

**Fire Safety Design and Sustainable Buildings: Challenges and Opportunities
Report of a National Symposium**

November 7 & 8, 2012

Courtyard Marriott – Magnificent Mile, Chicago, Illinois

**Co-organized by
National Fire Protection Association
Fire Protection Research Foundation**

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Abstract

The National Fire Protection Association (NFPA) and the Fire Protection Research Foundation (the Foundation) co-organized a one-and-a-half day symposium, “Fire Safety Design and Sustainable Buildings: Challenges and Opportunities,” that took place November 7 and 8, 2012, at the Courtyard Marriott Chicago Downtown/Magnificent Mile. The symposium featured perspectives from architects, engineers, and members of the sustainability community and research institutions on the challenges and opportunities of integrating fire safety and sustainable design.

Many new commercial facilities are designed and constructed with an objective of achieving a green certification. In addition, green building codes are being developed that dictate requirements for maintaining the same level of fire safety embodied in our current codes. However, many sustainable building features and products, singly or together, may have an impact on fire safety measures — unless there is a design approach included to mitigate those effects.

Conversely, the impact that required fire safety features have on the sustainability of a building can be reduced with appropriate design strategies. Additionally, fire itself is a very negative event in consideration of environmental sustainability over the life of a building, but there is no measure in green rating systems to account for the sustainability benefits that fire safety features provide.

The symposium was comprised of three sessions that address these issues: sustainable building design features and impacts on fire safety, fire safety features and impacts on sustainable building design, and life cycle sustainability of structures including fire safety features and practices. The goal of this event was to bring the fire protection and architectural communities together to discuss these topics, share ideas and best practices for sustainable fire safe design, and to chart a path forward for the future.

Thanks are extended to the program committee members:

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Introduction

The National Fire Protection Association (NFPA) and the Fire Protection Research Foundation (the Foundation) co-organized a one-and-a-half day symposium titled “Fire Safety Design and Sustainable Buildings: Challenges and Opportunities” on November 7 and 8, 2012, in Chicago. The symposium featured perspectives from architects, engineers, and members of the sustainability community and research institutions on the challenges and opportunities of integrating fire safety and sustainable design.

The symposium has presented both an opportunity and a challenge for the fire protection engineering and design communities. There is a potential for significant innovation for safety professionals to manage new hazards posed by sustainable buildings, but the challenge is moving the industry rapidly enough to keep up with these changes. Economic, social, and political factors have driven the emergence and priority of sustainable buildings worldwide; therefore, the fire safety community’s only option is to adapt and help to steer the direction of this movement to ensure the safety of future sustainable construction as well as increase the efficiency and sustainability of its own protection systems.

This is a tremendous task that will require directed research, new trends in industry, a broad approach to design and consulting, and the cooperation of regulatory and political bodies. The question is, is the fire protection community ready to make sustainability a priority as well? The impact of sustainability on fire safety is a part of the Foundation’s strategic research plan and will continue to be. However, research thus far has been limited, primarily because it requires the Foundation to reach out to new communities. This symposium was a first effort to bring the fire protection and architectural communities together to discuss these topics, share ideas and best practices for sustainable fire safe design, and chart a path forward.

The proceedings that follow contain summaries from each of the symposium presentations as well as the panel discussion that wrapped up the event. At the end, recommendations on future efforts are provided.

Summary of Presentations

Session 1: Sustainable Building Design Features and Impacts on Fire Safety

*Moderator: Peter Weismantle, Director of Supertall Building Technology,
Adrian Smith + Gordon Gill Architecture*

Welcoming Remarks

Carl Baldassarra, Executive Vice President, The RJA Group

Carl Baldassarra opened the event with a historical overview of the fire problem in the built environment, tracking the progressive changes undertaken to lower human and property losses due to fire. He recalled the 1973 watershed report, “America Burning,”¹ which put the nation’s fire problem in the spotlight. With a goal to reduce fire losses by 50 percent within a generation, the report brought the fire problem to the forefront of the public’s, government’s, and researcher’s attention, and a coordinated approach was developed that far exceeded expectations. He stressed that fire safety advocates would say this advance is not enough, and in many ways this is true. It is not that fire safety is changing, but that the actual building environment is adapting and changing, and there is a need to address challenges proactively. This presents the fire safety community with an ever-present task to stay at the forefront of building design to prevent large-scale disasters and dangerous trends. Just as the fire safety community responded to new hazards, such as the use of foam plastic insulation in construction during the 1970s, the community is presented with the challenge to adapt to new hazards introduced by sustainable design.

A notable report by the National Association of State Fire Marshals (NASFM), *Bridging the Gap: Fire Safety and Green Buildings*,² stated that there “...is a lack of knowledge about green buildings in the fire safety community ... due to the fact that many fire officials have yet to deal with green buildings in their work.” The report goes on: “At this point, NASFM is not sure how best to address this challenge and exactly where these problems and opportunities lie.” Carl highlighted that the answer just does not exist yet; therefore, these quotes establish the challenges faced by the fire safety community.

Potential scenarios such as passive air flows, double-wall glass exteriors, integrated radiant systems, photovoltaic cells, green roofs, new insulation materials, and the removal of fire retardants in furniture will all need to be addressed by fire protection professionals in the near future. Emerging issues include:

- Considering equivalency provisions or performance-based design options to resolve issues between existing codes and green initiatives
- Recognizing the developing issues relating to interaction between existing codes and green initiatives
- Recognizing the value of the early addition of a fire protection professional as part of the sustainable design team

¹ The National Commission on Fire Prevention and Control. 1973. *America Burning*. Washington DC: U.S. Government Printing Office. <http://www.usfa.fema.gov/downloads/pdf/publications/fa-264.pdf>

² Tidwell, Jim, and Jack J. Murphy. August 2010. “Bridging the Gap: Fire Safety and Green Buildings.” National Association of Fire Marshals. http://www.firemarshals.org/pdf/NASFM_greenfire_guide.pdf

Sustainability in buildings is not a fad. Regulations have been adopted by elected officials, the marketplace is changing (e.g., energy costs and sources), and energy conscious building owners all have cemented the direction of the building industry. It is now the job of the fire protection community to address these challenges. The good news is that the laws of physics and nature apply equally to green design and traditional design.

“The solution, when found, will be obvious.” — Anonymous

Keynote: The Language of Performance

Fire Safety Design and Sustainable Buildings: Challenges and Opportunities

Gordon Gill, Partner, Adrian Smith + Gordon Gill Architecture

Gordon Gill’s keynote address outlined what is ahead of us as he talked about the design of the world’s first net-zero energy skyscraper. There is a steep upward trend of people living in urban areas. In 2000, 36 percent of the world’s population lived in urban areas; this increased to 50 percent in 2010, and by 2030 it is expected to be 60 percent. This is especially relevant in China where there are currently 669 cities with over 1 million people, compared to only nine cities with that population in the United States. This increasing flow of populations into urban centers worldwide is driving urban design to new heights while at the same time increasingly emphasizing sustainability as a necessary part of the design process.

Buildings contribute over 70 percent of CO₂ emissions, three times more than cars do. To combat this, Gordon described the “language of performance,” coupling the relationship of form and environmental design. Technology and sustainability must be integrated into the process of a building design rather than being added to the end product, all while remaining economically viable.

Gordon presented several examples, including the Pearl River Tower in China, which used a modified body to direct wind through three fuselages at three levels and convert the wind into electricity while reducing the structural load on the building, which reduced material and construction costs. The example follows the concept of harnessing available environmental assets and using them efficiently, and not just energy: operational costs, cultural sustainability, and increased space (reducing drop spaces) were all considered.

He highlighted other design examples such as the Masdar Headquarters building in Abu Dhabi, which includes the incorporation of wind cones that span the height of the building and use passive ventilation so that the environment within the cone is 20 degrees cooler than the outside temperature without air conditioning while providing courtyard green space in the building.

Gordon also talked about a study that his firm has completed called the Chicago Central Area DeCarbonization Plan,³ which focuses on reducing the energy consumption of existing buildings instead of continuing to try to find alternative energy means to provide the current energy needs of these buildings. In the end, he posed new ideas related to fire safety, such as building envelopes to be used as a means of egress.

³ Smith, Adrian. 2011. *Toward Zero Carbon: The Chicago Central Area DeCarbonization Plan*. Chicago, IL: Images Publishing Dist Ac. <http://www.amazon.com/Toward-Zero-Carbon-Chicago-DeCarbonization/dp/1864704330>

Fire Safety Challenges of Green Buildings

Brian Meacham, Associate Professor, Worcester Polytechnic Institute

Brian Meacham presented an overview of fire safety challenges of green buildings that were studied as part of a Fire Protection Research Foundation Project. The results identified documented fire incidents in the built inventory of green buildings along with a set of specific elements in green building design, including configuration and materials, which, without mitigating strategies, increase fire risk, decrease safety, or decrease building performance in comparison with conventional construction. A synopsis of this worldwide incident search was presented, highlighting issues in several areas where future research is needed.

Competing objectives of sustainability and fire safety were presented, including natural ventilation versus smoke management, low conductivity thermal insulation versus material flammability, material toxicity versus fire retardant qualities, natural materials versus lightweight construction, green exteriors versus fuel loads and fire fighter access, and green and alternative energy roofs versus fire fighter access. To date, only limited research has investigated these potential fire issues in green buildings, despite many future dangers posed in sustainable buildings. To address these issues, Brian presented a green element/hazard matrix that highlights the materials, systems, or attributes that contribute to hazards and potential mitigation strategies, which can be found in the project report.⁴

A review of fire-rating schemes was also conducted and, although the German Sustainable Building Council and BREEAM-in-USE had some fire objectives, none had explicit fire safety objectives. Also, no current fire incident reporting systems in the United States or other countries surveyed specifically collect and track data on fire incidents in green buildings or on items labeled as green building elements or features.

Brian advocated a move toward a risk-analysis approach, where the relative fire risk or hazard can be illustrated, and some potential mitigation strategies can be identified. Some key recommendations he made were the following:

- Confront the lack of reported fire experience with green buildings and green building elements, especially in buildings that have a green rating or certification, and require modifications to data reporting systems such as the National Fire Incident Reporting System (NFIRS)
- Address the lack of analysis on fire risk associated with green building elements with a more extensive research project that would review existing studies and reports on fire performance of green building elements
- Develop a repository of positive case studies in green buildings and include analyses that were done to prove they are safe

He also advocated research to:

- Develop a clear set of comparative performance data between green and conventional methods.

⁴ Meacham, Brian, Brandon Poole, Juan Echeverria, and Raymond Cheng. November 2012. "Fire Safety Challenges of Green Buildings." Quincy, MA: Fire Protection Research Foundation.

<http://www.nfpa.org/assets/files//Research%20Foundation/RFFireSafetyGreenBuildings.pdf>

- Develop an approach to convert the relative performance data into relative risk or hazard measures.
- Conduct a risk (or hazard) characterization and ranking exercise, with a representative group of stakeholders, to develop agreed risk/hazard/performance levels.

Brian's talk closed with the idea that we need to identify and incorporate fire and life safety objectives as fundamental elements in green rating schemes and codes to develop holistically high-performing buildings.

Do We Understand the Impact of New “Sustainable” Materials on the Fire Load of Buildings?

Tom Chapin, Vice President Corporate Research, Underwriters Laboratories

Tom Chapin opened his talk by reminding us why sustainability, with its implications for urban planning, is an issue for society particularly because of the effects of global population growth. His presentation focused on the global supply chain and the safety continuum. All “stuff” comes from materials made into components, which are then made into products, which are then put into systems, and then finally used within buildings and structures. To look at the safety of the whole system, we cannot simply look at the material properties of each component; material properties do not give us any sense of the scale of implications. Instead, information about material properties must be used to determine product performance in areas such as fire, smoke, efficiency, etc., and addressed in systemic and structural levels by building codes, inspections, certifications, etc., to ensure life safety, sustainability, and human health.

He also discussed advanced materials, in particular the development of new polymer chemistry that has created an explosive growth in the use of plastics. Most of these materials are based on crude oil and downstream refining operations. The complexity of materials may lead to unintended consequences, one of which is an increase in the fuel load. At the material level, the heat of combustion of these new polymers is significantly higher than natural materials. In a modern room, these synthetic materials have a time to flashover of 2 to 4 minutes, compared to nonsynthetic materials that would have taken 14 to 20 minutes to reach flashover. The development of this new potential danger leads us to wonder: how do we consider the substitution of these materials, and how can they be defined as “safe”?

Another example presented was of smoke production from wires. Not all materials emit the same amount of smoke. The presence of plasticizers, which are aromatic compounds, greatly increases the amount of smoke produced. That is why polyvinyl chloride wires produce the most smoke. Understanding a material's heat-release rate (HRR) and smoke production allows a better understanding of its behavior in a system. In realistic scenarios, for example, in a plenum space, wires of different materials left over from contractors can build up and can present potential fire hazards.

The aspect of scale can also be explored with upholstered furniture flammability. Testing (using a cone calorimeter) can be completed on the material of interest, then on mock-ups, then on furniture, and finally on a room scale where tenability of persons within the space can be investigated. There is a convergence of fire safety and long-term exposure safety related to the use of fire retardants such as those that are bromine based. The removal of all flame retardants could have profound implications. Bromine is ubiquitous in the environment — what does it do to our bodies?

Fire Fighter Safety and Building Sustainability: A Fire Fighter's Perspective

Sean DeCrane, Battalion Chief, City of Cleveland Division of Fire

Sean DeCrane's presentation focused on how we need to understand the green movement's impact on fire fighters' work environments, and that we need to identify methods to minimize the negative impact on public and fire fighter safety through communication and collaboration with the design community. Acknowledging that the green movement is necessarily here to stay, fire fighters need to learn how to co-exist so that life safety is not impacted. Realistically, the station house provides only a staging area for fire fighters, so the fire ground, which is now being affected by the green movement, is the true work environment where fire fighters operate. Several potential conflicts in the fire fighter "workplace" are now appearing:

- Site design that restricts apparatus access (limitations on hardscape and turfgrass, traffic calming methods, urban villages with high-density populations, etc.)
- Building design issues including lightweight construction and large, open spaces that result in fuel-controlled fires as opposed to ventilation-controlled fires
- Foam insulation and new types of glazing
- Alternate power sources (solar or photovoltaic [PV], wind turbines, fuel cells, and battery technology)
- Green roofs, which increase the fire load, absorb water from fire-fighting operations, and leave potential hazards if they are left unirrigated
- Water conservation and water run-off concerns

The fire fighter community has begun to recognize these hazards. The National Association of State Fire Marshals (NASFM), with an Assistance to Firefighters Fire Prevention and Safety Grant, created a project to develop and communicate information to code officials and emergency responders on the fire safety gap between current fire safety practices and new green technologies. A fire and building safety guide on green construction was one result.⁵

However, many issues remain that need to be answered. The fire protection engineering community has a particular role in addressing many of them, which include the following:

- Increased fuel loads (more plastics and upholstered furniture in homes)
- Fires in unsprinklered attic spaces
- Code issues (nonpotable water to fire pumps, vestibules, straw-bale construction, elimination of standpipe systems, PV locations, protection of lightweight construction, etc.)
- Plenum space dangers to fire fighters such as drop-down entanglements

⁵ Tidwell, Jim, and Jack J. Murphy. August 2010. "Bridging the Gap: Fire Safety and Green Buildings." National Association of Fire Marshals. http://www.firemarshals.org/pdf/NASFM_greenfire_guide.pdf

Session 2: Fire Safety Features and Impacts on Sustainable Building Design

Moderator: Dan Finnegan, Industry Affairs Manager – North America, Siemens Industry

Fire Sprinklers and Sustainability

Russell Fleming, President, National Fire Sprinkler Association

Russell Fleming presented the sustainable benefits of sprinkler systems. “Everything the sprinkler industry does promotes sustainability because it results in the preservation of resources,” Russell stated. Material efficiency, water efficiency, and reduction of damaged property are three areas where sprinklers can contribute to the sustainable equation.

In 2010, the National Fire Sprinkler Association hired a green building systems firm to review Leadership in Energy and Environmental Design (LEED) regulations and was told that sprinklers did not fit into LEED credits. LEED does not give credits aimed at safety because it requires local code requirements for safety be met first.

Even if not recorded as meriting LEED credits, developments in sprinkler systems have reduced their environmental impact. Particularly, advancements in pipe materials and threading techniques reduced the amount of required raw materials and increased the flexibility of installation. In 1972, area density curves were introduced to NFPA 13, *Standard for the Installation of Sprinkler Systems*, and allowed for smaller systems to be designed. In 1988, the first early suppression fast response (ESFR) sprinklers eliminated in-rack sprinkler piping. Extended coverage sprinklers reduced the number of required sprinkler heads in a system. Some sprinkler valves and fittings currently exceed 90-percent recycled content by weight. These advances have provided not just a financial benefit for the manufacturers, but also a sustainable benefit for the environment.

It is widely acknowledged that sprinkler systems help reduce water consumption in the event of a fire, A Foundation project on residential fire sprinklers measured the total water usage during sprinkler actuation at a fire scene compared with water usage by the fire service and found that the average water usage for fire fighting in residences not protected by sprinkler systems could be up to 1200 percent higher than those that are protected by a sprinkler system.⁶ Water mist systems use significantly less water, but they lack hundreds of years of reliability data that fire sprinklers have. The technical committee for NFPA 25, *Standard for the Inspection, Testing, and Maintenance of Water-Based Fire Protection Systems*, was made aware of efforts in Australia to curtail the amount of water used in maintaining fire sprinkler systems. The committee modified the requirements for fire pump tests to reduce the amount of water that is wasted during testing. A Foundation project also explored the issue of changing the frequency of fire pump testing.⁷

Recycled water was discussed as an option for achieving LEED credit, but the reliability and quality of the water was questioned. The 2013 edition of NFPA 13, Section 24.2.1, recommends that water from recycled sources shall need to be evaluated to determine whether it would be detrimental to the

⁶ Utiskul, Yunyoug, and Neil P. Wu. February 2011. “Residential Fire Sprinklers — Water Usage and Water Meter Performance Study.” Quincy, MA: Fire Protection Research Foundation.

<http://www.nfpa.org/assets/files/PDF/Research/RFWaterUsageWaterMeterPerformance.pdf>

⁷ Pennel, Gayle. April 2012. “Fire Pump Field Data Collection and Analysis.” Quincy, MA: Fire Protection Research Foundation. <http://www.nfpa.org/assets/files/Research%20Foundation/RFFieldDataCollection.pdf>

components of the sprinkler system it comes in contact with. This information should be presented to the sprinkler contractor through the owner's certificate. Other options that can reduce the environmental impact of sprinkler use were discussed with the symposium attendees and included use of gravity tanks and recirculating water to test flow switches.

Sprinklers control fires, help reduce repair costs, and eliminate the need to rebuild entire structures. Their use eliminates not only the amount of wasted material that is thrown into landfills, but also eliminates the need for new raw materials for reconstruction. In some cases, adding a sprinkler system to a building can permit the use of less "beefed-up" requirements like alarm systems and fire-rated construction. The fire sprinkler industry suggests that complete automatic fire suppression systems should be a prerequisite for all LEED projects.

Use Your Building Automation System to Integrate Fire Protection into Your Green Building Project

Paul Turnbull, Applications Engineer, Siemens Industry

Paul Turnbull discussed using building automation systems to integrate fire protection into green buildings. Systems that can be integrated include HVAC, fire alarm, mechanical smoke barriers, and natural ventilation openings. Smoke barriers and ventilation openings that can be controlled as part of the building automation system can help maintain tenable environments in areas used for egress and can help assist emergency response personnel in post-fire smoke removal.

The International Building Code (IBC) requires smoke control in a few specific occupancies, like high-rise buildings and atria. Coordination with NFPA 92, *Standard for Smoke Control Systems*, is required in addition to requirements for overriding and sequencing components. The IBC also requires smoke control systems to run weekly self-tests that include running smoke control fans. The fans draw out the conditioned air from inside the building and replace it with unconditioned air from outside. This results in conditioned air that is wasted and additional air that must be conditioned before being brought back into the building. There are no exceptions for this requirement. Although this practice is not very sustainable, other changes can be made to counteract the negatives of running this test.

Designers can take steps to reduce the amount of equipment their systems require. Control equipment and control circuits for building automation systems can be integrated to reduce the number of panels needed. This will reduce redundant equipment.

The quality of the construction can help increase the effectiveness of smoke control systems and reduce the size of the required system. In an 11-story stairwell with loose construction, a system capable of 6,000 cubic feet per minute (cfm) is required to pressurize the stairwell. If the construction was average, it would only require 2,600 cfm. With tight construction, the same 11-story stairwell only needs a system capable of 950 cfm. Sealing cracks, caulking doors and windows, and aligning doors can allow a reduced fan and duct size. It can also help reduce the amount of exhausted air during tests. It was acknowledged that workmanship of construction can be an issue and that designers need to supervise to make sure construction is tight enough to reduce the smoke control needed.

Using unconditioned air to pressurize a stairwell can also allow smaller fan sizes. For example, in an 8-story stairwell using 73-degree F conditioned air, 3,760 cfm is required. If 10-degree F outside air is

used, only 3,240 cfm is required. This reduces the size of the required fan by approximately 500 cfm. One of the attendees of the symposium asked about the effect of the temperature on stairwell occupants. Designers would have to consider this when working in areas that have extreme climates.

Modification of the life safety design and building design can help reduce the required size of smoke control systems. Deployable barriers can be used to divide the building into smaller spaces, which would reduce the required size of fans and result in less conditioned air exhausted during tests. Large volume spaces can be created to collect smoke while people exit. This is referred to as the smoke-filling approach. If the evacuation time of the building is less than the smoke-filling time, then smoke control can be completely passive, and no energy is needed. This can be done by increasing the roof height above top floor walkways or providing glass walls around top floor walkways. Deeper smoke layers reduce the number of required exhaust grills and reduce the required sizes of fans because deeper layers can prevent plugholing.

Paul's presentation showed that many options exist for both integration of safety systems and for reducing the required size of smoke control systems. These options can reduce the amount of materials used and the amount of energy the system uses.

He also cautioned that designers need to balance integration because it is not the best concept to rely on one huge system to perform everything when it comes to maintenance and replacement.

Natural Ventilation and Smoke Control

What Conflicts Can Arise, and How Can They Be Overcome While Ensuring That the Sustainability Objectives of Natural Ventilation Are Still Met?

Simon Lay, Director of Fire Engineering, AECOM

Simon Lay discussed the importance of integrating sustainable goals with fire protection goals when it comes to ventilation and smoke control. Natural ventilation is the cornerstone of sustainable design. In ancient Iran, buildings were designed with wind catchers to funnel fresh air down into basements and up through the building. Ancient Roman buildings used internal courtyards to create cross flow and vertical exhaust of hot air and smoke. Over time, engineers and designers have reduced the use of natural ventilation because of the fire risks associated with air movement.

As cities grew, buildings were forced to occupy smaller footprints, leading to high-rise structures. These rectangular buildings with large floor areas reduce the flow of natural air. Operable windows and double skin facades are solutions to these problems, but they add to the cost of a building and can lead to fire spread risks. Simon specifically mentioned the London Underground office fire, when fire spread because of opened windows. It was also noted that it can be more difficult to control natural ventilation systems compared to mechanical ventilation.

Atria can also be used to help cross ventilation; however, there is very little test data for atrium spaces involved in multiple floor fires. The fire risks can be avoided if proper protection is added. For example, a bank building in Germany that wanted double skin facades installed compartmentation to avoid any open vertical shafts for smoke to travel. Draft or smoke curtains can be installed in atrium spaces to prevent the movement of smoke throughout the building; however, this adds to the cost of the building and these types of systems are not always reliable or tested properly.

Design, safety, and sustainability should be integrated. Fire protection engineers should be called in early in the design stages of a project, not after sustainable attributes have been designed. Fire protection engineers can help building owners work toward their sustainable goals while also providing a safe building.

Is “Performance-Based” Fire Protection the Best Way to Work Toward Sustainable Building Goals?

Ray Grill, Principal, Arup

Ray Grill discussed how performance-based design (PBD) can support sustainable goals. Improving space utilization, incorporating renewable resources, and lowering operational energy can all be done through PBD. This design method allows engineers to create solutions for fire resistance, evacuation, suppression, alarms, and smoke control while achieving sustainable goals when prescriptive codes would be restrictive.

The California Academy of Sciences building achieved LEED platinum in 2008. It features a green roof and photovoltaic (PV) cells. A structural fire engineering analysis was conducted to determine if an unprotected steel canopy could support the PV cells. Through PBD, the designers and engineers achieved LEED accreditation while providing an aesthetically pleasing and, most importantly, safe building.

PBD has many advantages for designers, but can lead to a few drawbacks. Some authorities having jurisdiction hesitate to agree to designs that do not meet the exact requirements of prescriptive codes. PBD adds significant costs without up-front guarantees and might even add time constraints. Using PBD for smaller projects is often difficult because of the cost.

To achieve greater acceptance of PBD, there should be more education and more participation from code developers. PBD is the perfect avenue for improving and achieving fire safety and sustainable goals.

Research Efforts in Fire Protection Engineering Are Contributing to Sustainability Goals

Dan O’Connor, Chief Technical Officer, Aon Fire Protection Engineering

Dan O’Connor discussed the fire protection engineering research efforts related to new sustainable technologies. New compact mobile shelving systems allow for high-density storage in small spaces. These systems are frequently used in office settings and can be considered sustainable because they occupy small spaces. At first these systems appeared to be a fire hazard because of the density and spacing of the stored paper. Through research and testing, it was found that these systems had peak heat-release rates (HRR) from 1.3 to 38.4 kW⁸, which is less than the HRR of a typical small trashcan fire. Fire development was very slow because there was not much airflow through the shelves. The technical committees for NFPA 13, *Standard for the Installation of Sprinkler Systems*, reviewed this data and determined that compact mobile shelving units that contained less than 5 percent plastics, were up to 8 feet in height, and had a minimum of 18 inches of clearance from the ceiling, could be protected as a light hazard and would require ordinary temperature or quick response sprinklers. Through research,

⁸ Schirmer Engineering Corporation. June 2008. “Compact Mobile Shelving System Fire Testing Project.” Quincy, MA: Fire Protection Research Foundation.

<http://www.nfpa.org/assets/files/pdf/research/compactshelvingfiretestingprojectschirmer.pdf>

information was provided to the committee, so it could develop an effective recommendation in the standard to address the new shelving systems.

Research is a very important aspect of understanding how to optimize fire protection systems. Waffle ceilings present a challenge for smoke detection because of the hundreds of pockets they create, which previously would require a detection device in each pocket. However, through research and fire modeling, it was determined that detectors can be used effectively in waffle ceiling applications at a spacing between 15 and 30 feet and that mounting detectors in the pockets or at the bottom of the beams is acceptable.⁹ This research provided the NFPA 72, *National Fire Alarm and Signaling Code*, technical committees with information that proved that placing a detector in each beam pocket, which could lead to the installation of hundreds of detectors, was unnecessary. Optimizing detector application reduces the carbon footprint of the manufactured product.

High-volume, low-speed (HVLS) fans are another new sustainable technology that concerned fire protection engineers. These fans reduce the number of small fans that are needed in a building that reduces CO₂, carbon emissions, and energy use. They can also achieve LEED credits. The main concern with HVLS fans is that the strong downward air flow can interrupt fire plumes. This can affect detection, sprinkler operation, and water distribution. Research was conducted to test rack storage of palletized Group A plastics with varied storage heights using early suppression fast response (ESFR) and control mode density area sprinklers with varying fan locations.¹⁰ The NFPA 13 technical committee used the research to develop code requirements for buildings using HVLS fans. The standard now requires HVLS fans to be centered approximately between four adjacent sprinklers with a minimum 3-foot vertical clearance between the fan and sprinkler deflectors. HVLS fans are required to shut down immediately upon water flow detection from the alarm system. Through research, the conflicts between HVLS technology and sprinklers were resolved.

New and existing sustainable design solutions should be carefully evaluated to determine their impact on fire safety features or methods. Codes and standards committees should utilize the available research opportunities when faced with these new technologies before imposing overly restrictive rules.

⁹ Mealy, Christopher, Jason Floyd, and Dan Gottuk. April 2008. "Spacing Requirements for Complex Beamed and Sloped Ceilings." Quincy, MA: Fire Protection Research Foundation.

<http://www.nfpa.org/itemDetail.asp?categoryID=2587&itemID=57409>

¹⁰ Aon Fire Protection Engineering. January 2011. "High Volume/Low Speed Fan and Sprinkler Operation: Phase II Research Program." Quincy, MA: Fire Protection Research Foundation.

<http://www.nfpa.org/assets/files//PDF/Research/RF%20HVLS%20Fans%20Ph2.pdf>

Session 3: Life Cycle Sustainability of Structures Including Fire Safety Features and Practices

Moderator: Lou Gritz, Vice President and Manager of Research, FM Global

NIST Metrics and Tools for Sustainable Buildings

Barbara Lippiatt, Economist, National Institute of Standards and Technology (NIST)

Barbara Lippiatt presented an effort by the National Institute of Standards and Technology (NIST) to develop a life cycle assessment (LCA) tool to measure the sustainability of whole buildings that considers both the environmental and economic aspects of sustainability. It involves transforming the bottom-up (i.e., process-based) database tool used by the Building for Environmental and Economic Sustainability (BEES) for building products into a hybrid database. She acknowledged that a building is not just a collection of products. The way the products work together is as important as energy use, so the hybrid approach being developed for whole buildings is an input-output, or top-down, approach combined with a bottom-up approach that considers both direct and indirect inputs (e.g., manufacturing). Using the top-down approach, NIST is developing a set of baseline sustainability measurements for 42 prototypical building and construction types, which accounts for all production materials by building type. Then, these baseline measurements will be adjusted using detailed bottom-up data to reflect a range of approximately 100 product and technology alternatives (e.g., day-lighting, wall insulation).

This tool, the Building Industry Reporting and Design for Sustainability (BIRDS) tool, calculates an environmental impact score that considers environmental metrics such as global warming, embodied energy, and land use integrated with economic performance metrics. The environmental impact score can be calculated on a per-square foot basis or a per-dollar basis and is scalable from micro to macro scales. The tool can be used to assess and compare the sustainability performance for whole buildings that meet a range of energy codes.

Using the tool that compared the current state energy code vs. a highly energy-efficient design over a 10-year period, Barbara presented a case study of a three-story office building. When just considering operating energy, the carbon footprint reduction was greatest in the states that had the oldest energy codes in place. A life cycle cost (LCC) comparison showed that in some of these same states a building with a highly energy-efficient design would not see LCC savings over a 10-year period because of the use of older energy codes combined with the fact that their power grid used mostly coal.

Using the same case study, and combining material and operating energy impacts, Barbara demonstrated that the carbon footprint shares vary over the operational life of the building, with embodied construction contributing the most in the first year and operational electricity contributing the most after 20 years. The environmental footprint shares vary as well with global warming, which is driven by energy use, increasing over a 40-year period. In comparison, the impact of land use decreases over the same period. To demonstrate the scalability of the approach, Barbara described an analysis that showed that new commercial construction makes up about 4 percent of the national environmental impact.

In closing, she emphasized that the BIRDS sustainability metrics used in the tool are unifying because they integrate macro and micro scales, and efficient because they will provide a single baseline LCA database for 42 building and construction types to yield comparable LCAs for both new construction, and

maintenance and repair made to existing construction. She noted during the discussion that the tool takes into account that the lifetime of building elements varies and that the input-output tables used give data for maintenance and repair by building type to capture what is actually happening. She also stated that NIST will be studying existing buildings as well as evaluating new home types (e.g., zero-energy homes) after the study is completed with new commercial.

Where Are Green Building Schemes Heading in the Future?

Debbie Smith, Director of Fire Sciences, BRE Global

Debbie Smith reflected on the history of the BREEAM method and the development plans related to this scheme. BRE's Environmental Assessment Method (BREEAM) was launched in 1990 as a response to concerns about the quality of the built environment. Today BREEAM is a family of products linked to life cycle stages of residential and commercial buildings. BREEAM in Use applies to buildings during occupation and includes fire safety management credits.

Building regulations in the United Kingdom are functionally based, and compliance is demonstrated using British Standards (BS), European Standards (ENs), and International Organization for Standardization (ISO) standards as well as Approved Documents. BREEAM goes beyond the compliance standards because the baseline assumption is that all buildings comply with base regulatory requirements. The issue with this structure is that there are "regulatory silos," and all the different standards and regulations are updated on their own timeframes without much thought to how the changes affect other regulations. Debbie stated that we need to consider the issues more holistically to avoid conflicts between sustainability and fire. She used the example of sustainable urban drainage systems, which make it easy to contaminate the water table with fire-fighting water run-off.

Up to this point, BREEAM has been largely about environmental issues, but sustainability is also about economics and social impacts. BRE Global is now developing a framework code that will be the sustainability code, which will be supported by a series of in-house and national codes and standards. The BREEAM series of schemes will be based on the information in these standards and the resulting data from life cycle analyses will be fed back into the codes and standards. Debbie emphasized that technically robust data is required to support the development of new generation "green schemes" such as BREEAM. She also spoke about the new series of European Standards, EN 15643, on sustainability of construction works and sustainability assessment of buildings, which were published in May 2012.

Some of the sustainability drivers and issues that have an impact on fire safety and need to be considered in the new schemes are the following:

- The increase of the use of recycled materials for construction
- The reduction of waste on construction sites leading to development of innovative construction methods such as modular construction
- Increasing thickness of insulation to meet energy requirements
- Increased airtightness of buildings
- Separation of buildings that have been historically based on traditional construction and need to be revisited for new materials
- Performance of new laminated glazing products

The new approaches need to include the impact of fires in the environment when considering cost-benefit analyses. Debbie cited an example of using sprinklers in residential buildings and presented statistical data that included the impact of sprinklers on deaths and injuries and the reduction in property damage. She also stressed that we need to assess the fire performance of systems and not just the materials individually, but there is a lack of data to do so. The construction industry, of which the fire community is part, lacks collaboration and common terms with consistent definitions.

In summary, Debbie said that future green schemes will consider and manage risks holistically and involve key stakeholders to commit and act in partnership to get fire protection measures that address the risks presented by modern methods of construction. There is also a push to develop more robust data that will be open to scrutiny and peer review to better quantify costs, benefits, risks of injury and death, and environmental and social impacts of fires. In addition, new methodologies are being developed for benchmarking materials, products, and systems within the sustainability framework for social and economic impacts as well as environmental.

During the discussion with the attendees, Debbie stated that BREEAM certification is possible in the United States but was not sure of any examples. She also clarified that the BREEAM stakeholders, a group of 150 professionals in the United Kingdom used to develop schemes and standards, include manufacturers, sustainability experts, and fire protection engineers. She was also asked about the United Kingdom's view on emissions, which she stated is the same as the European view, and there is initiative to eliminate dangerous substances by certain dates. This is an ongoing process and does include fire retardants.

The Integral Role of Fire Protection in Sustainability

Lou Gritz, Vice President and Manager of Research, FM Global

Lou Gritz started his presentation with the definition of sustainability that was developed by the United Nations in 1987: "Meeting the needs of the present without compromising the ability of future generations to meet their own needs." FM Global has an interest in sustainability and how it relates to safety. It released standards in 2007 to address sustainability and is thinking about instituting a company mandate that all new buildings are to be LEED certified. In addition, there is ongoing research on various sustainability topics.

Lou laid out five result areas that were the product of FM Global's sustainability research. The results were that sustainability:

- Has be measured over a life cycle
- Requires avoiding unintended consequences
- Needs to be economically viable over a period of time
- Limits pollution, conserves resources, and provides societal safety
- Requires managing trade-offs

Sustainability of building construction has to be measured over the lifetime of its use, which includes all the risks along the way from construction through operation to demolition. To date, efforts to measure the carbon emissions from a facility have only focused on normal operating conditions. A research project that used FM Global loss history data and other sources found that there was a 2 percent to 14 percent

increase in CO₂ emissions through the life cycle of a building when there was a fire and resulting rebuild.¹¹ Their research also found that efforts to improve sustainability of a building without considering risk have the potential to increase the fire risk by a factor of three, which means that risk is more important to manage in a green building. Lou stressed that effective risk management can be achieved through the use of automatic sprinkler systems. FM Global's data demonstrates that a sprinkler system that designed, built correctly, and maintained as designed is 98 percent effective.

There are fire risks related to green technologies that need to be addressed to avoid unintended consequences. Lou gave the example of the increased fire hazard that alternative fuels present. Specifically, hydrogen fueled forklifts are used in many storage and industrial operations, and hydrogen presents a higher explosive limit than other fuels, so FM Global did a full risk assessment on the use of these types of forklifts to determine what safety measures should be taken. The need to assess new technology is continuous as new renewable energy technologies are emerging all the time.

One of the benefits of sustainability is that it is meant to provide a net economic benefit over the lifetime of a building. FM Global found that the same is true of risk management. Lou also stated that their research has found that with buildings with strong risk management the average risk of fire loss is 55 times less than those without strong risk management. The economic impact of a fire varies greatly as well. With weak risk management, the average severity of a fire loss exceeds \$4.4 million compared to \$0.73 million with a strong risk management program. This same concept applies to natural hazards. The average risk of natural hazard losses is 28 times less with strong risk management.

The fourth research result area from FM Global's research is that sustainability risk management includes limiting damage and pollution, conserving resources, and providing societal safety. FM Global partnered with the Home Fire Sprinkler Coalition at NFPA to run a test program comparing a typical residential living room protected with sprinklers to one not protected by sprinklers to quantify the environmental impact of sprinklers.¹² In each case, the fire service was brought in 10 minutes after smoke detector activation. What they found was that the test of the sprinkler-protected room reduced greenhouse gases by 98 percent, which projects to a potential reduction of 979 million kg of CO₂ in a 10-year span (1998–2008) for the United States, where there were 2.9 million fires in homes.

They also discovered a reduction in water pollution. For the test room protected by sprinklers, the pH and cyanide levels were lower than the test room with no sprinklers. In addition, the total water usage was 50 percent less for the test room protected by sprinklers compared to the test room that relied on the fire service only. During the discussion with attendees it was asked if there was a database that quantifies emissions from fires. FM Global did measure for their tests and the National Institute of Standards and Technology (NIST) has some data, but the available data is dependent on the fire scenario and most is based on small-scale testing and may not relate directly to large-scale testing.

¹¹ Gritz, Louis A., William Doerr, Robert Bill, Hosam Ali, Shangyao Nong, and Larry Krasner. March 2009. "The Influence of Risk Factors on Sustainable Development." Norwood, MA: FM Global Research Division. <http://www.fmglobal.com/page.aspx?id=04010300>

¹² Wiczorek, Christopher J., Benjamin Ditch, and Robert G. Bill, Jr. March 2010. "Environmental Impact of Automatic Fire Sprinklers." Norwood, MA: FM Global Research Division. <http://www.fmglobal.com/page.aspx?id=04010300>

Lou wrapped up his talk by stating that sustainability requires managing trade-offs and demands a broader and deeper knowledge of material attributes and performance. FM Global reviewed the green certification systems worldwide and created a process that reduces the amount of material needed to test for approval. He concluded by discussing what to expect in a future that includes more renewable energy standards; new metrics for certification of materials; research on emerging technologies; and more collaboration between clients, industry leaders, and certification organizations.

LEED Certification

George K. Tuhowski III, General Superintendent, Director of Sustainability, Leopardo Companies

George Tuhowski provided an overview of the Leadership in Energy and Environmental Design (LEED) certification system and process. The LEED system is managed by the U.S. Green Building Council, a nonprofit organization that is a coalition of the country's leaders in the industry who promote buildings that are environmentally responsible; economically profitable; and healthy places to construct, live in, and work in. There are several LEED green building rating systems including systems for new construction, healthcare facilities, existing facilities, and homes. New rating systems are being developed all the time and new criteria for the existing systems are issued every 3 years based on input from people throughout the industry.

The LEED rating system has five categories:

- Sustainable sites, which considers the site both during and after construction
- Efficient water use
- Energy and atmosphere, to account for how much the facility uses to operate
- Materials and resources, which concerns the sources of material, the recycled content, and how waste is disposed
- Indoor environmental quality

The system is based on a 100-point scale, and there are four levels of achievement: certified, silver, gold, and platinum. A new concept that is a prerequisite for LEED for healthcare is integrated project delivery, which involves having all the stakeholders, including the contractor, at the table during design.

George stated that there are not a lot of ways to contribute to LEED certification from the fire protection side, but went on to discuss the innovation and design process to create one's own criteria for environmental responsibility. He gave an example of innovative thinking with the delivery company UPS, which found that they saved money by reducing fuel consumption if the drivers took only right turns.

He suggested approaches to contribute to the sustainability of a building, including using sustainable products and materials, using sustainable methods including water preservation during testing, using energy efficient equipment for operation and installation, and integrating design and installation with other sustainable systems like recapturing test water for other use. During the discussion with the attendees, he suggested that the best way for fire protection engineers to get involved with the process was at the local chapter level.

Panel Discussion: What Are Your Major Challenges Related to the Intersection of Fire and Sustainability in Your Day-to-Day Practice?

Moderator: Antony Wood, Executive Director, Council on Tall Buildings and Urban Habitat (CTBUH)

Jim Antell, Rolf Jensen and Associates (RJA)

Jim Antell provided the fire protection engineer's (FPE) perspective and discussed how the new sustainable materials and technologies have implications for code compliance. The issue is that there is no uniformity across building codes; however, all codes do allow "Alternative Means and Methods," which allow a performance-based design (PBD) approach to meet intent of prescriptive requirements. PBD gives the opportunity for FPEs to contribute to sustainability by optimizing systems such as smoke control. FPEs are in a unique position of pulling all the pieces together and have the opportunity to look at all the building systems and how they work together.

Mehdi Jalayerian, Executive Vice President, Environmental Systems Design

Mehdi Jalayerian offered a mechanical engineer's outlook. He presented some of the sustainability opportunities related to fire protection systems. They include optimizing water use by recirculating water from flow-switch tests and fire pump tests, and using low flow fire protection systems like water mist. He gave an example in Australia of a requirement for a water tank to capture test water to be reused as gray water. He also discussed optimizing power use by using gravity systems whenever possible and optimizing the pumping systems and associated electrical systems. He gave some examples of how to optimize material use such as efficiently designed sprinkler systems, dual duty fire protection piping systems, and optimizing primary pumping systems and components. In addition, he stated that environmentally safe clean agents, those with zero ozone depletion potential or one global warming potential, should be utilized for fire suppression.

Bob Sinn, Principal, Thornton Tomasetti

Bob Sinn presented from the perspective of a structural engineer. He discussed the difference between steel and concrete frames. Recently, there has been a shift from steel to concrete. One of the reasons related to sustainability is that concrete does not need applied fire protection, as steel does. He did present some examples of architecturally exposed exterior structural steel where the steel is removed enough from the building that it does not need fire protection. He also noted that a common practice in Europe is to apply intumescent fire protection off-site, which reduces waste. This is commonly done on-site in the United States.

Peter Weismantle, Director of Supertall Building Technology, Adrian Smith + Gordon Gill Architecture

Pete Weismantle gave the architect's perspective; he cited examples of architectural integration of sustainable elements, such as the integration of photovoltaics (PVs) into exterior walls. He also discussed the challenges of sustainable new-build urbanization, which related to new megastructures being built. This especially applies to Eastern cities where many of the buildings are interconnected to become one megastructure. Another thought that he presented was the practice of post-occupancy performance

evaluations and that we will be relying more and more on computer modeling in the future to predict how systems will perform.

Antony Wood, Executive Director, CTBUH

Antony Wood presented his thoughts on the issue of fire and sustainability and posited that the fire engineering profession seems to be reactive in contributions to sustainability rather than proactive. His ideas included optimization of egress by use of horizontal connections where possible and use of natural ventilation including double skin facades. He also discussed the difference in cultural attitudes toward fire safety.

Panel Discussion

Bob Sinn was asked a question on the type of analysis done for exposed external steel since the work by Margaret Law was restricted to cellulosic fuels. He stated that these projects did an audit of contents and the determination was that compartmentation was important.

Another topic related to structural fire protection was off-site intumescent application. Two reasons that it may be more popular in Europe are that there are more height limitations there, particularly in the United Kingdom, and there is limited requirement for more than a 2-hour fire protection rating. In addition, the United Kingdom has more success with off-site modular construction methods. There have been projects that have used modular technology in the United States, which is more feasible for occupancies like hotels and residences, but the prime consideration is economic feasibility.

A performance-oriented approach can be used to determine the amount of fire protection needed for steel structures, but there has not been much success for the approval of this approach in the United States. Bob said that the structural engineering profession is moving toward performance-based development on a whole, with improved tools.

There was a discussion of the inherent sustainability of steel vs. concrete. From an applied fire resistance standpoint, concrete comes out ahead in sustainability; however, this is not necessarily true in regard to the material itself; there are conflicting viewpoints. It was noted that the steel buildings built for the London Olympics are being disassembled and reused, but the increase in the use of concrete has been significant. CTBUH data shows that 30 years ago, 90 percent of the 100 tallest buildings in the world were made of steel -- today 12 percent are. Concrete is now more cost effective and more efficient to construct. It was noted that CTBUH has commissioned a study on alternative steel systems. There is an emerging trend of building high-rise buildings from wood because it is a sustainable material. We need to know more about how this impacts the fire safety of a building.

Another panel discussion topic was water-based protection systems. Low-flow mist systems are used for some applications but are not in widespread use. The challenge with designing more cost-effective sprinkler systems is that they need to be proven to be effective. In the end, the system needs to control the fire. There are also wide discrepancies on how buildings will be used, which increases the variables, but numerical tools can help.

It was also noted that computational fluid dynamics tools are not meant for shear-driven turbulence; we need to take tools to the next level and ensure they are validated for specific applications such as fire.

The idea of using a single-pipe system for commercial buildings was also discussed. It was noted that the system needs to be reliable. The approach tried by the General Services Administration in the 1970s, which was included in NFPA 13, *Standard for the Installation of Sprinkler Systems*, had corrosion issues. With improvements in materials and technology, it may be time to revisit this type of system.

A question was posed to the group: “What are the consolidated performance criteria that we want for buildings so we can design a building that meets objectives holistically?” A set of criteria needs to be developed. The code development work in the United Kingdom in the 1980s focused on protection of life of occupants and fire fighters. In the United States, the codes consider property protection. Performance-based design of egress systems need to take into account that fire service personnel may re-enter a building after the fire event. We also need to consider the use of enhanced elevators for evacuation as well as fire-fighting purposes.

Fire protection professionals need to get involved with the process and be more innovative, suggested one participant. On a project basis, fire protection engineers (FPEs) act as gatekeepers, make sure all the pieces work together, and look at systems holistically. It was generally agreed that FPEs are driven to PBD, but there are some impediments, such as acceptance by the authority having jurisdiction and costs. There are opportunities for PBD and innovation in emblematic buildings as well as in ordinary buildings.

Another attendant noted that there is confusion in the United States building industry about what an FPE is. Often, the term FPE is used to describe a plumbing engineer who designs the plumbing and sprinkler systems. It should be clarified that FPEs look for efficiencies in all systems, which typically result in savings. In the end, FPEs are in charge of public safety, and they need proven systems.

Some of the ideas in LEED can result in unintended consequences; they need to be more thoroughly understood from a safety perspective. Examples were given of wind technology, water retention, and HVLS fans. LEED sets goals, but does not explicitly state how to achieve them. We cannot solve problems instantly, we are learning along the way, and communication is important in the learning process.

Recommendations

Based on the presentations and discussion at the symposium, the following recommendations are made:

For Data

- Modify fire incident data reporting systems, such as NFIRS, to address the lack of reported fire experience with sustainable buildings, especially in buildings that have a green rating or certification.
- Develop a repertoire of positive case studies in sustainable buildings and include the analyses that were done to prove they are safe.
- Develop a fire and sustainable building data repository to facilitate better collection of relevant data on fire safety challenges with sustainable buildings.

For Research

- Address the lack of analysis on fire “risk” associated with green building elements with an extensive research project to review existing studies and reports on fire performance of green building elements, even if not explicitly identified as such (e.g., lightweight engineered lumber [LEL]).
- Research is also needed to:
 - Develop a clear set of performance data comparing green and “conventional” construction methods
 - Develop an approach to convert the performance data into relative risk or hazard measures
 - Conduct a risk (or hazard) characterization and ranking exercise, with a representative group of stakeholders, to develop agreed risk/hazard/performance levels
- Undertake investigations of the level of fire performance delivered by current standard test methods and of fire performance of installed green building elements. We need to clarify which current standard test methods are appropriate for evaluating both sustainability and fire safety criteria. Specifically, fire hazards of the following sustainable building elements need to be better quantified:
 - Photovoltaic (PV) panels
 - Foam insulation
 - Exterior walls that contain combustible materials (e.g., exterior insulation finish systems, sandwich panels, structural integrated panels)
 - Battery installations
 - LEL construction
 - Building facades, including double-wall glass exteriors
- Clarify, with research, whether other sustainable building elements present potential fire safety issues:
 - Green roofs
 - Removal of fire retardants in furniture
 - Changing fuel loads, especially with green or recycled materials
 - Natural ventilation of large atria
 - Integrated radiant systems

- Establish a holistic approach to the issues of fire safety and long-term exposure safety as they converge in the disciplines of science, engineering, medicine, and public policy. This applies to the use of flame retardants, smoke suppressants, advanced materials (e.g., plasticizers), and high-tech products (e.g., heavy metals).
- Clarify and communicate the hazards posed to fire fighters by the following design trends:
 - Increased fuel loads (more plastics and upholstered furniture in homes)
 - Nonsprinklered attic spaces
 - Code issues (nonpotable water to fire pumps, vestibules, strawbale construction, elimination of standpipe systems, PV locations, lightweight construction, etc.)
 - Plenum space dangers to fire fighters (e.g., drop-down entanglements)
- Establish a better understanding about how to optimize fire protection systems. This applies to individual product applications and the variety of fire systems that are part of a building design.
- Measure future sustainability and fire safety analyses over the life cycle of the building, including all the risks from construction through operation to demolition.

For Design and Collaboration

- Include fire protection engineers as an integral part of the design team from very early stages throughout construction and operational use of the building. Sustainable design must, by nature, include all aspects of building construction from very early planning throughout use stages. Without initial integration of fire protection at the beginning of a design, it will not be possible to optimize systems.
- Promote equivalency provisions or performance-based design options to resolve issues between existing codes and green initiatives.
- Create a collaborative environment with the fire service early in the design process to ensure that fire fighters are aware of potential new hazards. Fire fighter life safety should, as always, be included in the design process. Potential hazards include:
 - Site design that restricts apparatus access
 - Building design issues including lightweight construction and large, open spaces that result in fuel controlled fires as opposed to ventilation controlled fires
 - Foam insulation and new types of glazing
 - Alternate power sources (PVs, wind turbines, fuel cells, and battery technology)
 - Green roofs, which increase the fire load, absorb water from fire-fighting operations, and leave the potential for hazards if they are left unirrigated
 - Water conservation and water run-off concerns
- Develop a set of consolidated performance criteria for buildings with fire protection professionals so the team can design a building that meets objectives holistically.
- Build communication skills at the local level between the fire protection community and sustainable building organizations, such as the U.S. Green Building Council, to emphasize the benefits of proper fire protection (such as sprinklers) in the sustainable design of buildings with an aim to incorporate fire and life safety objectives into green rating systems and codes.