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Green Buildings: Sustainability Successes Challenge Fire Resiliency

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Over the last decade "going green" has become increasingly mainstream. In an effort to use less energy, save resources, and reduce pollution and waste, we now embrace alternative energy, support energy efficiency, and practice recycling. But It's important to recognize that going green isn't just about electric cars, solar panels or battery energy storage, it's also about buildings, as structures are significant consumers of energy.

While the world's cities occupy just 3 percent of the Earth's land, they account for 60-80 percent of energy consumption, 70 percent of global carbon emissions and over 60 percent of resource use, per the UN Environmental Programme Emissions Gap Report. Rapid urbanization is exerting pressure on our supply of global resources, driving the need for buildings to be more sustainable, energy efficient, and resilient to fire and other disasters.

In response to societal objectives, there has been substantial global investment in clean energy and energy efficiency, which drives new innovations, including development of green and sustainable products and systems. As a result of this dramatic investment, these systems and materials are proliferating at an exponential pace. 'Green' building materials, systems and features, collectively referred to as the "attributes" of a building, range from interior and exterior materials, systems and facades to alternative energy sources or electrification of infrastructure on-site. A recent study by the Fire Protection Research Foundation (FPRF) on the fire safety challenges of green buildings and attributes identified over 100 'green' attributes that are being incorporated into modern building designs or sites.

'Green' building designs are fundamentally rooted in environmental, economic, and social sustainability, but aren't necessarily focused on fire resiliency. The FPRF study found that while fire hazards and risks of 'green' buildings and attributes have been addressed in many regards, fire safety is still considered relatively late in the design process. If it is considered, these efforts don't always carry through to the operational phase of a building. And there are clear fire safety implications, as a result.

Over the last decade, there have been several major fire events, which involved 'green' building features or technologies, notably the Grenfell Tower fire in London (combustible insulation), the Dietz & Watson cold storage warehouse in Delanco, New Jersey (photovoltaic panels, combustible insulation), and a plethora of fires in buildings under construction using lightweight timber framing.

These fire incidents indicate that the adoption of such systems can sometimes have unexpected consequences when safety considerations are not considered early in the development phase or where unexpected combinations of materials are used to create and install systems outside of the original specifications. Having fire safety take a back seat to other performance parameters in buildings is nothing new—fire safety often seems to be playing catch-up with developments occurring in the construction industry. Even when fire safety professionals are aware of a potential problem, a catastrophic incident often occurs before the issue starts to be addressed holistically. But this is no longer acceptable. Fire safety must move in lockstep with sustainability and be given due diligence up-front in the design process to avoid potential roadblocks in sustainable building.

Key fire safety challenges with emerging 'green' building trends are summarized below.

Structural Materials & Systems

In the 1980's, the concept of lightweight construction materials was introduced as a green alternative to traditional building materials and a way to reduce consumption of raw materials. Since then, a vast array of materials and engineered solutions have been introduced, such as lightweight engineered lumber, fiber-reinforced polymer (RFP) elements, plastic lumber, bio-polymer lumber, bamboo, mass timber (e.g., cross laminated timber), among others. However, in comparison to traditional building materials, they present a heightened fire risk. They can contribute to the fuel load, burn readily once ignited, and increase the heat release rate. These lightweight structural materials and systems also introduce the potential for reduced time to failure, along with concerns of stability, flame spread, and adequate fire department access. Further, materials such as mass timber, e.g., CLT, can delaminate, further contributing to the fuel load and structural integrity issues. Additive manufacturing/3D printing technology has been applied to building applications where it is hoped that savings may be made in manufacturing costs or in building construction sustainability by reducing waste and material production emissions and life-safety at construction sites. However, it presents performance trade-offs when compared to traditional building materials, as it can fail more quickly, present stability issues and challenge egress and fire service response. For most of these materials and systems, utilizing approved or listed materials and incorporating fire resistive barriers where appropriate are significant steps in the direction of safety.

Structural Materials & Systems	*Vegetative roof systems*
Lightweight engineered lumber	*Extended solar roof panels*
Lightweight concrete	*Mass Timber (e.g., CLT)*
FRP elements	*Additive manufacturing/3D printing*
Plastic lumber	*Inflated steel structure*
Bio-polymer lumber	*Hempcrete*
Bamboo	*Ultra-High-Performance Concrete*
Phase-change materials	*Carbon fiber composites*
Nano materials	*Modular Construction*

Exterior materials, systems, and façade features.

To facilitate energy conservation, green buildings often include interior or exterior insulation. Various types exist, such as fiber-reinforced polymer (FRP), rigid foam, spray-applied foam, structural integrated panels (SIP), or exterior insulation and finish systems (EIFS). These insulating materials are attractive from an energy conservation perspective as they are lightweight and composed of recycled plastics and have a high thermal resistance. However, if non-approved materials are used, adequate protection and barriers are not in place, or if the insulation materials are not properly constructed, some insulation materials can present a high fire risk if left unmitigated. This can result in fast fire spread, increased burn intensity and the generation of toxic products of combustion.

Exterior Materials and Systems	*PET for façade system*
Structural integrated panel (SIP)	*Interactive printed graphene*
Exterior insulation & finish (EFIS)	*Novel biological materials*
Rigid Foam Insulation	*Building integration carbon capture*
Spray-applied foam insulation	*Organic insulation*
Foil-insulation systems	*Composite window framing material*
High-performance glazing	*Mass timber & timber façade systems*
Low emissivity & reflective coating	*Ultra-high-performance concrete*
Double-skin façade	*Additive manufacturing/3D printing*
Bamboo, other cellulosic	*Hempcrete*
Biopolymers, FRP's	**Façade Features**
Vegetative roof systems	*Area of glazing*
PVC rainwater catchment	*Area of combustible material*
Exterior cable/cable trays	*Exterior solar shades and awnings*
Exterior solar shades/awning	*Exterior vegetative covering*
Exterior vegetative covering	*Out of plane geometries*
Allusion panels	*Solar radiance concentration*

On February 9, 2009, a fire at China Central Television headquarters in Beijing demonstrated how nonapproved extruded plastic insulation panels behind curtain walls could fuel and quickly spread the blaze through the entire building. Data also shows that some metal class materials (MCM) used for exterior cladding has contributed to reduced fire safety in some cases, fueling the fire. The Grenfell tower fire in 2017 brought concern of combustible exterior walls and cladding systems to the forefront, as it prevented the egress of over 70 people.

It should also be noted that while the well-insulated nature of these structures is a clear attribute for energy efficiency, under fire conditions these structures also retain the heat from the fire, accelerating the time to reach flashover, further challenging fire service response. Standardized fire tests and adoption and enforcement of codes and standards can play an important role in helping ensure the use of appropriate materials and proper installation and arrangement of these systems.

Alternative Energy Systems

Photovoltaic (PV) systems are a commonly used green technology to generate electrical power, where the PV module can generate direct current from the sun's energy and convert it into alternating current. However, PV systems can contribute to the fuel load, present an ignition and shock hazard. Research indicates some indication that for roof-mounted solar panels, the space between the roof and the installation can create flue-like conditions accelerating the spread of flame. In this case, the size of the space and angle of incline are important parameters to identify the fire risk.

Alternative Energy Systems
PV roof panels
Oil-filled PV panels
Wind Turbines
Hydrogen fuel cells
Battery/energy storage systems
Cogeneration systems
Wood pellet systems
Building integrated photovoltaics
Solar radiance concentration

Battery Energy Storage Systems (ESS) are another critical element of today's dramatic push for sustainable and renewable electrical energy, as they provide a means of storing energy produced via other renewable energy sources. Since 2018, there have been over 40 incidents in large-scale lithium-ion battery energy storage sites,

globally, that involved some failure resulting in fire or explosion. Incidents in 2021 impacted a combined capacity of over 1.7 GWh. While a variety of battery technologies are used, lithium-ion is a dominant technology at this time, which presents unique challenges from a fire and explosion perspective. While substantial research on-going, there are still many unknowns and challenges with respect to li-ion battery ESS. From controlling or stopping thermal runaway, to finding an effective suppression solution and mitigating the explosion hazard, to establishing proper fire fighter response tactics to ESS incidents, to decommissioning and dealing with the stranded energy hazards.

Site	Reduced Water Supply
Permeable concrete systems	*Hydrogen infrastructure*
Permeable asphalt paving/pavers	*Community changing stations*
Extent (area) of lawn	*EES fuel loads/hazards*
Water catchment / features	*EV fuel load/hazards/chargers*
Vegetation for shading	*Propane vehicle hazards*
Building orientation	*Fuel-cell vehicle hazards*
Increased building density	*Bicycle storage impact exits*
Localized energy production	*Reduced FD apparatus access*
Localized water treatment	*Densification / fire spread*
Localized waste treatment	*EV chargers on building exterior*

At the site. Increasing density is one approach to sustainable development. But with increased densification comes the need for alternative modes of transport for city mobility, such as car-sharing, dockless electric bikes and electric scooters. For these alternative options, ownership of the transport vehicle no longer belongs to the user, thus, dockless e-bikes or e-scooters can be available anywhere in a city and are dropped off at the user's destination. As a result, the presence and charging lithium-ion batteries for electric mobility (e.g., electric vehicles, electric bikes, and electric scooters) become an increasingly present hazard at residential and commercial sites. For example, e-scooters and e-bikes sparked 330 fires in the U.S. from 2015 to 2018, causing more than $9 million in property damage, according to the Consumer Products Safety Commission (CPSC). In 2020, New York City had 44 scooter fires that resulted in 23 injuries; the number of fires doubled in 2021.

Another serious concern is if local restrictions or conditions, such as a drought, restrict the available water supply at the site or facility. This may present a high hazard with respect to not having an adequate water supply for fire suppression activities. To mitigate this potential hazard prior to an unforeseeable incident, emergency response planning with the local jurisdiction should be conducted. The impacts of climate change and limited water supplies on fire protection systems is currently being studied by the SFPE Foundation.

Conclusion

With these representative challenges in mind, risk and performance considerations should be included in overall assessments of whether structures meet design criteria across all societal dimensions so that 'safer' solutions for buildings, fire service personnel, and the community are ultimately achieved. To attain our desired future of safe and sustainable buildings, we must focus on how to obtain our sustainability objectives with fire resilient strategies.

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