying a load to a foam component on a building's façade, such as the weight of a firefighter, might cause it to fail. Foam should not be expected to carry any load; ladders, firefighters, equipment, and turnout gear should not be placed on foam core outcroppings of buildings or other façade components that might fail under load.

- Buildings under construction may not have completed all of the required protection schemes for foam insulation material, and a partial exterior application may burn profusely. These fires are spectacular, but many times don't damage the building beyond the shell.

- Welding and other hot work around foam insulation systems require the foam to be carefully protected against flame, slag, or other hot material coming in contact with the foam.

Many spectacular fires have occurred in foam systems applied to buildings, including the 2009 Monte Carlo fire in Las Vegas, the Borgata Water Club fire in Atlantic City in 2007, and the Mandarin Oriental Hotel fire in Beijing in 2009. These events are worth further review regarding the use of foam materials on the exteriors of buildings. Interestingly, in two of these fires, the buildings' interiors were not severely impacted, but the exteriors suffered extensive damage. (Appendix D, Case Studies 2 and 3)

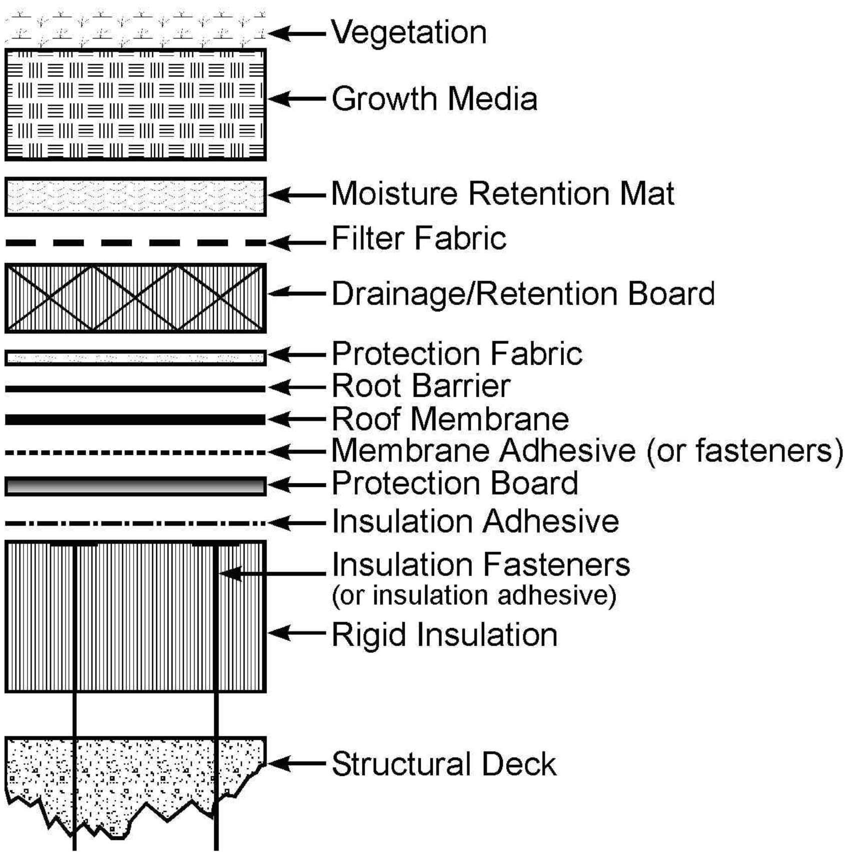
B. Vegetative Roof Systems

A vegetative roof system consists of a top layer of living plant materials and soil known as either growth media or engineered soil that is supported by the roofing assembly below. These systems may also be referred to as a green roof, roof garden, eco roof, landscaped roof or a vegetated roof cover.

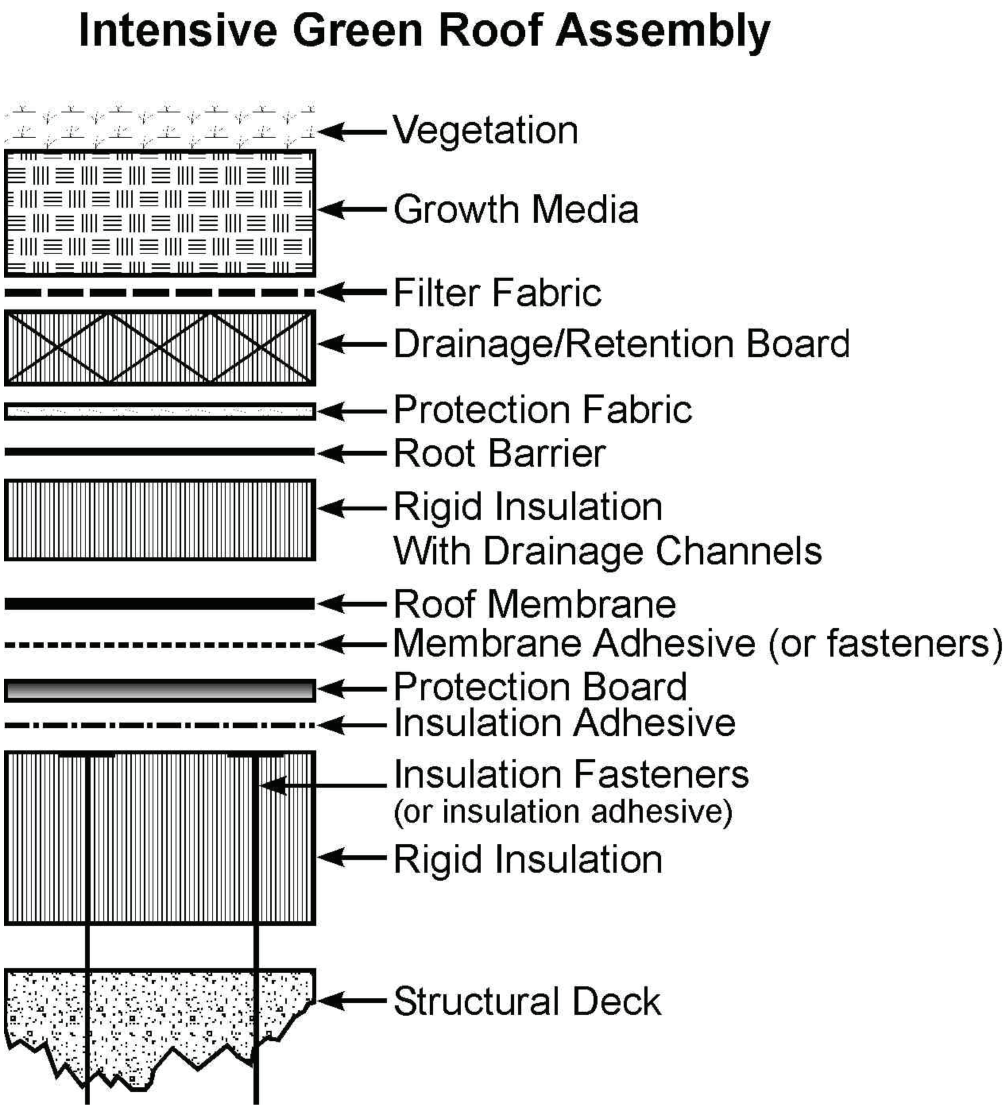
Vegetative roof systems are categorized into three types: Extensive, Intensive, and Simple Intensive. Each type is defined by the depth of the growth media layer and the kind of vegetation.

An extensive Green Roof System includes growth media (soil) less than 6 inches in depth that typically ranges from 3 to 4 inches. It requires minimal maintenance once the vegetation has become well established, usually after two or three growing seasons. Typical vegetation consists of low-growing, non-woody plants, including succulents, mosses, and grasses. These ideal plants have tolerance to drought and temperature extremes, exhibit good growth and survival rates, and have a strong horizontal root system. Extensive green roofs are the most common of the green roof systems.

Extensive Green Roof Assembly



An Intensive Green Roof System has a growth media of 8 inches or more in depth and can be well over 12 inches. This green roof system requires substantial maintenance at regular intervals, including irrigation, mowing, fertilizing, and weeding.

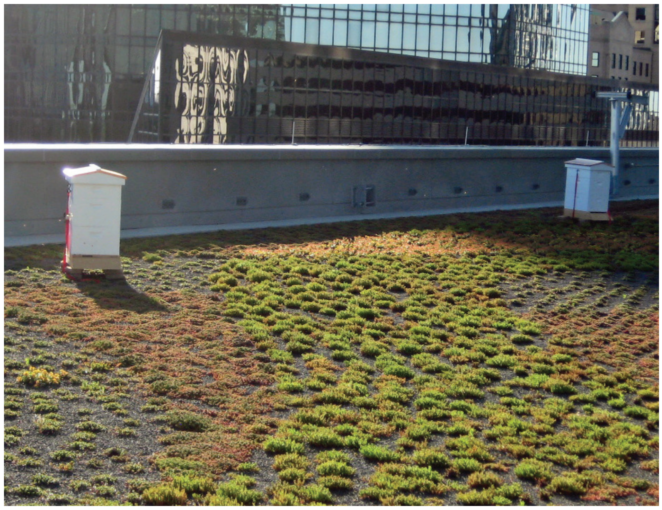


A Simple Intensive Green Roof System is a hybrid system, composed of characteristics of both Extensive and Intensive Green Roof Systems. This type of roof has a growth media that is generally from 6 to 8 inches in depth and may include plants that would normally be considered part of each of the other systems. Maintenance will be dependent upon the plants installed. Each roof type has the potential to pose significant issues to be addressed by the fire service during planning and emergency operations.

Vegetative Roof Categories

	Intensive	Extensive	Simple Intensive
Growth media Depth:	>8"	<6"	6-8"
Types of Vegetation:	Low, non-woody; succulents, mosses, grasses	Large plants, including shrubs and trees as well as ground covers	Low-growing plants with some shrubs for texture
Maintenance Level:	Low to none; plants are self sustaining after two or three growing seasons	Extensive maintenance, including mowing, irrigation, and trimming	This hybrid type may include plants that require greater maintenance and irrigation

Fire Department Concerns Include:


Courtesy Bruce Clark

The load on this vegetative roof includes beehives.

- Roof Load: The loads applied to a green roof will be substantially different than a traditional roof. The growth media and plants will add considerably to the load, and if the roof is intended for gatherings of people, that load also will need to be calculated. When calculating the roof load, complete saturation of the growing media should be included. Many green roofs include stone or concrete pavers that may not show on preliminary drawings, but must be included in the load calculations. If future changes or additions may be contemplated, a robust safety factor for the load-carrying capacity of the roof may be in order.

  Wind uplift pressures and wind loads should be included in the process of designing the structural system. Particular attention should be given to areas prone to high winds, such as those that occur during hurricanes. All calculations for wind events should be made in a dry condition and without a vegetation load. Any roofing material or objects placed on the roof that might become flying debris should be avoided.

  For buildings at or below grade, vehicle loads may need to be incorporated in the design. In these cases, the access paths for vehicles should be clearly marked, and bollards or other barriers should be placed to prevent vehicles from accessing areas not designed to accommodate that load. Where significant slope occurs, measures must be taken to avoid mudslides and similar events.

- Roof Drainage: Closely linked to roof load issues is the subject of drainage. Adding plants and a growth media to the roof has the potential to radically change the water retention characteristics and, thus, the drainage characteristics of a traditional roof. Most building codes require a primary and secondary roof drainage system, and this should be the norm for green roofs. In addition, arrangements must be made to prevent roof drains from being obstructed by growth media or other material from the planted roof. This should include a combination of design features and maintenance criteria.

- Roof Slope: As with any roof, green roofs will need to be sloped in order to drain. A minimum of 2 to 3 percent slope is normally required, and is dependent upon the type of structural roof system (concrete or steel). However, unlike traditional roofs, increased slopes may require additional engineering to preclude the growth media and plants from shifting during a major rain event. As roof slope increases, provisions must be made to keep the green roof in place, and to avoid damaging the drainage system. Failure to consider this may result in roof collapse during storms or during firefighting operations where large quantities of water are applied to the roof.


Courtesy Jack J. Murphy

Growth media on a rolling-style roof

  Factory Mutual (FM) suggests that green roofs with a slope greater than 20 percent be provided with anti-shear stability layers or anchorage, in addition to erosion control. Also, FM suggests that a green roof not be installed on roofs with a slope of 40 percent or greater.

- Roof Access: Roof access provisions should be made for firefighters. A clear space around the roof perimeter should be wide enough to accommodate firefighters and their equipment. In addition, pathways should be provided so that firefighters can access rooftop equipment, skylights, etc., so that vertical ventilation operations can be undertaken. FM suggests "that green roofs should be divided into sections no larger than 15,625 square feet, with no dimension greater than 125 feet."[7] Sections should be separated by non-combustible walkways wide enough to accommodate a firefighter and equipment.

- Supporting Structures: Support may be either concrete or steel, as long as all of the loads are considered. FM suggests "using a structural concrete deck for green roofs with a growth media of six inches or greater."[7] One consideration that may be overlooked is the corrosion resistance of any anchors, fasteners, or roof components. Some corrosion-resistant treatments perform differently under conditions where they are constantly wet or damp, as opposed to being in a wet/dry cycle. It would be prudent for the design team to consult with a corrosion engineer or other qualified professional to assure the corrosion resistance of the roof system will meet their expectations.

- Fire Exposure: While there are no current ratings for green roofs, FM suggests "that green roofs be considered similar to traditional roofs with regard to exposure from an interior fire – if the roof is metal deck, it will be considered a Class I or II; if it's concrete deck, it will be considered non-combustible. When considering exterior fire exposure, a careful evaluation is necessary."[7] It is this hazard that should be considered when selecting plants and other materials that will be on the roof. Plants with high moisture content, such as low-growing succulents and similar plants, will enhance the roof's fire performance, assuming they're maintained. Plants with high levels of volatile oils or resins should be avoided, especially in areas prone to wildland fires.

  Where a building is divided by firewalls or separations that penetrate the roof, consideration should be given to providing a clear space wide enough to assure a roof fire in the vegetation won't spread from one side of the firewall to another.

- Parapets: To avoid a loss of growth media and provide for the safety of anyone below a green roof, consideration should be given to providing a parapet along the perimeter of the roof. The parapet should be tall enough to assure it will contain any material that would be subject to floating or sliding from the roof during an extended weather event.

C. High Performance Glazing

Sustainable buildings depend a great deal upon natural lighting to create the interior environment desired and to save on artificial lighting. Therefore, windows become an important issue, because of the potential energy loss resulting from heat transfer between the interior and exterior of the building. Reflective coatings, low "e" (emissivity) glass, and gas-filled cavities are all components of energy-efficient windows. The primary difficulty that high performance glazing presents to firefighters is that it is sometimes more difficult to ventilate horizontally because virtually all of the energy-efficient windows are manufactured with multiple layers of glass. Normally, this doesn't present a significant problem, but it is something for responding firefighters to consider when determining what equipment to take into a structure.

Fire Department Concerns Include:

- Some glazing systems will make it extremely difficult to break through the window for ventilation or rescue purposes. Where security is a concern, a blast-resistant film is often applied to glazing, making it virtually impossible to penetrate with normal tools. Consideration should be given to inserting breakout panels similar to those required in high-rise buildings. These panels should be clearly identified so that, in case of emergency, the firefighters can use these panels for entry or ventilation.

D. Miscellaneous Issues

- Vestibules: Vestibules are used to inhibit the migration of outside air to the interior of the building. These will increase the degree of difficulty to deploy hose lines to the interior of buildings. Door chocks will need to become standard equipment for firefighters if they aren't already.

- Awnings: Buildings with awnings used to reduce the effect of the sun's heat may inhibit the deployment of ladders on the exterior of the building. Pre-incident planning is necessary to be sure this is included in contingency plans.

- Recycling practices are accepted as important and significant components of a sustainable building project. Building reuse, the use of brownfield sites, recycling construction waste, and, of course, the use of recycled materials in the actual construction of buildings, are all ecologically sound. Of concern to the fire service are practices that could change the burning characteristics of the building, i.e., composite building materials, recycled carpet, etc. It's important that all materials used in building meet code requirements for ignition resistance, flame spread, and smoke generation. Also, when materials are recycled, they are often transformed into a form that has completely different burning characteristics – sometimes for the better, sometimes not. Consider tire shredding and recycling operations; when the shredded material burns, it does so much differently than whole tires.

E. Building Design Attributes

There are many methods to alter a building's use of energy and other consumables through design techniques. For instance, the building's orientation to the sun will have an effect on heating and cooling needs; constructing the building to take advantage of natural light will reduce the need for artificial lighting, and the elimination of alcoves and similar spaces on the outside of the building will enhance security without requiring additional lighting.

One of the more relevant design attributes to fire safety is the use of large, open spaces. This style building has grown in popularity for a number of reasons, not the least of which is that it provides an opportunity to use more natural lighting; fewer barriers to air movement, thus greater heating and cooling efficiency; and an overall feeling of openness for the occupants. People enjoy the high ceilings and open spaces; therefore, they demand this feature in their homes and, where feasible, in their work places. From a fire safety perspective, these large open spaces present an opportunity for faster fire growth due to the greater volume of air and the more readily available fuel sources. This type of design also creates a lack of compartmentation that would serve to limit fire spread to a smaller area, such as a room or a wing or a floor of a building.

Most fires in buildings are ventilation-controlled fires; that is, the size of the fire is controlled by the availability of oxygen. In many room fires, the lack of oxygen stymies fire growth until someone (many times a firefighter) opens a door or window and allows additional oxygen. In others, a window or other opening that the fire has either burned through or, in the case of windows, broken out, limits the rapidity of fire growth if the size of the opening is limited. When buildings are divided into smaller compartments (rooms), typical gypsum board walls separate fuel sources from the fire, resulting in fires that are easier to contain.


Courtesy of James Z.

Large atrium with substantial fuel load.

When designers move toward the utilization of large open spaces in commercial buildings, additional code provisions may come into play. For instance atria, because of their large volume of open space, require additional protection by building and fire codes. Some protection features attributable to the atrium include automatic sprinklers, fire alarm systems, smoke control systems, passive fire protection, and fire safety and evacuation planning. While other occupancies and construction types may trigger some of these requirements, the fact that a building, by virtue of having an atrium, is required to meet all of these requirements is recognition by the code authorities that the large, open spaces present an additional fire and life safety hazard.

In homes constructed to the residential codes, no such recognition exists. This is probably due to the fact that residences are perceived to be smaller, and less hazardous than commercial buildings. From a fire safety and fire suppression perspective, however, the occupancy is less important than the building feature in this case. All due caution should be taken when working a fire in a residence with large open spaces. The span of support beams is longer and the ceilings are taller, representing a far greater risk of collapse. If a collapse does occur, the area of the collapse is likely to be considerably larger, resulting in entrapment of firefighters working in the space.

An additional issue is the use of natural ventilation. In order to take full advantage of natural ventilation, many of these buildings automatically program windows to open and close based upon weather conditions. The designers must consider this feature when designing the smoke control system, if provided; failure to do so will undoubtedly render the smoke control system ineffective.

Fire Department Concerns Include:

- Ventilation controlled fires will no longer be the norm, as the large open spaces will provide all the ventilation necessary to consume any and all combustibles in a building. A department's strategies and tactics on the fireground should consider controlling ventilation using positive pressure techniques or otherwise direct the airflow. In addition, firefighters should be aware of the fuel load of the building and make appropriate plans to control a free-burning fire that may not have vented to the exterior.

- Large open spaces require support beams with long spans. Utilization of lightweight construction, along with long spans in large spaces, will contribute to early structural failure in these buildings.

- In large commercial buildings that use automatically-controlled windows for energy conservation, their controls should be integrated with the fire alarm system and provide manual control for fire department operations. It's likely that, without full building system integration, some of these features will contribute to fire spread and interfere with fire department emergency operations.

F. Skylights/Solar Tubes

Another green practice that contributes to fire spread within buildings is the use of new reflective technologies to transmit natural lighting relatively long distances – from the exterior to deep within a building through relatively small tubes finished with highly reflective coatings.

Fire Department Concerns Include:

- These tubes provide an additional means for fire transmission and smoke migration through spaces that might otherwise be separated. The designers of these products may not consider the installation of smoke or fire dampers where they penetrate a rated separation; regardless, firefighters and command officers need to be aware of this additional method for fire spread within buildings.

G. Structural Components of Concern

Lightweight construction, by its very nature, is considered "green". This is due to several factors, including:

- Lightweight engineered lumber (LEL) uses tree products and by-products that can be sustainably produced. There are currently 24 million acres of sustainable tree farms in the United States, which reduces the use of older forests.[8]

- LEL uses many wood byproducts, lessening the number of trees needed for construction. (Think of chipboard, oriented strand board, particleboard, etc.)

- Engineered lumber can incorporate insulation as an integral component of a structural member, using the insulation as part of the load-carrying capacity of the beam or column. In this example, a stiff foam core is sandwiched between two pieces of plywood or strand board, effectively increasing the overall strength of the assembly.

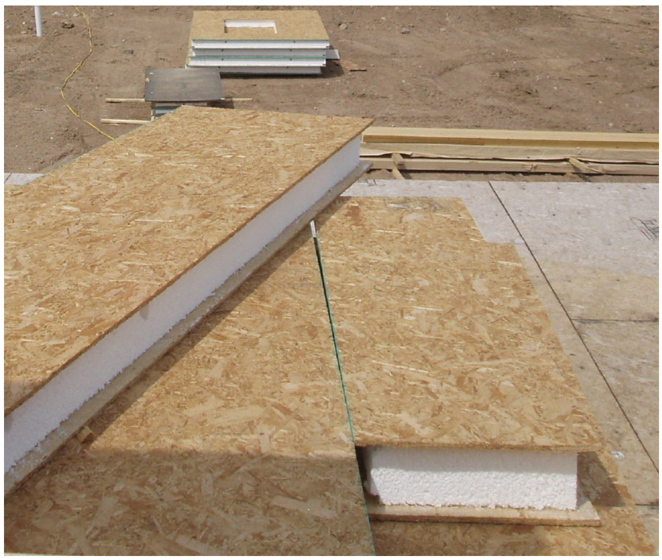
- LEL uses less wood than sawn lumber, reducing the amount of wood necessary to build a home or other building.

- Overall, there is far less waste when LEL is used; therefore, LEL is preferred over traditional sawn lumber.

Other positive attributes of engineered lumber include:

- Engineered lumber includes components that are not lightweight at all, such as engineered beams. Some of these beams can be considered the same as heavy timber construction, even from a fire resistance perspective. The advantage to being able to manufacture the beams is that they can be of virtually any size someone is willing to finance, carrying substantial loads over long spans.

- Engineered lumber, as its name implies, can be produced to exacting specifications relative to load-bearing capacity, dimensions, etc.



Courtesy of Scott Stookey

Structural Insulated Panels (SIP's)

- Engineered lumber can be produced that addresses problems associated with sawn (dimensioned) lumber, including squeaky floors, warping, and curling.

- Engineered lumber is cost effective.

The down side of LEL is the same as one of its strengths, its lighter weight, which is a result of reduced mass. The law of physics being what it is, any attack on a component with less mass will result in damage more quickly than one with greater mass. Whether it's a roof leak or fire, building components with less mass will fail sooner than those with greater mass. Therefore, it's in a fire department's best interests to know and understand the construction of buildings in its response area.

Wood is not the only engineered product considered lightweight construction. Lightweight steel (usually bar joist) construction will present many of the same issues as lightweight wood; however, the mechanism of failure is different. Under fire conditions, lightweight wood components fail earlier because the fire is actually consuming the mass of the member. In steel construction, the fire is heating the member, causing it to lose its weight-bearing strength. The lower the mass of a steel component, the less of a heat sink is available to absorb heat; therefore, lighter weight steel will rise in temperature and fail more quickly than heavier steel components.

Steel will first expand as it's heated, which will cause a beam or bar joist to push confining walls out of their normal position, potentially causing the wall to fail. If failure has not occurred at that point, the continued heat will weaken the steel, thus resulting in complete failure and collapse of that portion of the structure being supported.

Lightweight concrete, typically used in upper floors of buildings, doesn't normally support structural loads of buildings; rather, they support only the floor load, and are supported by other structural components (usually steel). The issue with lightweight concrete is that when heated, it will spall, as all concrete will, and the reduced mass of the concrete contributes to the early failure of the floor system.

Solutions to the use of lightweight structural components of buildings that should be considered are:

- Added fire protection to the members – typically sprayed-on fire proofing, gypsum board, or other insulating materials.

- Sprinkler protection to limit fire growth.

Depending upon the size, height, and use of a building, codes and standards may require these solutions. If they do not, and a building is constructed using unprotected lightweight construction, the fire suppression forces should be aware of the hazards and implement the appropriate strategies to protect firefighters during an emergency.

Fire Department Concerns Include:

- Early collapse of building elements, creating the potential for widespread building collapse very early in a fire.

- For steel construction, exterior walls may be pushed out due to the expansion of steel beams. These walls may collapse prior to the steel being heated to the point of elasticity.

- Lightweight concrete may spall, reducing its load-carrying capacity.

H. Water Conservation

Water conservation is an extremely important component to sustainability. Some interesting statistics include the following:

- The average household uses more than 127,000 gallons of water annually."[9]

- "1.5 million barrels of crude oil are used annually to produce the plastic bottles used for bottled water, enough to fuel 100,000 U.S. vehicles for a year"[10]

- "Energy production accounts for about 39 percent of all water used in the U.S."[11]

- Only 1 percent of the world's water is available for agriculture, manufacturing, and personal use.[12]

The greatest opportunities for saving water are simple conservation techniques such as low use fixtures, low water demand landscaping, etc. However, there are two techniques the green community has embraced that deserve attention: rainwater collection systems and grey water systems.

Rainwater collection systems collect rain for use in landscape irrigation and other uses that don't require significant treatment. If rainwater is collected and stored on rooftops or the upper floors, they add a significant structural load, and that load must be addressed. In new construction this is relatively easy. Design engineers simply calculate the additional load when designing the structure. But the structural design engineer must be aware of the additional load during the design phase.

Retrofitting a collection system on existing buildings poses a far more difficult problem. If the structure isn't reinforced up to carry the additional load, it may be in jeopardy of collapse regardless of whether there is a fire in the building. Roofs are designed to withstand considerable weather-related loading, including snow loads and rainwater loads for 100-year weather events (typical). It's possible that the added load in the form of rainwater collection vessels can be applied to a roof system without incident until the additional, temporary load of a rainstorm, snowstorm, or other load is applied.

If the collection vessels are located on or below grade, they may pose a problem for the fire service. For example, if rainwater is collected in a large rain cavern or cistern underground, and is located under a vehicle parking lot or access road, it's possible that the weight of fire apparatus would exceed the load-carrying capacity of the collection vessel. Structural failure of the vessel under the load of a fire apparatus would obviously incapacitate the apparatus. It's imperative that these additional loads be considered during the installation of water conservation systems, including the containment vessels, piping, and collection systems.

Grey water is typically recognized as a source of potential recycling of water that has been used, but not polluted. This normally comes from bathing, washing, and similar activities. Grey water can be collected and reused for landscape irrigation and other uses that don't require potable water. One re-use currently practiced is to use warm grey water to pre-heat water in piping systems through something akin to a heat exchanger. This reduces the energy required to heat potable water, and the grey water is still available for other uses.

These systems pose a potential health problem for the fire service. While the grey water isn't polluted, it may contain certain microbes and pathogens that could pose a health hazard should people be exposed. Most recommendations for grey water use include keeping exposure to a minimum, suggesting that the water be used underground in irrigation systems, and limiting any use that would allow the inhalation of the product as an aerosol.

It's possible (even likely) that some designers will want to use grey water as a supply for fire protection systems. If permitted, this would pose a significant health risk to firefighters or anyone else exposed to the grey water. In addition, the grey water may change the corrosion characteristics, causing the piping to succumb to Microbial Induced Corrosion (MIC) or other types of corrosion more quickly, shortening the system's useful life. It is suggested that this is an inappropriate use of grey water unless the liquid is appropriately treated, which would probably defeat the purpose of using the grey water in the first place.

Fire Department Concerns Include:

- Underground cisterns or rain caverns may not be identified. Driving over one of these could result in collapse of the vessel and the disabling of a fire apparatus.

- Added loads to a structure may result in early, violent collapse. It's critical to consider "point loading" of a roof or floor system resulting from the addition of water tanks.

- If grey water is used, it's possible that firefighters could be exposed to unknown biological hazards. Careful investigation of grey water makeup should be undertaken prior to any emergency operations in the building.

IV. BUILDING SYSTEMS AND ALTERNATIVE POWER SOURCES

Alternative Power Systems

There are a number of alternative power systems currently on the market; the two most common are photovoltaic systems (PV) and wind power generators (wind turbines). Both systems generate direct current (DC) power, which must be converted to alternating current (AC) for use in buildings. Some of these systems utilize a battery storage system to store excess generated power. More common, however, is a system that sends excess generation into the power grid for distribution to other electricity users. While wind turbines and photovoltaic systems have a lot in common, it's necessary to consider each separately to assure all of the hazards are considered. Other alternative power sources mentioned below are either expanding their current technology or are still in the development stages.

A. Photovoltaic (PV) Solar Power Systems

Solar energy production has increased an average of more than 20 percent each year since 2002, making it the world's fastest-growing energy technology. The fire service can be sure that at some point in the near future they will have at least one emergency involving a building with a solar power generation system.


Courtesy of Bruce Clark

Large PV installation on a warehouse rooftop, effectively preventing any fire dept. roof operations.

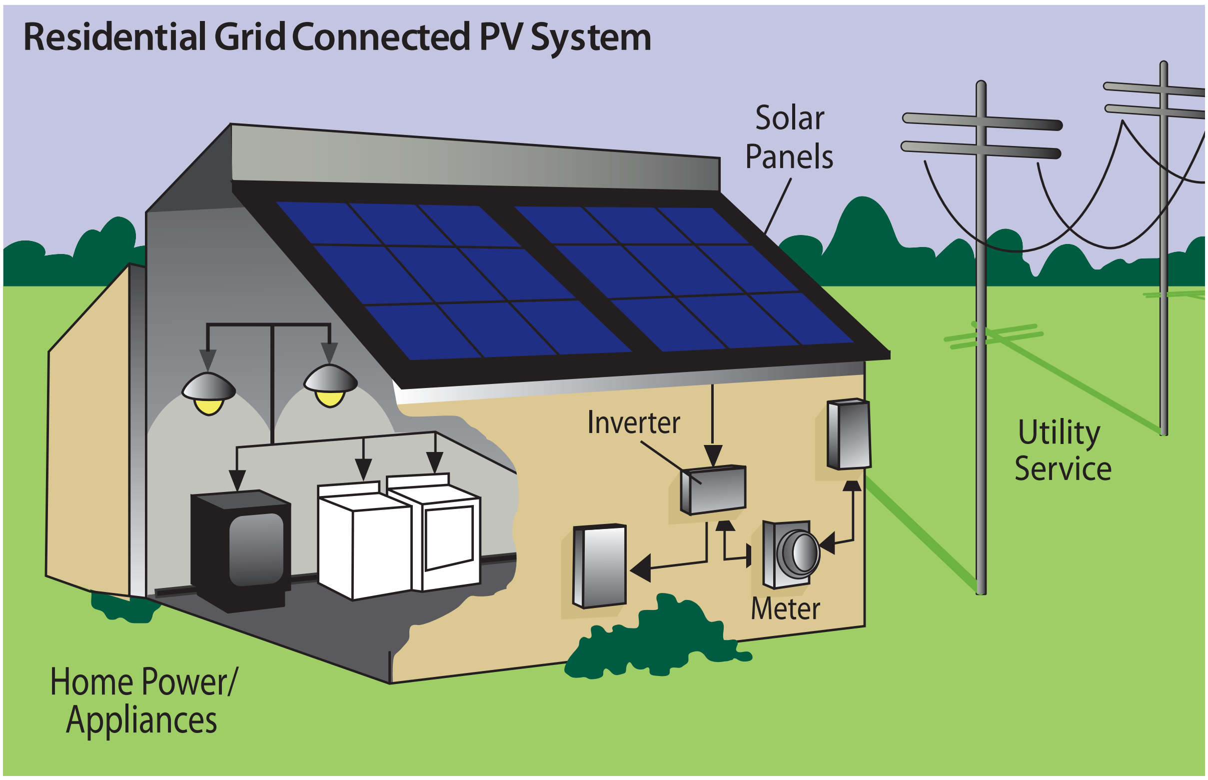
Photovoltaic power is derived from cells that contain a solar photovoltaic material that converts solar radiation into direct current (DC) electricity. Solar cells use sunlight to produce DC electricity, which can be used to power equipment or to recharge a battery. These systems may be used for grid-connected power generation that uses an inverter to convert the DC to Alternating Current (AC).

A solar cell requires protection from the environment and is usually packaged tightly behind a glass sheet. The PV panel construction should be tested by an accredited laboratory as an assembly to meet the same fire rating as the roof upon which it's being mounted.

The PV (solar) cell is the smallest unit and the backbone of a photovoltaic system. These solar cells are covered with an anti-reflective material, placed on a backing material and encapsulated together within a glass and aluminum frame. When several cells are connected together in series and parallel, the voltage and amperage is accumulated to achieve the desired electrical output. Photovoltaic cells connected together in this manner form a PV module. Photovoltaic panels have no moving parts and require very little maintenance. The panels themselves are designed to be completely weatherproof. When two or more modules are connected together they then form a PV array. The modules are wired together in series to accumulate voltage, and the strings (interconnected PV panels in series) are wired together in parallel to increase amperage. A residential system outputting 600 volts is not uncommon.

A typical array will be designed to generate the desired voltage and amperage to be distributed to a building's electrical system. That power is then fed into an inverter, which converts the direct current to alternating current. In addition, the inverter will match the cycle to that of the building's electrical system. Inverters may contain a number of features, including shut-offs for the DC power, monitoring power generation, and, in general, management of all system power functions.

Inverters differ in cost and complexity; many have communication features allowing a building's energy control system to monitor and adjust the power coming from various energy sources. It is within the inverter where most automatic shutdowns occur under emergency conditions. Power companies require that any alternative energy source be separated from the grid in such a way as to automatically stop sending power to the utility company's distribution system upon loss of primary power. This is to assure the safety of their employees working on their power distribution system. Imagine if an interruption in power from the electric utility occurred, but



Courtesy U.S. Department of Energy

power was still being fed to the grid via solar arrays – the electricians working on the power grid components would be subject to a significant shock hazard. This requirement is a positive feature for the fire service. If power from the grid is shut down to the building, the inverter will no longer send power to the building from the PV system; however, depending upon the arrangement of the system components, it's possible that the system could continue to power the building's electrical system. Certainly, all wiring between the power generating device (solar panels in this case) and the inverter will be energized as long as the device is generating electricity.

PV works best when the sun is shining, although power may be generated if any light is available to the panel. Some PV systems are equipped with a battery storage system to provide power when the PV's are not generating electricity. Another option is a grid-tied system, which allows the building owner to generate and use solar power during the day and deliver excess power directly to the utility grid, effectively reversing the meter. In some installations, these options are combined to provide the greatest degree of flexibility to the building operator.

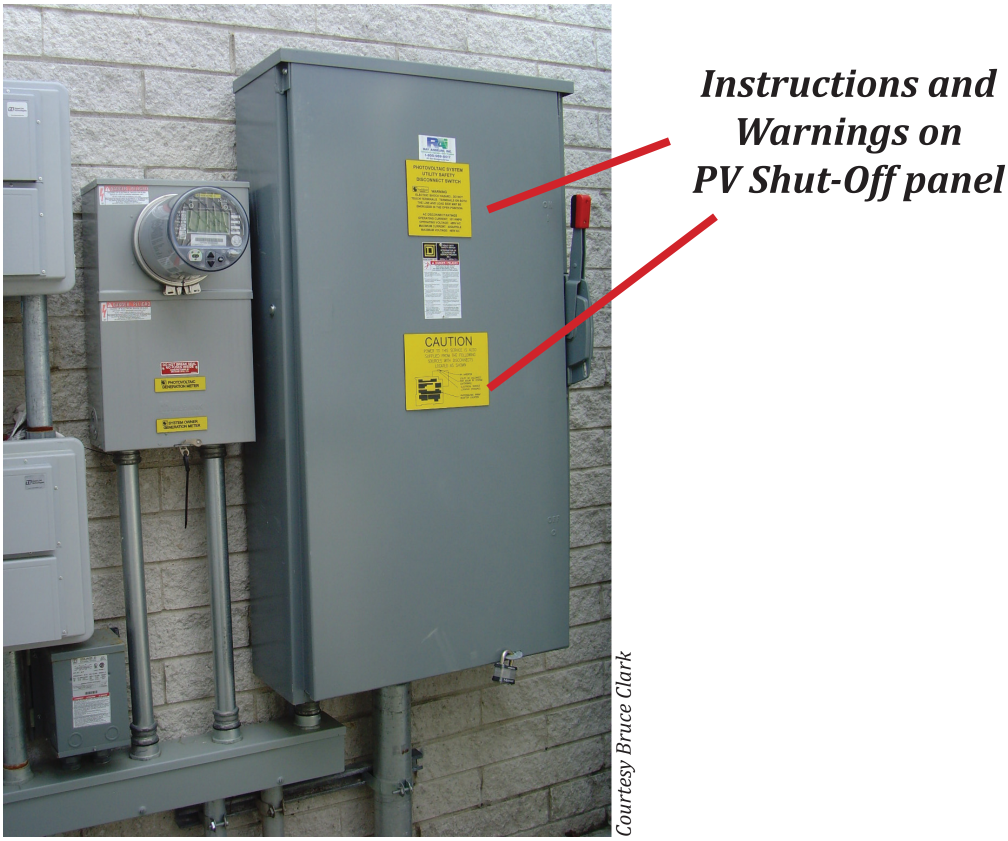
A majority of PV modules and installations are built onto a roof or an exterior wall of a building, although some are installed as a ground-mounted system. In a PV emergency condition involving firefighters, they need to be aware of potential dangers and hazards. The obvious danger is electric shock, inhalation from module chemicals used in manufacturing solar panels, and tripping hazards when installed on rooftops.

For residential buildings, some PV shingle systems are manufactured in the form of roof tiles or shingles and are integrated into the home roof covering. This type of roofing system, while aesthetically pleasing, takes more installation time, wiring and bundling the individual tiles or shingles together to install this PV system. The PV shingle systems currently available meet the standard set forth for Class-A roofing material by using a fire-resistant underlayment beneath the roof section they cover.

Fire Department Concerns Include:

- Power Shut-offs: There may be several places to shut off power to a PV system; however, the safest point of shut-down would be internal to the PV panel itself. While current technology would make this arrangement easily achievable, no manufacturer has done so. This leaves the next best location for shut-down at the inverter, and this is a fairly standard design. The system should be designed to automatically shut off the power to the building's electrical system should the inverter lose power from the power company's grid. This would result in firefighters being able to terminate power at the inverter by using routine power cutting techniques.

  If this is accomplished, the next consideration is the inverter location. For fire suppression purposes, the inverter should be located as close to the solar generating devices as possible, because the wiring between the generating device and the inverter will always



Power Shut-Off for PV System including Inverter

be energized. Micro-inverters are now available, individually controlling each solar array. Installation of these devices will typically be in close proximity to the array they control, and are preferable to any other arrangement currently available.

If a system is very small and doesn't have the appropriate shut-offs, it's possible to reduce or eliminate power generation by covering the panels with a tarp or other material that effectively eliminates any light getting to the panels. This is not the best choice, and may not immediately reduce the power generation to zero. However, in an emergency, all options should be considered.

- Marking/Labeling: Clearly marking a building that has any alternative power source is important to firefighters; this marking should be at a location where it will be noticed, usually at the power feed to the building. Power shut-off locations should be indicated and marked accordingly. Any wiring that will remain energized after normal power is shut off also should be labeled. This is in addition to the labeling of components and other wiring. If exposed to the weather, the markings should consist of materials that will withstand the elements. Also, trip hazards should be identified and marked, with consideration being given to firefighters working on a roof in a smoky environment.

- Roof Ratings: All PV cells should be tested and listed by a recognized testing laboratory. Their fire resistance should be at least as robust as the roof they're being mounted upon to comply with most building and fire codes. It's possible, even likely, that a PV array roof installation will change the way the roof reacts under fire conditions. This is due to the proximity of the panels to the roof, resulting in thermal feedback, and the wind tunnel effect between the panel and the roof that can be achieved under certain conditions. Where possible, it's best to avoid placing firefighters on rooftops, especially where solar panels are installed.

- Roof Access for Ventilation: Placing a solar panel or two upon the roof of a building won't normally create a significant problem with roof ventilation. However, if a large percentage of the roof is covered, the problem becomes severe unless this concern is addressed during the planning stages. Consideration should be given to providing access routes and ventilation points on roofs with these systems. The California Fire Marshal's Office has a draft guideline that provides dimensions and locations for residential and commercial buildings.[13]

  On a residential hip roof layout where PV panels are installed "pathways should be located with at least one 3-foot-wide access pathway from the eave to the ridge on each roof slope where modules are located. The access pathway should be located at a structurally strong location on the building (such as a bearing wall)."[13] On commercial flat roofs, the pathway should be at least six feet in width, should be provided on all edges of the roof, and ventilation points should be provided at least every 150 feet in a matrix or similar pattern on the roof. Every attempt should be made to provide pathways over robust structural members. Even with this configuration, firefighter safety concerns may dictate a command decision on the fireground that roof ventilation is not worth the risk, and utilize alternative tactics.[13]

- Roof Loading: For new systems, the additional load of solar panels should be considered when developing the structural design for the building. For retrofit applications, it is critical to assure the roof system has the carrying capacity for the panels and will withstand any additional loads, i.e., wind loads, especially in areas subject to hurricanes and similar weather events.

Courtesy Bruce Clark

Solar panels on rooftop

- Fire: If a fire occurs within a solar array, it should be treated like any other energized equipment. It should never be assumed that the fire has affected the power-generating capacity, and all circuits should be considered energized. If a fire occurs within a building supplied by an alternative power source, power shut-down must be verified prior to operating within the structure. *(Appendix D, Case Study 4)*

- Pre-Incident Planning: For any fire company responding to buildings with solar power generating systems, pre-fire planning will provide the necessary information to develop strategies and tactics appropriate to that facility. Consideration for the safety of the responding firefighters should be paramount in this activity.[14]

B. Wind Turbine Power Systems

The wind turbine is a rotary device that takes energy from the wind, converting it to electricity. The machine can be called a wind generator, wind turbine, wind power unit, or wind energy converter. Wind turbines are typically located where constant high wind speeds bring best results. Wind turbines can rotate either on a horizontal or vertical axis, the former being more common. The components of a horizontal-axis wind turbine are a gearbox, rotor shaft and brake assembly. With large horizontal-axis wind turbines, the main rotor shaft and electrical generator are located at the top of a tower, and must be pointed into the wind. Large turbines generally use a wind sensor coupled with a servo motor. A wind turbine tower produces turbulence behind it; the turbine is usually pointed upwind. Turbine blades are made stiff to prevent the blades from being pushed into the tower by high winds. Additionally, the blades are placed a considerable distance in front of the tower and are sometimes slightly tilted forward into the wind.

Turbines used in wind farms for commercial production of electric power are usually three-bladed and pointed into the wind by computer-controlled motors. These turbines may have speeds of more than 200 miles per hour, and are highly efficient and reliable. The blades are usually colored light gray so as to blend in with the clouds, and range in length from 65 to 130 feet or more. The tubular steel towers can range from 200 to 300 feet tall. The blades rotate at 10 to 22 revolutions per minute. At the highest rotation, tip speed can exceed 300 feet per second. A gear box is commonly used to step up the speed of the generator. All turbines are equipped with shut-down features to avoid damage at high wind speeds. Wind turbines on buildings present similar issues as any other applied live load. The building must be able to withstand not only the weight of the device and its peripheral equipment, but consideration must be made for the forces of wind against the blades and any forces exerted by the blades' rotation. These

Courtesy of Charlie Effinger, Oklahoma Department of Central Services

Oklahoma State Capitol with wind generator in foreground calculations can become relatively complex, and a structural engineer should be involved in the overall assessment of the structural viability of the entire structure.

Whether the wind generator is mounted on a stand-alone tower or a building, the electrical system is the same, and is very similar to PV systems. The wind generator sends direct current electricity to an inverter, which converts the power to alternating current, and synchronizes the sine wave, voltage, and amperage with a traditional building power source. As with the PV systems, any loss of power from the primary power source should automatically shut off power coming from the inverter. An additional safeguard available with wind turbines is a system whereby the inverter sends a signal to the turning blades to apply a braking system. Once the brake is applied on the device, the blades will slow to a stop, and power generation will cease at this source. From a firefighter safety perspective, this feature should be installed on every wind turbine generator supplying power to a building.

Fire Department Concerns Include:

- Power Shutoffs: Unlike PV systems, wind turbine systems can be equipped with a braking system that automatically stops the turbine from turning, effectively stopping the generation of power. Wind generators supplying buildings should be equipped with automatic and manual shutoffs that shut down power at the inverter, and incorporate the braking system into the shut-down process.

- Calculating roof or other structural loading becomes somewhat more complex when installing wind generators. Not only must the live load be calculated, but also the load created by the wind and the motion of the spinning blades.

- Marking and labeling should be accomplished as with PV systems.

C. Hydrogen Fuel Cell Power Systems

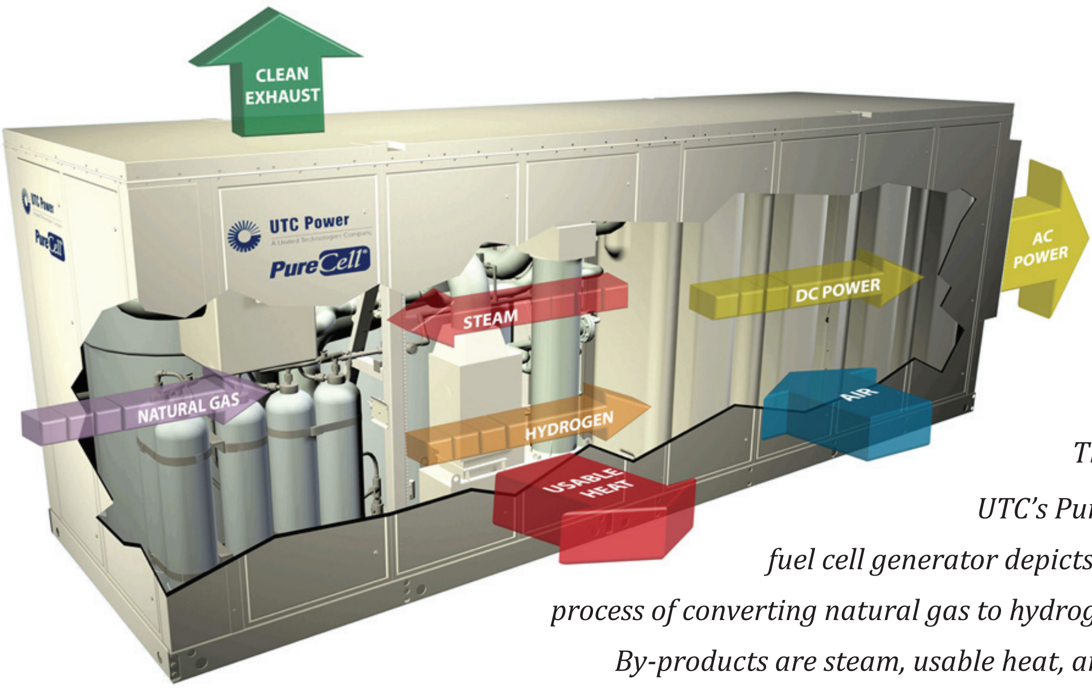
Fuel cells are devices that convert chemical energy into electrical energy. By this definition, your car battery is a fuel cell. The fuel cells under discussion here, however, are somewhat more technologically advanced than the battery in your car. The fuel of choice for modern fuel cells is hydrogen. A hydrogen fuel cell uses both hydrogen and oxygen to generate electricity. The byproduct is water. This is far more environmentally friendly than almost any current energy technology, but there are barriers to the development and use of these devices. For one thing, they’re expensive. For another, a fuel cell is considerably larger than a typical fuel tank on an automobile. And, as with any new technology, there are many technical issues to work through before they become viable for any particular application. Regardless, there are hydrogen fuel cells currently available and in use around the country, and it is anticipated that they’ll become more prevalent as the technology advances.

The U.S. Department of Energy (DOE) Fuel Cell Technologies Program is engaged in comprehensive efforts to overcome the technological, economic, and institutional obstacles to the widespread commercialization of fuel cells and related technologies. The program's mission is to enable the widespread commercialization of fuel cells in diverse sectors of the economy to emphasize applications that will most effectively improve our environment.

These fuel cells may receive the fuel (hydrogen) by two basic methods:

1. Stored hydrogen for use by the fuel cell, either in liquid or gaseous form.
2. Generated hydrogen from another source (usually natural gas) at the site of the fuel cell.

Both methods have their advantages and disadvantages. Storing hydrogen on site provides pure, available hydrogen to the fuel cell. It's a simpler installation, as there is no separator to manage and the quality and quantity of the fuel is known. The down side is that hydrogen is considered a dangerous gas. It has the widest flammable range of any gas, thus making it more prone to accidental ignition than any other fuel. There is a perception by many people that hydrogen is highly explosive because of movies and books about the 1937 Hindenburg blimp disaster. Realistically, hydrogen has some attributes that make it very attractive from a fire safety standpoint. Hydrogen is far more miscible in air than most fuels. Hydrogen is very light – the lightest element in the periodic table – which means that it will dissipate in air, and effectively dilute any flammable mixture very quickly. Also, there are methods to detect hydrogen in very small quantities, so that appropriate automatic and manual actions can be accomplished to avert accidental ignitions. As with any other flammable gas, hydrogen should be treated with great respect, and appropriate safeguards put in place to avoid unwanted ignition.



Courtesy of UTC Power Corporation

This illustration of UTC's PureCell™ hydrogen fuel cell generator depicts the stages of the process of converting natural gas to hydrogen, to electricity. By-products are steam, usable heat, and clean exhaust.

Fuel cells are now being marketed that use hydrogen derived from natural gas through a process that separates the hydrogen from the methane, called reformation. The by-product of this reformation is CO_2, but it doesn't create any more CO_2 than burning the methane as a traditional fuel. The benefits of this method include the fact that no on-site storage of hydrogen is necessary, the hazards involved in transporting and off loading the hydrogen are eliminated, and natural gas is a plentiful fuel in the United States. The downside is that there is another process to maintain, and if natural gas isn't available on site, storage can present similar challenges as storing hydrogen.

Viable hydrogen-powered automobiles are likely decades in the future; however, hydrogen fuel cell generators are here today, and are likely to become much more prevalent. Whether it's a fuel cell UPS for a desktop computer or a large hydrogen fuel cell-powered generator for a large campus, emergency responders need to be ready. For the fire service, this means we should be alert to new installations and generator replacements; determine if any are using natural gas or on-site hydrogen storage, and plan accordingly. Gas detection with automatic shut-down and security for the storage sites should be considered for any installation. Familiarization with the site, the technology, and the operation will assist with on-scene tactics should an emergency arise involving these installations.

Fire Department Concerns Include:

- Highly flammable gases are always present in some quantity. Either natural gas, hydrogen, or both will be present in a hydrogen fuel cell generator. If the generator reforms natural gas into hydrogen, the gas will usually be piped in from the utility.

- If hydrogen is stored on site, it will typically be stored in cylinders at relatively high pressure. Therefore, all the hazards associated with compressed gas, as well as the hazards of hydrogen, will be present. While hydrogen dissipates very quickly in air, it also burns with no visible flame, and has the broadest flammable range of any material.

D. Battery Storage Systems

Many renewable energy systems incorporate batteries. Batteries can be used in all types of systems, including photovoltaic (PV), also known as solar panels; wind power systems using turbines; hydroelectric generators; hybrid renewable energy systems; and other power sources.

A battery system typically serves two purposes:

1. The batteries serve to store power, either from the grid or a generating source (PV, wind generators, etc.) to be used in cases when the normal source of power becomes unavailable. This could be for power outages, if the building is on the utility grid, or during times of reduced generation for those buildings that depend solely on alternative power sources.

2. The battery system also serves to filter the power coming into the building's internal power grid. Many power sources, including normal electricity from a utility power company, contain peaks and valleys of voltage and amperage. Routing all power through a battery system effectively removes the variances that could damage electrical equipment within a building.

The batteries that make up these systems may be one of several types. Lead acid batteries continue to be the most common because the overall cost is lower than other types. Lead acid batteries generate hydrogen gas in relatively small quantities as they are being charged, so it's necessary that these systems be located in well-ventilated rooms. Another concern to firefighters is that the electrolyte used in these batteries is sulfuric acid. As long as the acid is contained within the battery, it presents no significant threat. However, if the batteries are damaged, either from fire or mechanical action, the acid is highly corrosive and toxic.

Additional precautions for dealing with toxic, corrosive, hazardous material should always be considered when responding to an incident involving these systems. Other batteries using similar technology are commonly called gel-cell batteries. These batteries use the same technology, but the electrolyte has silica suspended in the solution, stiffening the liquid into a gel. This reduces the hydrogen production during charging, and any spill is more easily handled because the high viscosity of the medium inhibits its ability to spread.

Other battery types are seldom used because of the additional cost involved. However, battery technology is evolving very quickly, with new materials and methods for storing energy entering the market virtually non-stop. Of particular note is the evolution of lithium ion batteries. These batteries are lighter, carrying more capacity per pound than most other units (lithium ion batteries have about six times the capacity of a similar-sized lead acid battery). From a safety perspective, it's useful to note that all these batteries require an internal protection circuit to keep the voltage, current, and temperature within safe limits. Should the circuit fail, or should physical damage be inflicted on the battery, it's possible that these could ignite with significant heat output.


Courtesy of Scott Stookey

Battery room at a large data center

The size of the installation is an important factor in determining the risk associated with battery systems. A stand-alone UPS battery pack supplying a desktop computer shouldn't create a significant problem. However, a storage system capable of supplying an entire network of computers in a building or on a floor poses a greater risk. Now, consider a battery bank capable of supplying a large data center. The amount of hazardous material is significant, and the off-gassing of certain types of batteries must be addressed by using redundant ventilation techniques. Firefighters should be well aware of the large electrical installation and its potential for shock hazards.

Evolving within the field of alternative energy generation is the storage of electricity in large amounts. The concept is that, if we can store large quantities of electricity, it's possible to meet the demand curves without additional generation capacity. For instance, if, during the summer, excess generating capacity during the cooler, night-time hours could be stored, it could then be used during the warmer, high-demand daytime hours. The effect would be to avoid building new generation facilities, commonly perceived to be a significant contributor to carbon emissions. Storage of this magnitude will present significant challenges to the fire service. The sheer size of the facility, with the potential for hazardous materials emergencies and coupled with the electrical hazards is something seldom encountered today. As alternative energy sources are planned in any community, the fire service should be consulted during the planning, design, and construction.

Fire Department Concerns Include:

- Shock Hazard: Many, if not most, battery systems in buildings contain enough energy to electrocute a person. These should be treated as any other energized circuits, and extinguishing methods appropriate for electrical fires should be used.

- Hazardous Materials Exposure: Traditional batteries contain highly corrosive acid. Contact with this material will be very injurious to the emergency responder, and inhaling the fumes from the acid could result in long-term medical disability or even death. SCBA and appropriate protective gear should always be worn in these environments.

- Combustible Metal: Some technologies use exotic metals and other materials to achieve certain goals. The use of water on some of these materials will generate a violent reaction. Firefighters should know the appropriate extinguishing medium to use when encountering these installations or, if it is unknown what the reaction will be, take appropriate measures to protect both firefighters and the public.

E. Nuclear-Generated Power

The demand for nuclear power is rising in the United States. Nuclear-generated electricity, which does not have greenhouse gas emissions, is a relatively clean source of energy. At the time of this writing, nuclear reactors in the United States generate just 19 percent of its total electricity, compared with France (80 percent), Sweden (44 percent), and Japan (29 percent). More than two-thirds of the United States' power plants generate electricity by coal, oil, and natural gas.

Nuclear energy becomes an increasingly attractive option as the cost of oil remains unstable. As of this writing, the U. S. Nuclear Regulatory Commission (NRC) is reviewing applications for twenty-one new reactor sites. Ten facilities are along the East Coast, some of which will be in densely populated areas.

While the NRC governs all nuclear facilities, some guidance can be taken from NFPA documents that range from construction to decommissioning nuclear-generated power plants. NFPA 804–Fire Protection for Advanced Light Water Reactor Electric Generating Plants is a prescriptive approach to implementing a fire protection program for new plants. Another is NFPA 805–Performance-Based Standard for Fire Protection for Light Water Reactor Electric Generating Plants. This standard addresses protecting the public, the environment, and plant staff from fire and its potential effects on safe reactor operations so as to ensure the utmost in plant safety.

With electricity demands outstripping current generating capacity, all power sources are being considered, including nuclear. There are many advantages to nuclear power generation, including the ability to produce hydrogen though a process called "steam methane reforming." Whether the general public is willing to accept traditional nuclear reactors and the associated risks remains to be seen.

In the future, it's likely that mini-nuclear reactors will be able to run on depleted uranium. This new class of nuclear reactor will be 100 times smaller than a standard reactor. A micro-sized nuclear reactor, which can be 20 feet by 6 feet in size, will be able to power large houses, apartment blocks or some city blocks. The designed reactor is engineered to be fail-safe, totally automatic, and will not overheat. The whole process is sustainable and can last up to 30 years without refueling. Currently companies are in the preliminary design review stage before the NRC.

F. HVAC Systems

Heating, Ventilation, and Air Conditioning (HVAC) Systems are of prime importance to the green movement for a number of reasons. First, these systems consume vast amounts of energy, so any additional efficiency that can be achieved translates into significant savings, from the building to the power generation facility. The other two issues commonly associated with HVAC systems and the green movement is the use of Ozone Depleting Potential (ODP) and Global Warming Potential (GWP) refrigerants.

The two classes of ODP refrigerants are Chlorofluorocarbons (CFCs, R-11 and R-12 being the most common) and Hydro-chlorofluorocarbons (HCFCs, R-22 being the most common). Both product classes are known to cause significant damage to the earth's ozone layer. CFCs have essentially been phased out, and HCFCs will no longer be manufactured in any meaningful quantity in the near future. Many of the product replacements are known as Hydro-fluorocarbons (HFCs), of which R-134a is the most common. While HFCs have less impact on the ozone layer, they contribute a far greater amount of greenhouse gases; some estimate that HFCs contribute the equivalent to 1,000 pounds of CO_2 for each pound of HFC. Thus, the scientific community is searching for appropriate replacements for these gases as well. The fire service will recognize that halogenated fire extinguishing agents (Halon 1211 and 1301) are CFCs, and have been replaced, for the most part, by new clean agents. However, most clean agents are HFCs, and will probably come under the same scrutiny as Halon agents soon.

The search for replacements for refrigerant gases has been underway for some time. One of the replacement classes is the hydrocarbon class. Currently, the researchers have found that propane and isobutene contain all the attributes for good refrigerants. The obvious problem, from a fire protection perspective, is the flammability of these gases. So far, the Environmental Protection Agency has prohibited the highly flammable replacements, but the fire service should monitor this effort closely, and be sure that the fire safety issues are considered along with the environmental concerns.[15]

A relatively rare, but important type of fire protection in highly insulated cold storage facilities is oxygen depletion. In these cases, nitrogen is used to supplant the oxygen in the building, effectively eliminating any chance of ignition and fire. No occupancy is permitted, and all product picking and transportation within the space is fully automated. Should a fire department need to make entry into such a building, they should know in advance what the hazards are, and utilize appropriate personal protective equipment (PPE) and tactics. (The authors are unaware of any U.S. facility using this technology at the time of this publication.)

These facilities aren't the only ones that pose a suffocation hazard; in some large facilities ammonia and other gases are used as refrigerants. A leak in a mechanical room can present fire hazards, toxicity hazards, and suffocation hazards.

Fire Department Concerns Include:

- Ammonia gas and newer refrigerants may have characteristics that change the response strategy for a particular building. Where ammonia is leaking, a high level of personal protection is necessary. Further, while it's rare, ammonia has been known to explode under the right conditions. Familiarization with the characteristics of refrigerants is necessary to respond appropriately to an emergency in these facilities.

- Future development of replacements for current refrigerants will include an evaluation of many different gases. The fire service should remain vigilant to be sure that public safety and firefighter safety continue to be considered in these evaluations.

- Buildings using oxygen-depleted atmospheres should be carefully monitored, and if permitted, pre-incident planning should include actions to mitigate this particular hazard. At the time of publication, we were unable to locate a facility using this technology in the United States.

G. High Volume/Low Speed (HVLS) Fans

Courtesy of Jon Roberts, Oklahoma State Fire Marshal's Office.

HVLS Fan in warehouse-showroom of Tietsort Design in Oklahoma City.

A high volume/low speed (HVLS) fan can range from 6 to 24 feet in diameter. The HVLS ceiling and vertical fans are developed to provide significant energy savings and improve occupant comfort year-round in large commercial, industrial, agricultural, and institutional buildings. A massive 24-foot diameter fan is capable of moving as much as 350,000 (cfm) and can be powered with a 2-hp motor at a mere 440 watts.

The HVLS fan works in both hot and cold environments to even the temperature by mixing the air throughout the space. The two primary considerations are:

- HVLS fans have the ability to obstruct sprinkler spray, resulting in less water reaching the fire, and/or a change in droplet size and geometry.
- HVLS fans can cause accelerated fire spread by providing additional airflow, oxygen, and velocity, resulting in unique fire spread characteristics.

The National Fire Protection Research Foundation has completed Phase 1 of its research project to determine the effects of HVLS fans on fires in buildings equipped with Early Suppression Fast Response (ESFR) sprinkler systems. While the results of this research may not be indicative of every installation, the report does provide data that can be used to generally guide us in our efforts to avoid any negative impact on facilities where these fans are used.[16]

The researchers conducted two full-scale fire tests to determine the impact of HVLS fans. The only difference between the two tests was the fan location in relation to the ignition point; everything else remained the same. In each test, a typical HVLS fan was mounted and operating at capacity. The conclusion on this project was that "such performance from ESFR sprinklers is considered acceptable for the challenges presented in Tests 1 and 2."[16] However, it's clear from the testing these fans do have an impact on the performance of the fire sprinkler systems. In the first test, with the ignition source placed near the tip of the operating fan blades, the fire was considered "suppressed" with three sprinklers operating. When the ignition source was directly under the fan in the second test, the fire was considered "controlled" by eight operating sprinklers – a substantial difference in performance.

Because we have only a small amount of data, and because we know these fans have an impact on an ESFR sprinkler system capability, the following suggestions should be considered in buildings equipped with HVLS fans and ESFR sprinkler systems:

- Fans should stop upon activation of a fire sprinkler flow switch.

- Fans should have a braking system or other means to stop its rotation in a short period of time (30 seconds has been accepted by some jurisdictions).

- There should be at least a three-foot vertical clearance between the sprinkler and the fan blades.

- Fans should be installed in the center, equidistant, from four sprinklers.

- Minimize any additional obstructions, as the testing indicates the fans serve as a significant obstruction even when not turning.

Another sustainable ventilation system includes wind-driven, roof-mounted fans. This natural ventilator is an alternative to traditional industrial ventilators and doesn't consume energy. On a calm day with an outside wind of 9 mph, one manufacturer claims that the fan will exhaust about 3,305 cubic feet per minute (cfm). A series of these units can be found in warehouses and "big box" structures. These fans also will have an impact on the building sprinkler system operation, because they are wind-driven, and have no shut-off or braking system. They will continue to operate during a fire scenario, providing substantial roof ventilation for the fire.

Regardless of the type of ventilation system, it's critical that firefighters understand the impact of system on the fire and on the structure – and plan and execute accordingly.

Fire Department Concerns Include:

- Airflows within buildings equipped with HVLS fans will be dramatically different than those without. In sprinklered fires, the potential result is that cold smoke will be distributed throughout the space.

- HVLS fans will probably have an impact on sprinkler effectiveness. Even though the initial research indicates that ESFR systems did perform in an acceptable fashion with these fans in place, they did not perform as well as prior tests without the fans. Strategies and tactics consistent with the department's normal risk profile should be developed for these contingencies.

- In unsprinklered facilities, these fans will accelerate fire spread.

V. CONCLUSION

In conclusion, it is important to mention that just because a building is labeled as a "green building," it may not equate to a safe building when faced with a fire condition unless steps are taken during the development and planning stages of the building project. A collaborative design process, along with heightened awareness on the part of emergency responders, will result in safer, more sustainable buildings. This will offer the opportunity to avoid unintended consequences due to a lack of information.

APPENDIX A

A. Checklists

COMMUNITY ASSESSMENT TOOLS

As with any other hazard a community faces, those related to green construction would need to be assessed in relation to the overall community attributes. When considering the effect of green construction on your jurisdiction, consideration should be given to your community's geographic location, climate, weather patterns, and topography, along with your department's technical expertise, response capability, etc.

Included in this appendix are a series of checklists in the form of matrices that identify green building components and relate each component to a series of potential concerns. There are examples of one jurisdiction's assessment, along with blank checklists for your use in gauging the level of concern for each green building component based upon your community's needs. These checklists aren't intended to be exhaustive risk assessments; rather, they can be used to gain a high level perspective of gaps that may exist in your community's ability to address particular concerns relating to green construction.

SAMPLE Green Pre-Construction Checklist (Plan Review)

COMPONENT	Apparatus Access	Emergency Ventilation	Exposure Hazard	Extinguishing Systems	FD Personnel Access	Flame Spread	Fire Growth	Haz-Mat	Ignition Propensity	Roof Access	Shock Hazard	Smoke Spread	Structural Stability
Site Selection and Use													
Building Orientation	Yellow	Red	Red	Green	Yellow	Yellow	Green	Green	Yellow	Red	Green	Green	Green
Landscape	Red	Red	Red	Yellow	Yellow	Yellow	Yellow	Green	Yellow	Red	Green	Green	Green
Permeable FD Access Roads	Yellow	Green	Green	Yellow	Green	Green	Green	Green	Green	Green	Green	Green	Green
Traffic Calming Devices	Red	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green
Urban Village	Yellow	Red	Red	Green	Yellow	Yellow	Red	Green	Green	Red	Green	Yellow	Green
Building Envelope and Design Attributes													
Awnings	Yellow	Yellow	Yellow	Green	Red	Yellow	Green	Green	Yellow	Red	Green	Green	Green
Insulation	Green	Red	Red	Green	Green	Red	Red	Yellow	Yellow	Green	Green	Red	Green
High Performance Glazing	Green	Red	Green	Green	Red	Green	Green	Green	Green	Green	Green	Green	Green
Lightweight Construction	Green	Green	Green	Green	Green	Red	Red	Green	Green	Green	Green	Green	Red
Open Design Concept	Green	Red	Green	Yellow	Green	Red	Red	Green	Green	Green	Green	Red	Yellow
Skylights/Solar Tubes	Green	Red	Green	Green	Green	Red	Red	Green	Green	Green	Green	Yellow	Green
Vegetative Roof Systems	Green	Red	Yellow	Green	Red	Yellow	Yellow	Green	Yellow	Red	Green	Green	Red
Vestibules	Green	Red	Green	Green	Red	Green	Green	Green	Green	Green	Green	Green	Green
Water Conservation	Green	Green	Green	Red	Green	Green	Red	Yellow	Green	Green	Green	Green	Green
Building Systems and Alternative Power Sources													
Battery Storage Systems	Green	Green	Green	Green	Green	Green	Green	Red	Yellow	Green	Red	Green	Green
High Volume Low Speed (HVLS) Fans	Green	Red	Green	Red	Green	Yellow	Yellow	Green	Green	Green	Yellow	Red	Green
HVAC Systems	Green	Red	Green	Yellow	Green	Yellow	Yellow	Red	Yellow	Green	Yellow	Red	Green
Hydrogen Fuel Cell Power Systems	Green	Green	Green	Green	Green	Green	Yellow	Red	Yellow	Green	Red	Green	Green
Nuclear Generated Power	Green	Green	Green	Green	Green	Green	Green	Red	Green	Green	Red	Green	Green
Photovoltaic (PV) Solar Power Systems	Green	Yellow	Yellow	Green	Red	Yellow	Green	Green	Yellow	Red	Red	Green	Yellow
Wind Turbine Power Systems	Green	Green	Yellow	Green	Green	Green	Green	Green	Yellow	Red	Red	Green	Yellow

RANKINGS

Green	Component is Not a Concern
Yellow	Component May Be a Concern
Red	Component Poses Public/Firefighter Safety Hazards That Must Be Addressed

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Green Pre-Construction Checklist (Plan Review)

COMPONENT	Apparatus Access	Emergency Ventilation	Exposure Hazard	Extinguishing Systems	FD Personnel Access	Flame Spread	Fire Growth	Haz-Mat	Ignition Propensity	Roof Access	Shock Hazarrd	Smoke Spread	Structural Stability
Site Selection and Use													
Building Orientation													
Landscape													
Permeable FD Access Roads													
Traffic Calming Devices													
Urban Village													
Building Envelope and Design Attributes													
Awnings													
Insulation													
High Performance Glazing													
Lightweight Construction													
Open Design Concept													
Skylights/Solar Tubes													
Vegetative Roof Systems													
Vestibules													
Water Conservation													
Building Systems and Alternative Power Sources													
Battery Storage Systems													
High Volume Low Speed (HVLS) Fans													
HVAC Systems													
Hydrogen Fuel Cell Power Systems													
Nuclear Generated Power													
Photovoltaic (PV) Solar Power Systems													
Wind Turbine Power Systems													

RANKINGS

- ● (green) Component is Not a Concern
- ● (yellow) Component May Be a Concern
- ● (red) Component Poses Public/Firefighter Safety Hazards That Must Be Addressed

SAMPLE Green Construction Checklist (Suppression)

COMPONENT	Apparatus Access	Emergency Ventilation	Aerial Ladder Operations	Extinguishing Systems	FD Personnel Access/Egress	Preconnect Deployment	Fire Growth	Haz-Mat	Supply Line Deployment	Roof Access	Shock Hazard	Ground Ladder Operations	Structural Stability
Site Selection and Use													
Building Orientation	Yellow	Yellow	Yellow	Green	Yellow	Yellow	Green	Green	Yellow	Yellow	Green	Yellow	Green
Landscape	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow	Green	Yellow	Yellow	Green	Yellow	Green
Permeable FD Access Roads	Yellow	Green	Yellow	Green	Yellow	Yellow	Green	Green	Yellow	Green	Green	Green	Green
Traffic Calming Devices	Red	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green
Urban Village	Red	Red	Red	Green	Yellow	Red	Yellow	Green	Red	Red	Green	Red	Green
Building Envelope and Design Attributes													
Awnings	Yellow	Yellow	Red	Green	Yellow	Green	Green	Green	Green	Red	Green	Red	Green
Insulation	Green	Yellow	Green	Green	Green	Green	Red	Yellow	Green	Green	Green	Green	Green
High Performance Glazing	Green	Red	Green	Green	Red	Green	Green	Green	Green	Green	Green	Green	Yellow
Lightweight Construction	Green	Yellow	Green	Green	Green	Green	Yellow	Green	Green	Yellow	Green	Green	Red
Open Design Concept	Green	Yellow	Green	Green	Yellow	Yellow	Red	Green	Green	Green	Green	Green	Yellow
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Vegetative Roof Systems	Green	Red	Yellow	Green	Yellow	Yellow	Yellow	Green	Green	Red	Green	Green	Red
Vestibules	Green	Red	Green	Green	Red	Yellow	Green	Green	Green	Green	Green	Green	Green
Water Conservation	Yellow	Green	Green	Red	Green	Green	Green	Yellow	Green	Green	Green	Green	Green
Building Systems and Alternative Power Sources													
Battery Storage Systems	Green	Yellow	Green	Green	Green	Green	Green	Red	Green	Green	Red	Green	Green
High Volume Low Speed (HVLS) Fans	Green	Red	Green	Red	Green	Green	Yellow	Green	Green	Green	Yellow	Green	Green
HVAC Systems	Green	Yellow	Green	Yellow	Green	Green	Yellow	Red	Green	Green	Yellow	Green	Green
Hydrogen Fuel Cell Power Systems	Green	Yellow	Green	Green	Green	Green	Yellow	Red	Green	Green	Red	Green	Green
Nuclear Generated Power	Green	Green	Green	Green	Green	Green	Green	Red	Green	Green	Red	Green	Green
Photovoltaic (PV) Solar Power Systems	Green	Red	Red	Green	Yellow	Green	Yellow	Green	Green	Red	Red	Red	Yellow
Wind Turbine Power Systems	Green	Green	Yellow	Green	Green	Green	Green	Green	Green	Green	Red	Green	Yellow

RANKINGS

Green	Component is Not a Concern
Yellow	Component May Be a Concern
Red	Component Poses Public/Firefighter Safety Hazards That Must Be Addressed

Green Construction Checklist (Suppression)

COMPONENT	Apparatus Access	Emergency Ventilation	Aerial Ladder Operations	Extinguishing Systems	FD Personnel Access/Egress	Preconnect Deployment	Fire Growth	Haz-Mat	Supply Line Deployment	Roof Access	Shock Hazarrd	Ground Ladder Operations	Structural Stability
Site Selection and Use													
Building Orientation													
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Urban Village													
Building Envelope and Design Attributes													
Awnings													
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Lightweight Construction													
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Vestibules													
Water Conservation													
Building Systems and Alternative Power Sources													
Battery Storage Systems													
High Volume Low Speed (HVLS) Fans													
HVAC Systems													
Hydrogen Fuel Cell Power Systems													
Nuclear Generated Power													
Photovoltaic (PV) Solar Power Systems													
Wind Turbine Power Systems													

RANKINGS	
● (green)	Component is Not a Concern
● (yellow)	Component May Be a Concern
● (red)	Component Poses Public/Firefighter Safety Hazards That Must Be Addressed

APPENDIX B

B. Glossary of Terms

ACCESSIBILITY — A term describing the degree to which something is accessible by as many people as possible. In transportation design, accessibility is often used to focus on people with disabilities and their right of access to thoroughfares, buildings and public transportation. Accessibility also refers to transportation facilities that comply with *Public Rights-of-Way Accessibility Guidelines* (PROWAG).

ACCESS MANAGEMENT — Access management is defined as the management of the interference with through traffic caused by traffic entering, leaving and crossing thoroughfares. It is also the control and regulation of the spacing and design of driveways, medians, median openings, traffic signals, and intersections on arterial streets to improve safe and efficient traffic flow on the road system.

ARTERIAL — A street that typically emphasizes a high level of traffic mobility and a low level of property access. Arterials accommodate relatively high levels of traffic at higher speeds than other functional classes and serve longer distance trips. Arterial streets serve major centers of activity of a metropolitan area and carry a high proportion of the total urban area travel. Arterials also serve significant intra-area travel, such as between central business districts and outlying residential areas, between major inner city communities or major suburban centers. Arterial streets carry important intra-urban as well as intercity bus routes.

BUILDING THERMAL ENVELOPE — The basement walls, exterior walls, floor, roof, and any other building elements that enclose conditioned space. This boundary also includes the boundary between conditioned space and any exempt or unconditioned space.

BICYCLE BOULEVARD — A roadway that motorists may use that prioritizes bicycle traffic through the use of various treatments. Through motor vehicle traffic is discouraged by periodically diverting it off the street. Remaining traffic is slowed to approximately the same speed as bicyclists. STOP signs and signals on the bicycle boulevard are limited to the greatest extent possible, except when aiding bicyclists in crossing busy streets.

BROWNFIELD — Real estate property that is or potentially is contaminated.

CLUSTERED VILLAGE — A denser rendering of an urban village.

CONTEXT ZONE — One of a set of categories used to describe the overall character of the built and natural environment, building from the concept of the “transect”—a geographical cross-section through a sequence ranging from the natural to the highly urbanized built environment. There are six context zones plus special districts describing the range of environments, including four urban context zones for the purpose of CSS—suburban, general urban, urban center and urban core.

CORRIDOR — A transportation pathway that provides for the movement of people and goods between and within activity centers. A corridor encompasses single or multiple transportation routes or facilities (such as thoroughfares, public transit, railroads, highways, bikeways, etc.), the adjacent land uses and the connecting network of streets.

DAYLIGHTING — The lighting of a building using daylight directly or indirectly from the sun.

DEMAND RESPONSE AUTOMATION INTERNET SOFTWARE — Software that resides in a Building Energy Management Control System that can receive a demand response signal and automatically reduce HVAC and lighting system loads. Demand Response programs developed by the electric utility and the independent system operator typically depend upon timely and reliable communications of events and information to the buildings participating in the programs.

ECOSYSTEM — The term is used for the combined physical and biological components of an environment.

EDGE ZONE — The area between the face of curb and furnishing zone, an area of required clearance between parked vehicles or traveled way and appurtenances or landscaping.

ENERGY MANAGEMENT AND CONTROL SYSTEM, BUILDING (EMCS) — A computerized, intelligent network of electronic devices, designed to automatically monitor and control the energy using systems in a building.

ENVIRONMENT — The natural and built places within or surrounding a community. The natural environment includes the topography; natural landscape; flora and fauna; streams, lakes and watersheds; and other natural resources, while the human/built environment includes the physical infrastructure of the community, as well as its institutions, neighborhoods, districts, and historical and cultural resources.

FRONTAGE ZONE — The distance between the throughway and the building front or private property line that is used to buffer pedestrians from window shoppers, appurtenances, and doorways. It contains private street furniture, private signage, merchandise displays, etc. The frontage zone also can be used for street cafes. This zone is sometimes referred to as the “shy” zone.

FURNISHINGS ZONE — The area of the roadside that provides a buffer between pedestrians and vehicles. It contains landscaping, public street furniture, transit stops, public signage, utilities, etc.

GREEN BUILDING — The practice of creating a sustainable/high-performance structure that is a holistic approach to design, construction, and demolition so as to minimize the building’s impact on the environment, the occupants, and the community. These buildings and processes are environmentally responsible and resource-efficient throughout a building’s lifecycle, from the site design, to construction, operation, maintenance, and deconstruction. A green building practice expands and complements the classical building design concerns of economy, utility, durability, and comfort so as to reduce the overall impact of the built environment on human health and nature.

GREENFIELD — Real estate property that is not contaminated, either potentially or in fact.

GROWTH MEDIA — Engineered soil that contains porous aggregate materials, such as crushed clay brick, expanded shale, and crushed pumice that is specifically designed to retain water, provide aeration, and allow for proper drainage.

HARDSCAPE — The practice of landscaping that refers to the paved areas like streets and sidewalks for large business complexes, housing developments, and other industrial areas where the upper-soil-profile is no longer exposed to the actual surface of the earth.

HIGH-PERFORMANCE BUILDING — The term "high performance building" means a building that integrates and optimizes all major high-performance building attributes, including energy efficiency, durability, life-cycle performance, and occupant productivity.

HYBRID VENTILATION — The combination of natural and mechanical outdoor air ventilation.

LEED — Leadership in Energy and Environmental Design (LEED) is a rating system devised by the United States Green Building Council (USGBC) to evaluate the environmental performance of a building and encourage market transformation towards sustainable design. The system is credit-based, allowing projects to earn points for environmentally friendly actions taken during construction and use of a building.

MICROTURBINE — A distributed power that combines heat and power applications. They are one of the most promising technologies for powering hybrid electric vehicles. They range from handheld units producing less than a kilowatt to commercial-sized systems that produce tens or hundreds of kilowatts.

NEW URBANISM — A multidisciplinary movement dedicated to the restoring of existing urban centers and towns within metropolitan regions, reconfiguring sprawling suburbs into real neighborhoods and diverse districts, conserving natural environments and preserving a community's built legacy. The new urbanism vision is to transform sprawl and establish compact, walkable, sustainable neighborhoods, streets, and towns.

NON-RENEWABLE — Energy resources that can generally be freely used without net depletion or that have the potential to renew in a reasonable period of time.

PLACE/PLACEMAKING — A holistic and community-based approach to the development and revitalization of cities and neighborhoods. Placemaking creates unique places with lasting value that are compact, mixed-use, and pedestrian- and transit-oriented, and that have a strong civic character.

PHOTOVOLTAIC

- ALTERNATING CURRENT (AC) — A type of electrical current, the direction of which is reversed at regular intervals or cycles. In the United States, the standard is 120 reversals or 60 cycles per second. Electricity transmission networks use AC because voltage can be controlled with relative ease.

- ANGLE OF INCIDENCE — The angle that a ray of sun makes with a line perpendicular to the surface. For example, a surface that directly faces the sun has a solar angle of incidence of zero, but if the surface is parallel to the sun (for example, sunrise striking a horizontal rooftop); the angle of incidence is 90°.

- ANODE — The positive electrode in an electrochemical cell (battery). Also, the earth or ground in a cathodic protection system and the positive terminal of a diode.

- ANTI-REFLECTION COATING — A thin coating of a material applied to a solar cell surface that reduces the light reflection and increases light transmission.

- ARRAY — A mechanically integrated assembly of modules or panels with a support structure and foundation, or a tracker, and other components, as required, to form a direct-current power-producing unit.

- ARRAY OPERATING VOLTAGE — The voltage produced by a photovoltaic array when exposed to sunlight and connected to a load.

- BATTERY — Two or more electrochemical cells enclosed in a container and electrically interconnected in an appropriate series/parallel arrangement to provide the required operating voltage and current levels. Under common usage, the term battery also applies to a single cell if it constitutes the entire electrochemical storage system.

- BATTERY CAPACITY — The maximum total electrical charge, expressed in ampere-hours, that a battery could deliver to a load under a specific set of conditions.

- BATTERY CELL — The simplest operating unit in a storage battery. It consists of one or more positive electrodes or plates, an electrolyte that permits ionic conduction, one or more negative electrodes or plates, separators between plates of opposite polarity, and a container for all the above.

- BATTERY CYCLE LIFE — The number of cycles, to a specified depth of discharge, that a cell or battery can undergo before failing to meet its specified capacity or efficiency performance criteria.

- BATTERY ENERGY CAPACITY — The total energy available, expressed in watt-hours (kilowatt-hours), which can be withdrawn from a fully charged cell or battery. The energy capacity of a given cell varies with temperature, rate, age, and cut-off voltage. This term is more common to system designers than it is to the battery industry, where capacity usually refers to ampere-hours.

- BATTERY LIFE — The period during which a cell or battery is capable of operating above a specified capacity or efficiency performance level. Life may be measured in cycles and/or years, depending on the type of service for which the cell or battery is intended.

- BIPV (BUILDING-INTEGRATED PHOTOVOLTAICS) — A term for the design and integration of photovoltaic (PV) technology into the building envelope, typically replacing conventional building materials. This integration may be in vertical facades, replacing view glass, spandrel glass, or other façade material; into semitransparent skylight systems; into roofing systems, replacing traditional roofing materials; into shading "eyebrows" over windows; or other building envelope systems.

- BLOCKING DIODE — A semiconductor connected in series with a solar cell or cells and a storage battery to keep the battery from discharging through the cell when there is no output, or low output, from the solar cell. It can be thought of as a one-way valve that allows electrons to flow forwards, but not backwards.

- CATHODE — The negative pole or electrode of an electrolytic cell, vacuum tube, etc., where electrons enter (current leaves) the system; the opposite of an anode.

- CATHODE PROTECTION — A method of preventing oxidation of the exposed metal in structures by imposing a small electrical voltage between the structure and the ground.

- CLOUD ENHANCEMENT — The increase in solar intensity caused by reflected irradiance from nearby clouds.

- CUT-OFF VOLTAGE — The voltage levels (activation) at which the charge controller disconnects the photovoltaic array from the battery or the load from the battery.

- DIFFUSE INSOLATION — Sunlight received indirectly as a result of scattering due to clouds, fog, haze, dust, or other obstructions in the atmosphere. Opposite of direct insolation.

- DIFFUSE RADIATION — Radiation received from the sun after reflection and scattering by the atmosphere and ground.

- DIRECT CURRENT (DC) — A type of electricity transmission and distribution by which electricity flows in one direction through the conductor, usually relatively low voltage and high current. To be used for typical 120 volt or 220 volt household appliances, DC must be converted to alternating current, its opposite.

- DIRECT INSOLATION — Sunlight falling directly upon a collector.

- EDGE-DEFINED FILM-FED GROWTH (EFG) — A method for making sheets of polycrystalline silicon for photovoltaic devices in which molten silicon is drawn upward by capillary action through a mold.

- ELECTRODE — A conductor that is brought in conducting contact with a ground.

- FILL FACTOR — The ratio of a photovoltaic cell's actual power to its power if both current and voltage were at their maxima. A key characteristic in evaluating cell performance.

- FIXED TILT ARRAY — A photovoltaic array set in at a fixed angle with respect to horizontal.

- FULL SUN — The amount of power density in sunlight received at the earth's surface at noon on a clear day (about 1,000 watts/square meter).

- GRID-CONNECTED SYSTEM — A solar electric or photovoltaic (PV) system in which the PV array acts like a central generating plant, supplying power to the grid.

- HYBRIAD SYSTEM — A solar electric or photovoltaic system that includes other sources of electricity generation, such as wind or diesel generators.

- INCIDENT LIGHT — Light that shines onto the face of a solar cell or module.

- INFRARED RADIATION — Electromagnetic radiation whose wavelengths lie in the range from 0.75 micrometer to 1000 micrometers; invisible long wavelength radiation (heat) capable of producing a thermal or photovoltaic effect, though less effective than visible light.

- INSOLATION — A measure of solar radiation energy received on a given surface area in a given time.

- INVERTER — A device that converts direct current electricity to alternating current either for stand-alone systems or to supply power to an electricity grid.

- ISPRA GUIDELINES — Guidelines for the assessment of photovoltaic power plants, as published by the Joint Research Centre of the Commission of the European Communities, Ispra, Italy.

- I-V CURVE — A graphical presentation of the current versus the voltage from a photovoltaic device as the load is increased from the short circuit (no load) condition to the open circuit (maximum voltage) condition. The shape of the curve characterizes cell performance.

- JUNCTION BOX — A photovoltaic (PV) generator junction box is an enclosure on the module where PV strings are electrically connected and where protection devices can be located, if necessary.

- JUNCTION DIODE — A semiconductor device with a junction and a built-in potential that passes current better in one direction than the other. All solar cells are junction diodes.

- LIFECYCLE COST — The estimated cost of owning and operating a photovoltaic system for the period of its useful life.

- LINE–COMMUTATED INVERTER — An inverter that is tied to a power grid or line. The commutation of power (conversion from direct current to alternating current) is controlled by the power line, so that, if there is a failure in the power grid, the photovoltaic system cannot feed power into the line.

- LOCK-OUT — A method for keeping equipment from being set in motion and endangering workers.

- MAINTENANCE-FREE BATTERY — A sealed battery to which water cannot be added to maintain electrolyte level.

- MAXIMUM POWER POINT TRACKER (MPPT) — Means of a power conditioning unit that automatically operates the photovoltaic generator at its maximum power point under all conditions.

- MODULARITY — The use of multiple inverters connected in parallel to service different loads.

- MODULE — See photovoltaic (PV) module.

- MODULE DERATE FACTOR — A factor that lowers the photovoltaic module current to account for field operating conditions such as dirt accumulation on the module.

- NATIONAL ELECTRICAL CODE (NEC) — Contains guidelines for all types of electrical installations. The 1984 and later editions of the NEC contain Article 690, "Solar Photovoltaic Systems," which should be followed when installing a PV system.

- NATIONAL ELECTRICAL MANUFACTURERS ASSOCIATION (NEMA) — The organization that sets standards for some non-electronic products like junction boxes.

- NORMAL OPERATING CELL TEMPERATURE (NOCT) — The estimated temperature of a photovoltaic module when operating under 800 w/m2 irradiance, 20°C ambient temperature and wind speed of 1 meter per second. NOCT is used to estimate the nominal operating temperature of a module in its working environment.

- OPEN-CIRCUIT VOLTAGE (Voc) — The maximum possible voltage across a photovoltaic cell; the voltage across the cell in sunlight when no current is flowing.

- OPERATING POINT — The current and voltage that a photovoltaic module or array produces when connected to a load. The operating point is dependent on the load or the batteries connected to the output terminals of the array.

- PARALLEL CONNECTION — A way of joining solar cells or photovoltaic modules by connecting positive leads together and negative leads together; such a configuration increases the current, but not the voltage.

- PEAK POWER CURRENT — Amperes produced by a photovoltaic module or array operating at the voltage of the I-V curve that will produce maximum power from the module.

- PEAK POWER POINT — Operating point of the I-V (current-voltage) curve for a solar cell or photovoltaic module where the product of the current value times the voltage value is a maximum.

- PEAK SUN HOURS — The equivalent number of hours per day when solar irradiance averages 1,000 w/m2. For example, six peak sun hours means that the energy received during total daylight hours equals the energy that would have been received had the irradiance for six hours been 1,000 w/m2.

- PEAK WATT — A unit used to rate the performance of solar cells, modules, or arrays; the maximum nominal output of a photovoltaic device, in watts (Wp) under standardized test conditions, usually 1,000 watts per square meter of sunlight with other conditions, such as temperature specified.

- PHOTOVOLTAIC(S) (PV) — pertaining to the direct conversion of light into electricity.

- PHOTOVOLTAIC (PV) ARRAY — An interconnected system of PV modules that function as a single electricity-producing unit. The modules are assembled as a discrete structure, with common support or mounting. In smaller systems, an array can consist of a single module.

- PHOTOVOLTAIC (PV) CELL — The smallest semiconductor element within a PV module to perform the immediate conversion of light into electrical energy (direct current voltage and current). It may also be called a solar cell.

- PHOTOVOLTAIC (PV) CONVERSION EFFICIENCY — The ratio of the electric power produced by a photovoltaic device to the power of the sunlight incident on the device.

- PHOTOVOLTAIC (PV) DEVICE — A solid-state electrical device that converts light directly into direct current electricity of voltage-current characteristics that are a function of the characteristics of the light source and the materials in and design of the device. Solar photovoltaic devices are made of various semiconductor materials including silicon, cadmium sulfide, cadmium telluride, and gallium arsenide, and in single crystalline, multi-crystalline, or amorphous forms.

- PHOTOVOLTAIC (PV) EFFECT — The phenomenon that occurs when photons, the “particles” in a beam of light, knock electrons loose from the atoms they strike. When this property of light is combined with the properties of semiconductors, electrons flow in one direction across a junction, setting up a voltage. With the addition of circuitry, current will flow and electric power will be available.

- PHOTOVOLTAIC (PV) GENERATOR — The total of all PV strings of a PV power supply system, which are electrically interconnected.

- PHOTOVOLTAIC (PV) MODULE — The smallest environmentally protected, essentially planar assembly of solar cells and ancillary parts, such as interconnections, terminals, [and protective devices such as diodes] intended to generate direct current power under unconcentrated sunlight. The structural (load-carrying) member of a module can either be the top layer (superstrate) or the back layer (substrate).

- PHOTOVOLTAIC (PV) PANEL — Often used interchangeably with PV module (especially in one-module systems), but more accurately used to refer to a physically connected collection of modules (i.e., a laminate string of modules used to achieve a required voltage and current).

- PHOTOVOLTAIC (PV) SYSTEM — A complete set of components for converting sunlight into electricity by the photovoltaic process, including the array and balance of system components.

- PHYSICAL VAPOR DEPOSITION — A method of depositing thin, semi-conductor photovoltaic films. With this method, physical processes, such as thermal evaporation or bombardment of ions, are used to deposit elemental semiconductor material on a substrate.

- P-I-N — A semiconductor photovoltaic (PV) device structure that layers an intrinsic semiconductor between a p-type semiconductor and an n-type semiconductor; this structure is most often used with amorphous silicon PV devices.

- P/N — A semiconductor photovoltaic device structure in which the junction is formed between a p-type layer and an n-type layer.

- POLYCRYSTALLINE SILICON — A material used to make photovoltaic cells, which consist of many crystals unlike single-crystal silicon.

- POWER CONDITIONING EQUIPMENT — Electrical equipment, or power electronics, used to convert power from a photovoltaic array into a form suitable for subsequent use. A collective term for inverter, converter, battery charge regulator, and blocking diode.

- POWER CONVERSION EFFICIENCY — The ratio of output power to input power of the inverter.

- PULSE-WIDTH-MODULATED (PWM) WAVE INVERTER — A type of power inverter that produces high quality (nearly sinusoidal) voltage, at minimum current harmonics.

- PV — See photovoltaic(s).

- QUALIFICATION TEST — A procedure applied to a selected set of photovoltaic modules involving the application of defined electrical, mechanical, or thermal stress in a prescribed manner and amount. Test results are subject to a list of defined requirements.

- RATED MODULE CURRENT (A) — The current output of a photovoltaic module measured at standard test conditions of 1,000 w/m2 and 25 C cell temperature.

- REGULATOR — Prevents overcharging of batteries by controlling charge cycle – usually adjustable to conform to specific battery needs.

- REVERSE CURRENT PROTECTION — Any method of preventing unwanted current flow from the battery to the photovoltaic array (usually at night). See blocking diode.

- RIBBON (PHOTOVOLTAIC) CELLS — A type of photovoltaic device made in a continuous process of pulling material from a molten bath of photovoltaic material, such as silicon, to form a thin sheet of material.

- SERIES CONNECTION — A way of joining photovoltaic cells by connecting positive leads to negative leads; such a configuration increases the voltage.

- SERIES CONTROLLER — A charge controller that interrupts the charging current by open-circuiting the photovoltaic (PV) array. The control element is in series with the PV array and battery.

- SERIES REGULATOR — Type of battery charge regulator where the charging current is controlled by a switch connected in series with the photovoltaic module or array.

- SHUNT REGULATOR — Type of a battery charge regulator where the charging current is controlled by a switch connected in parallel with the photovoltaic (PV) generator. Shorting the PV generator prevents overcharging of the battery.

- SILICON (Si) — A semi-metallic chemical element that makes an excellent semiconductor material for photovoltaic devices. It crystallizes in face-centered cubic lattice like a diamond. It's commonly found in sand and quartz (as the oxide).

- SOLAR CELL — See photovoltaic (PV) cell.

- SOLAR CONSTANT — The average amount of solar radiation that reaches the earth's upper atmosphere on a surface perpendicular to the sun's rays; equal to 1353 watts per square meter or 492 BTU per square foot.

- SOLAR ENERGY — Electromagnetic energy transmitted from the sun (solar radiation). The amount that reaches the earth is equal to one billionth of total solar energy generated, or the equivalent of about 420 trillion kilowatt-hours.

- SOLAR-GRADE SILICON— Intermediate-grade silicon used in the manufacture of solar cells. Less expensive than electronic-grade silicon.

- SOLAR NOON — The time of the day, at a specific location, when the sun reaches its highest, apparent point in the sky; equal to true or due, geographic south.

- SOLAR RESOURCE — The amount of solar insolation a site receives, usually measured in kwh/m2/day, which is equivalent to the number of peak sun hours.

- SOLAR SPECTRUM — The total distribution of electromagnetic radiation emanating from the sun. The different regions of the solar spectrum are described by their wavelength range. The visible region extends from about 390 to 780 nanometers (a nanometer is one billionth of one meter). About 99 percent of solar radiation is contained in a wavelength region from 300 nm (ultraviolet) to 3,000 nm (near-infrared). The combined radiation in the wavelength region from 280 nm to 4,000 nm is called the broadband, or total, solar radiation.

- SOLAR THERMAL ELECTRIC SYSTEMS — Solar energy conversion technologies that convert solar energy to electricity by heating a working fluid to power a turbine that drives a generator. Examples of these systems include central receiver systems, parabolic dish, and solar trough.

- STAEBLER-WRONSKI EFFECT — The tendency of the sunlight to electricity conversion efficiency of amorphous silicon photovoltaic devices to degrade (drop) upon initial exposure to light.

- STAND-ALONE SYSTEM — An autonomous or hybrid photovoltaic system not connected to a grid; may or may not have storage, but most stand-alone systems require batteries or some other form of storage.

- STAND-OFF-MOUNTING — Technique for mounting a photovoltaic array on a sloped roof, which involves mounting the modules a short distance above the pitched roof and tilting them to the optimum angle.

- STANDARD REPORTING CONDITIONS (SRC) — A fixed set of conditions (including meteorological) to which the electrical performance data of a photovoltaic module are translated from the set of actual test conditions.

- STRING — A number of photovoltaic modules or panels interconnected electrically in series to produce the operating voltage required by the load.

- SUBSTRATE — The physical material upon which a photovoltaic cell is applied.

- SUPERSTRATE — The covering on the sunny side of a photovoltaic (PV) module, providing protection for the PV materials from impact and environmental degradation while allowing maximum transmission of the appropriate wavelengths of the solar spectrum.

- SYSTEM AVAILABILITY — The percentages of time (usually expressed in hours per year) when a photovoltaic system will be able to fully meet the load demand.

- SYSTEM OPERATING VOLTAGE — The photovoltaic array output voltage under load. The system operating voltage is dependent on the load or batteries connected to the output terminals.

- TAG-OUT — A method of tagging, labeling, or otherwise marking an isolation device during a hazard abatement operation to prevent accidental removal of device.

- TEMPERATURE FACTORS — It is common for three elements in photovoltaic system sizing to have distinct temperature corrections: a factor used to decrease battery capacity at cold temperatures; a factor used to decrease PV module voltage at high temperatures; and a factor used to decrease the current-carrying capability of wire at high temperatures.

- THIN FILM — A layer of semiconductor material, such as copper indium diselenide or gallium arsenide, a few microns or less in thickness, used to make photovoltaic cells.

- TILT ANGLE — The angle at which a photovoltaic array is set to face the sun relative to a horizontal position. The tilt angle can be set or adjusted to maximize seasonal or annual energy collection.

- TOTAL AC LOAD DEMAND — The sum of the alternating current loads. This value is important when selecting an inverter.

- TRACKING ARRAY — A photovoltaic (PV) array that follows the path of the sun to maximize the solar radiation incident on the PV surface. The two most common orientations are (1) one axis, where the array tracks the sun east to west and (2) two-axis tracking, where the array points directly at the sun at all times. Tracking arrays use both the direct and diffuse sunlight. Two-axis tracking arrays capture the maximum possible daily energy.

- UTILITY-INTERACTIVE INVERTER — An inverter that can function only when tied to the utility grid, and uses the prevailing line-voltage frequency on the utility line as a control parameter to ensure that the photovoltaic system's output is fully synchronized with the utility power.

- WAFER — A thin sheet of semi-conductor (photovoltaic material) made by cutting it from a single crystal or ingot.

- ZENITH ANGLE — The angle between the direction of interest (of the sun, for example) and the zenith (directly overhead).

RENEWABLE ENERGY SOURCE, ON-SITE — Energy derived from solar radiation, wind, waves, tides, landfill gas, biomass, or the internal heat of the earth. The energy system providing on-site renewable energy is located on or adjacent to the building site, and generates energy for use on the building site.

ROOF COVERING — The covering applied to the roof deck for weather resistance, fire classification or appearance.

SMART GROWTH — Land use development practices that create more resource efficient and livable communities, with accessible land use patterns. It is an alternative to sprawl development patterns.

SOLAR INSOLATION — A measure of solar radiation energy received on a given surface area in a given time, expressed as average irradiance in kilowatt-hours per square meter per day (kwh/(m^2·day).

SOLAR PHOTOVOLTAIC EQUIPMENT — Devices such as solar cells and inverters that are used to transform solar radiation into energy.

SOLAR REFLECTANCE — A measure of the ability of a surface material to reflect sunlight. It is the fraction of solar flux, including the visible, infrared, and ultraviolet wavelengths, reflected by a surface, expressed as a percentage on a scale of 0 to 1. Solar reflectance is also referred to as "albedo."

SOLAR REFLECTANCE INDEX (SRI) — A value that incorporates both solar reflectance and infrared emittance in a single measure to represent a material's temperature in the sun. SRI quantifies how hot a surface would get relative to standard black and standard white surfaces. SRI is calculated using equations based on previously measured values of solar reflectance and infrared emittance as laid out in ASTM E1980. SRI is expressed as a fraction, 0.0 to 1.0, or percentage, 0 percent to 100 percent.

SOLAR THERMAL EQUIPMENT — A device that uses solar radiation to heat water or air for use within the facility for service water heating, space heating, or space cooling.

STANDBY MODE (ELEVATOR) — An operating mode during periods of inactivity in which electrical loads are reduced to conserve energy. For elevators, standby mode begins up to 5 minutes after an elevator is unoccupied and has parked and completed its last run and ends when the doors are re-opened. For escalators and moving walkways, standby mode begins after traffic has been absent for up to 5 minutes and ends when the next passenger arrives.

SUSTAINABLE — Providing the needs of the present without detracting from the ability to fulfill the needs of the future.

TRADITIONAL URBAN ENVIRONMENTS — Places with development pattern, intensity, and design characteristics that combine to make frequent walking and transit use attractive and efficient choices, as well as provide for automobiles and convenient and accessible parking. Traditional urban environments typically have mixed-land uses in close proximity to one another, building entries that front directly on the street, building, landscape and thoroughfare design that is pedestrian-scale, relatively compact development, a highly-connected, multimodal circulation network, usually with a fine "grain" created by relatively small blocks, thoroughfares and other public spaces that contribute to "place-making" (the creation of unique locations that are compact, mixed-use, and pedestrian- and transit-oriented, that have a strong civic character and with lasting economic value).

UNINTERRUPTED POWER SUPPLY (UPS) — An electrical apparatus that provides emergency power to a load when the input power source, typically the utility mains, fails. A UPS differs from an auxiliary or emergency power system or standby generator in that it will provide instantaneous or near-instantaneous protection from input power interruptions by means of one or more attached batteries and associated electronic circuitry for low power users, and or by means of diesel generators and flywheels for high power users.

URBAN VILLAGE — An urban village is a planning and design concept that refers to an urban form that is typically characterized by medium density development, mixed-use zoning, good public transit provisions with an emphasis on urban designing, a walkable community, and open public space. Urban villages are seen as an alternative to recent patterns of urban development in many cities, especially urban sprawl and modernization.

VEGETATIVE ROOF:

- EXTENSIVE VEGETATION ROOF — A low profile roof with a growth media less than 8 inches in depth, composed of plants that can thrive in a rooftop environment with limited water, shallow roots, and sparse nutrients.

- INTENSIVE VEGETATION ROOF — A high profile roof with a growth media 8 inches or more in depth that can support a wide range of vegetables, shrubs, and small trees.

WALKABLE COMMUNITIES — Walkable communities possess these two attributes: first, by location, in a mixed-use area within an easy and safe walk of goods (such as housing, offices, and retail) and services (such as transportation, schools, and libraries) that a community resident or employee needs on a regular basis. Second, by definition, walkable communities make pedestrian activity possible, thus expanding transportation options, and creating a streetscape that better serves a range of users—pedestrians, bicyclists, transit riders, and automobiles. To foster walkability, communities must mix land uses and build compactly, and ensure safe and inviting pedestrian corridors.

WASTE ENERGY RECOVERY — The application and use of systems and equipment to capture and reuse any form of energy that would otherwise be discarded and not otherwise be used by the building and its systems.

WATER

- GREY WATER — Untreated wastewater that has not come into contact with wastewater from water closets, urinals, kitchen sinks, or dishwashers. Grey water includes but is not limited to wastewater from bathtubs, showers, lavatories, clothes washers, and laundry trays.

- MUNICIPAL RECLAIMED WATER — Wastewater that has been reclaimed, recycled, reused, or treated by a municipality for specific non-potable uses.

- NON-POTABLE WATER — Water that is not safe for drinking, personal, or culinary utilization.

- POTABLE WATER — Water that is free from impurities present in amounts sufficient to cause disease or harmful physiological effects and conforming to the bacteriological and chemical quality requirements of the Public Health Service Drinking Water Standards or the regulations of the public health authority having jurisdiction.

- RAINWATER COLLECTION AND CONVEYANCE SYSTEM — Rainwater collection system components extending between the collection surface and the storage tank that convey collected rainwater, usually through a gravity system.

- RECLAIMED WATER — Non-potable water that has been derived from the treatment of wastewater by a facility licensed or permitted to produce water meeting the jurisdiction's water requirements for its intended uses. Also known as "Recycled Water."

- RETENTION (STORMWATER) — The permanent holding of storm water on a site, preventing the water from leaving the site as surface drainage and allowing for use of the water on site, or loss of the water through percolation, evaporation, or absorption by vegetation.

WIND POWER CLASS — As a renewable energy source, wind is classified according to wind power classes based on typical wind speeds. These classes range from Class 1 (the lowest) to Class 7 (the highest). At the 50-meter (164 feet) height, wind power Classes 4 and higher are considered good for development.

APPENDIX C

C. Green Organizations

Many organizations are now engaged in the quest for sustainability; some have been involved for decades; others are more recent additions to the landscape. The leading national organizations with a focus on sustainable construction are listed in the table below, with a brief synopsis of their efforts and functions. In addition to these organizations are a host of local and regional organizations with a focus on specific geographic areas, as well as many organizations whose missions aren't primarily concentrated on sustainability, but have included it as a component of their respective missions.

GREEN ORGANIZATIONS		
NAME	DESCRIPTION	PRIMARY FUNCTION
United States Green Building Council *Established 1993* www.usgbc.org	The U.S. Green Building Council (USGBC) established in 1993 is a Washington, D.C.-based 501(c)(3) nonprofit organization committed to a prosperous and sustainable future for our nation through cost-efficient and energy-saving green buildings. USGBC works toward its mission of market transformation through its LEED green building certification program, robust educational offerings, a nationwide network of chapters and affiliates, the annual Greenbuild International Conference & Expo, and advocacy in support of public policy that encourages and enables green buildings and communities.	Provides the most widely used green rating system in the U.S. (LEED)
United States Department of Energy *Established 1977* www.energy.gov	The Department of Energy (DOE) contributes to the future of the Nation by ensuring energy security, maintaining the safety, security and reliability of the nuclear weapons stockpile, cleaning up the environment from the legacy of the Cold War, and developing innovations in science and technology. After more than 30 years in existence, the Department now operates 24 preeminent research laboratories and facilities, four power marketing administrations, and an energy information administration, as well as managing the environmental cleanup from 50 years of nuclear defense activities that impacted two million acres in communities across the country. DOE Staff and Support Offices provide administrative, management, and oversight support to the DOE's Program Offices to assist them in the successful accomplishment of their respective missions.	Research and development of energy conservation and alternative energy production technologies; incentive based programs for energy conservation by business & consumers

GREEN ORGANIZATIONS		
NAME	DESCRIPTION	PRIMARY FUNCTION
American Society of Heating, Refrigerating and Air Conditioning Engineers *Established 1894* www.ashrae.org	American Society of Heating, Refrigerating and Air Conditioning Engineers (ASHRAE), founded in 1894, is an international organization of 51,000 persons. ASHRAE fulfills its mission of advancing heating, ventilation, air conditioning and refrigeration to serve humanity and promote a sustainable world through research, standards writing, publishing and continuing education.	Development of standards; education of design community; certification of designers and installers
United States Environmental Protection Agency *Established 1970* www.epa.gov	The United States Environmental Protection Agency (EPA) mission is to protect human health and to safeguard the natural environment -- air, water and land -- upon which life depends. The EPA was established in 1970 EPA's purpose is to ensure that: • all Americans are protected from significant risks to human health and the environment where they live, learn and work; • national efforts to reduce environmental risk are based on the best available scientific information; • federal laws protecting human health and the environment are enforced fairly and effectively; • environmental protection is an integral consideration in U.S. policies concerning natural resources, human health, economic growth, energy, transportation, agriculture, industry, and international trade, and these factors are similarly considered in establishing environmental policy; • all parts of society -- communities, individuals, businesses, and state, local and tribal governments -- have access to accurate information sufficient to effectively participate in managing human health and environmental risks; • environmental protection contributes to making our communities and ecosystems diverse, sustainable and economically productive; and • The United States plays a leadership role in working with other nations to protect the global environment.	Primarily a regulatory agency; develops rules and regulations to protect all components of the environment

GREEN ORGANIZATIONS		
NAME	DESCRIPTION	PRIMARY FUNCTION
Green Building Initiative *Established 2004* www.thegbi.org	The Green Building Initiative (GBI) is a not for profit organization established in 2004 whose mission is to accelerate the adoption of building practices that result in energy-efficient, healthier and environmentally sustainable buildings by promoting credible and practical green building approaches for residential and commercial construction. The Green Building Initiative™ was originally conceived as a way to bring green building into the mainstream by helping local Home Builder Associations (HBAs) develop green building programs modeled after the National Association of Home Builders' (NAHB) Model Green Home Building Guidelines. While developing a strategic partnership with the NAHB, an opportunity emerged to bring a revolutionary learning tool developed in Canada to commercial builders in the United States. Near the end of 2004, the GBI finalized an agreement to bring the Green Globes™ environmental assessment and rating tool into the U.S. market.	Industry coalition focused on cost effective solutions to green construction needs.
Sustainable Building Industry Council *Established 1980* www.sbicouncil.org	The Sustainable Buildings Industry Council (SBIC) which was founded in 1980 is an independent, non-profit organization and a pioneer advocate of the whole building approach to sustainable facilities. Founded in 1980 as the Passive Solar Industries Council by the major building trade groups, large corporations, small businesses, and individual practitioners who recognized that energy and resource efficient design and construction are imperative to a sustainable built environment. Today, we view energy use and sustainability within a larger context of benefits related to productivity and overall efficiency, health and safety, serviceability, and other performance factors. Our ideas are reflected in the Whole Building Design Guide, and in recent federal legislation mandating high-performance buildings, as well as the High-Performance Building Council agenda.	Promulgates the most widely utilized building and fire codes in the U. S.; currently in process of producing the International Green Construction Code (IgCC), which will be a compatible addition to the other I-Codes. The Green Code is intended as an overlay regulation to the other International Codes, not a stand-alone model code.

GREEN ORGANIZATIONS		
NAME	DESCRIPTION	PRIMARY FUNCTION
International Code Council *Established 1994* www.iccsafe.org	The International Code Council (ICC) which was established in 1994 is a membership association dedicated to building safety and fire prevention. ICC develops the codes and standards used to construct residential and commercial buildings, including homes and schools. The International Codes, or I-Codes, published by ICC, provide minimum safeguards for people at home, at school and in the workplace. The I-Codes are a complete set of comprehensive, coordinated building safety and fire prevention codes. Building codes benefit public safety and support the industry's need for one set of codes without regional limitations. Fifty states and the District of Columbia have adopted the I-Codes at the state or jurisdictional level. Federal agencies including the Architect of the Capitol, General Services Administration, National Park Service, Department of State, U.S. Forest Service and the Veterans Administration also enforce the I-Codes. The Department of Defense references the International Building Code for constructing military facilities, including those that house U.S. troops, domestically and abroad. Puerto Rico and the U.S. Virgin Islands enforce one or more of the I-Codes.	Promulgates the most widely utilized building and fire codes in the U. S.; currently in process of producing the International Green Construction Code (IgCC), which will be a compatible addition to the other I-Codes. The Green Code is intended as an overlay regulation to the other International Codes, not a stand-alone model code.
Alliance to Save Energy *Established 1977* www.ase.org	Founded in 1977, the Alliance to Save Energy (ASE) is a non-profit coalition of business, government, environmental and consumer leaders. The ASE supports energy efficiency as a cost-effective energy resource under existing market conditions and advocates energy-efficiency policies that minimize costs to society and individual consumers, and that lessen greenhouse gas emissions and their impact on the global climate. To carry out its mission, the Alliance to Save Energy undertakes research, educational programs, and policy advocacy, designs and implements energy-efficiency projects, promotes technology development and deployment, and builds public-private partnerships, in the U.S. and other countries.	Advocates for energy saving practices throughout the U.S. and across the globe.

GREEN ORGANIZATIONS		
NAME	DESCRIPTION	PRIMARY FUNCTION
New Buildings Institute *Established 1998* www.newbuildings.org	New Buildings Institute (NBI) is a nonprofit organization working to improve energy performance of commercial buildings. It was established in 1998. We work collaboratively with commercial building market players—governments, utilities, energy efficiency advocates and building professionals—to remove barriers to energy efficiency, including advocating for advanced design practices, improved technologies, public policies and programs that improve energy efficiency. We also develop and offer guidance to individuals and organizations on designing and constructing energy-buildings through our Advanced Buildings™ suite of tools and resources. While NBI is working to achieve net-zero energy buildings—those that meet all power needs through renewable resources—we recognize that they are not easily attainable today. The good news is that buildings with significantly better performance than current standards are possible. NBI's current efforts a re working to provide the policy and program direction and promote design practices and technologies that will result in buildings that are better for people and the environment	Advocates for energy conservation through regulations, education, and research activities.

GREEN ORGANIZATIONS		
NAME	DESCRIPTION	PRIMARY FUNCTION
Association of State Energy Officials *Established 1986* www.naseo.org	The National Association of State Energy Officials (NASEO) is the only national non-profit organization whose membership includes the governor-designated energy officials from each state and territory. NASEO was formed by the states and through an agreement with the National Governors Association in 1986. The organization was created to improve the effectiveness and quality of state energy programs and policies, provide policy input and analysis, share successes among the states, and to be a repository of information on issues of particular concern to the states and their citizens. NASEO is an instrumentality of the states and derives basic funding from the states and the federal government. Members are senior officials from the State and Territory Energy Offices, as well as affiliates from the private and public sectors. Member state agencies work on an extremely wide range of energy programs and policies, including: • Energy efficiency in homes, commercial/public buildings, industry and agriculture; • Renewable energy, such as solar, wind, geothermal and biomass; • Residential, commercial and institutional energy building codes; • Transportation and heating fuel supplies, pricing and distribution; • Oil, natural gas, electricity and other forms of energy production and distribution; • Energy-environment integration (such as using conservation to reduce air emissions); • New and emerging high efficiency transportation fuels and technologies; and • Energy security and emergency preparedness, and many other energy matters. States manage and invest more than $3 billion of their own funds derived from appropriations and system benefit charges each year.	Each state has an energy official; this association represents those individuals to assure state issues are heard at the national level

APPENDIX D

D. Case Studies

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APPENDIX E

E. Works Cited

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14. National Fire Protection Association. NFPA 1620. “Standard for Pre-Incident Planning.” 2010 edition. http://www.nfpa.org/aboutthecodes/AboutTheCodes.asp?DocNum=1620.

15. “Unacceptable Substitute Refrigerants.” U.S. Department of Environmental Protection (EPA). http://www.epa.gov/ozone/snap/refrigerants/lists/unaccept.html.

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APPENDIX F

F. FM Global Tables 14

Table 14: Controlled Burn Air Emissions (Table 3-1 extracted from Reference 38)

Criteria Pollutants	Emissions (lbs/burn) 17 September No Sprinkler	Emissions (lbs/burn) 1 October Sprinkler	Ratio of Emissions, No Sprinkler vs. Sprinkler
CO	26.42	0.23	113
NO2	0.14	0.14	1
SO2	0.48	0.20	2.4
Total VOC - THC (as CH4)	3.77	0.02	184
Particulate	17.76	1.39	13

Greenhouse Gases	Emissions (lbs/burn) 17 September No Sprinkler	Emissions (lbs/burn) 1 October Sprinkler	Ratio of Emissions, No Sprinkler vs. Sprinkler
CO2	793.95	12.98	61
Methane	1.80	0.01	130
Nitrous Oxide (N2O)	0.17	0.02	7

Metals	Emissions (lbs/burn) 17 September No Sprinkler	Emissions (lbs/burn) 1 October Sprinkler	Ratio of Emissions, No Sprinkler vs. Sprinkler
Antimony (Sb)	0.017	0.00056	30
Arsenic (As)	0.00056	0.00023	2.5
Barium (Ba)	0.012	0.012	1
Beryllium (Be)	0.0014	0.000056	25
Cadmium (Cd)	0.0014	0.00012	12
Total chromium (Cr)	0.050	0.015	3.3
Copper (Cu)	0.016	0.0091	1.8
Mercury (Hg)	0.0082	0.0048	1.7
Lead (Pb)	0.013	0.0087	1.5
Manganese (Mn)	0.081	0.010	8.3
Nickel (Ni)	0.043	0.0095	4.6
Phosphorous (P)	0.012	0.0084	1.5
Selenium (Se)	0.012	0.00063	19
Silver (Ag)	0.00052	0.00026	2
Thallium (Tl)	0.00070	0.00028	2.5
Zinc (Zn	0.147	0.018	8.4

Table 14: Controlled Burn Air Emissions (Table 3-1 extracted from Reference 38) (Cont'd)

Air Toxics and Other Pollutants	Emissions (lbs/burn) 17 September No Sprinkler	Emissions (lbs/burn) 1 October Sprinkler	Ratio of Emissions, No Sprinkler vs. Sprinkler
Acetaldehyde	0.32	0.0016	200
Acrolein	0.21	0.35	0.6
Benzene	0.69	2.06	0.3
Ethanol	0	1.44	0
Ethylene	0.51	0.012	43
Formaldehyde	0.15	0.0092	17
Hydrogen Fluoride (HF)	0.0026	0.0045	0.6
Hydrogen Chloride (HCl)	0	0.016	0
Isopropyl Alcohol (IPA)	0	0.35	0
Methanol	0.20	0.037	5.5
NH3	0.0026	0	---
NO	0.91	0.021	44
Toluene	0.58	0.084	6.9
Hydrogen Cyanide (HCN)	0.07	0.013	5.4
1,1,1-Trichloroethane	0.46	0.56	0.8
Bromoform	0	0.0011	0
Carbon Disulfide	25.15	0.037	678
Chloroform	0.046	0.012	3.8
Methyl Ethyl Ketone (MEK)	3.52	0.053	67
Iodo-methane	1.042	0.077	14
1,2,3-Trichloropropane	28.31	0	---
Carbon Tetrachloride	0.13	0	---
m(eta)-Xylene	0.057	0.016	3.5
o(rtho)-Xylene	2.97	0	---
p(ara)-Xylene	7.22	0.90	8
Total Xylenes	10.24	0.91	11
Methyl Isobutyl Ketone (MIBK)	3.16	0.032	98

Table 14: Controlled Burn Air Emissions (Table 3-1 extracted from Reference 38) (Cont'd)

Semi-Volatile Organic Air Toxics	Emissions (lbs/burn) 17 September No Sprinkler	1 October Sprinkler	Ratio of Emissions, No Sprinkler vs. Sprinkler
1,2,4-Trichlorobenzene	0	0	---
1,2-Dichlorobenzene	0	0	---
1,3-Dichlorobenzene	0	0	---
1,4-Dichlorobenzene	0	0	---
1-Chloronaphthalene	0	0	---
1-Methylnaphthalene	0.0056	0.0017	3.3
2,4,5-Trichlorophenol	0	0	---
2,4,6-Trichlorophenol	0	0	---
2,4-Dichlorophenol	0	0	---
2,4-Dimethylphenol	0	0	---
2,4-Dinitrophenol	0	0	---
2,4-Dinitrotoluene	0	0	---
2,6-Dinitrotoluene	0	0	---
2-Chloronaphthalene	0	0	---
2-Chlorophenol	0	0	---
2-Methylnaphthalene	0.0065	0.0011	5.7
2-Methylphenol	0.0095	0.0017	5.5
2-Nitroaniline	0	0	---
2-Nitrophenol	0	0	---
3 & 4-methylphenol	0.015	0.0020	7.6
3,3'-Dichlorobenzidine	0	0	---
3-Nitroaniline	0	0	---
4,6-Dinitro-2-methylphenol	0	0	---
4-Bromophenyl phenyl ether	0	0	---
4-Chloro-3-Methylphenol	0	0	---
4-Chloroaniline	0	0	---
4-Chlorophenyl phenyl ether	0	0	---
4-Nitroaniline	0	0	---
4-Nitrophenol	0	0	---
Acenaphthene	0	0	---
Acenaphthylene	0.021	0.00029	75
Aniline	0	0	---
Anthracene	0.0032	0.00023	14
Benzidine	0	0	---
Benzo(a)anthracene	0.0017	0.00023	7.4
Benzo(a)pyrene	0.0018	0.00029	6.1
Benzo(b)fluoranthene	0.0029	0.00023	13
Benzo(g,h,i)perylene	0.0021	0.00023	9
Benzo(k)fluoranthene	0.00088	0.00029	3.1

Table 14: Controlled Burn Air Emissions (Table 3-1 extracted from Reference 38) (Cont'd)

Semi-Volatile Organic Air Toxics	Emissions (lbs/burn) 17 September No Sprinkler	Emissions (lbs/burn) 1 October Sprinkler	Ratio of Emissions, No Sprinkler vs. Sprinkler
Benzoic Acid	0.15	0.0011	130
Benzyl Alcohol	0.0011	0.00029	3.7
Benzyl butyl phthalate	0.00026	0.0044	0.1
Biphenyl	0.013	0.0011	12
Bis(2-chloroethoxy)methane	0	0	---
Bis(2-chloroethyl)ether	0	0	---
Bis(2-chloroisopropyl)ether	0	0	---
Bis(2-ethylhexyl)phthalate	0.15	0.061	2.5
Carbazole	0	0	---
Chrysene	0.0013	0.00023	5.5
Dibenz(a,h)anthracene	0.00042	0.00023	1.8
Dibenzofuran	0	0	---
Diethyl phthalate	0	0	---
Dimethyl phthalate	0	0	---
Di-N-butyl phthalate	0	0	---
Di-N-octyl phthalate	0	0	---
Fluoranthene	0.0085	0.00061	14
Fluorene	0.0035	0.00023	15
Hexachlorobenzene	0	0	---
Hexachlorobutadiene	0	0	---
Hexachlorocyclopentadiene	0	0	---
Hexachloroethane	0	0	---
Indeno(1,2,3-cd)pyrene	0.0019	0.00029	6.7
Isophorone	0	0	---
Naphthalene	0.092	0.0012	78
Nitrobenzene	0	0	---
N-Nitrosodimethylamine	0	0	---
N-Nitroso-di-n-propylamine	0	0	---
N-Nitrosodiphenylamine	0	0	---
Pentachlorophenol	0	0	---
Phenanthrene	0.024	0.00055	44
Phenol	0.075	0.00085	88
Pyrene	0.0067	0.00029	23

Note: Carbon dioxide (CO2), nitrous oxide (N2O), and methane (CH4) are greenhouse gases that were measured during the controlled burns. A result of zero indicates that the constituent was either not detected or controlled burn test results were below the detection limit of the analysis. A dash (---) indicates that ratio was not calculated, because a constituent was not detected in the analysis.