

Sustainable Infrastructure Starts with Continuity: Protecting Critical Structures and Systems from Lightning

By Kelley Collins

SUSTAINABILITY IS MORE than building green; it is about ensuring that the systems powering modern life are reliable, safe, and efficient. Data centers, renewable power grids, electrification projects, and advanced manufacturing facilities share one common requirement: uninterrupted operations. As these industries lean more heavily on electricity, they also become more vulnerable to disruption.

Coordination among the trades becomes vital to securing the sustainability of systems and structures. This coordination begins by better understanding the goals and challenges of each trade. This article highlights the fundamentals of lightning protection systems and showcases how they can be an integral part of the building enclosure. With this information, questions and conversations can be started among building enclosure consultants and lightning protection

professionals to ensure the sustainability and safety of our structures.

THE OVERLOOKED SUSTAINABILITY THREAT

Among the most consistent and destructive natural forces is lightning, which strikes the earth about 6,000 times every minute (**Fig. 1**). A single bolt can carry hundreds of millions of volts and deliver 30,000 to 50,000 amps of current (with peaks over 200,000 amps). The surrounding air is then heated to approximately 50,000°F (28,000°C), which is five times hotter than the surface of the sun.

This immense energy does more than ignite fires: it can crack concrete, shatter glass, damage electronics (**Fig. 2**), accelerate corrosion of structural steel, and disrupt operations in critical facilities. Lightning protection systems are therefore an essential yet often overlooked component of sustainable resiliency planning.

Every sustainability plan highlights efficiency, carbon reduction, and operational performance. But when lightning strikes a critical structure or system without a lightning protection system, these goals are not achieved.

LIGHTNING PROTECTION SYSTEMS: HOW THEY PROTECT

A lightning protection system is much more than a single rod and a cable. A complete system is a coordinated network of components designed to intercept and safely redirect lightning energy away from vulnerable

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Figure 1. Lightning striking near transmission lines, highlighting the risk a single event poses to grid disruption. Courtesy of the Lightning Protection Institute.

structures and equipment. A compliant system will have five components:

- **Strike termination devices (air terminals/"rods"):** metal rods that intercept a lightning strike.
- **Conductors:** heavy braided cables that carry current toward the ground.
- **Grounding (earth termination):** electrodes/ loops that disperse energy into the earth.
- **Bonding/potential equalization:** connects metal and internal systems (such as water, fire, security) so they rise/fall in voltage together, preventing side-flash.
- **Surge protective devices (SPDs):** protects power/data/controls from transient overvoltages.

Systems missing any of these components, or those that do not adhere to national standards, are insufficient. Compliance with standards such as NFPA 780, *Standard for the Installation of Lightning Protection Systems*;¹ UL 96A, *Standard for Installation Requirements for Lightning Protection Systems*;² and LPI 175, *Standard for the Design—Installation—Inspection of Lightning Protection Systems*³ is essential to ensure complete protection.

Proper installation and certification are critical for a lightning protection system to function effectively. Systems should be designed and installed by certified lightning protection contractors, who ensure that systems conform to national standards. Systems should then be inspected and certified by an independent third-party inspection program. Ongoing maintenance and re-inspection, especially after a storm or roof or structural changes, ensure that the system continues to operate as intended.

Lightning protection systems, installed according to the standards, defend against both direct and indirect strikes. Direct strikes occur

when a lightning bolt hits a building, potentially causing fire, structural damage, or electrical failure. Air terminals intercept the strike, and conductors safely route energy to the ground. Indirect strikes happen when nearby lightning induces surges through utility lines, piping, or the ground. SPDs, bonding, and grounding systems manage these surges, helping to protect life-safety systems, critical operations, and business continuity.

Lightning protection systems are woven into every part of the building enclosure—air terminals on the roof, conductors routed through parapets and wall cavities, and bonding of structural steel, mechanical equipment, as well as the services running through those walls to the grounding system. Because of this, coordination among the design and construction teams is essential to the success of the project.

Building enclosure consultants, architects, engineers, and certified lightning protection professionals need to understand each other's codes, details, and constraints so penetrations are detailed correctly, conductors can run continuously to ground, and performance and safety are preserved.

WHY LIGHTNING PROTECTION BELONGS IN SUSTAINABILITY PLANNING

Resiliency in the built environment means designing structures to withstand, adapt to, and recover from adverse events. Today's sustainability plans emphasize energy efficiency, embodied and operational carbon reduction, and climate adaptation (Fig. 3-5).

Data centers, power grids, manufacturing plants, and critical facilities all share one thing



Figure 3. Georgia Tech's net-zero energy garage, home to the iconic Ramblin' Reck. Atlanta Lightning Protection received the Lightning Protection Institute's Most Innovative Design Award for integrating a lightning protection system that preserves both sustainability and tradition. Courtesy of LPI Member, Atlanta Lightning Protection.



Figure 2. Damaged circuit board due to a lightning strike that caused a surge in the building.



Figure 4. Specialized air terminal design maintains aesthetics while ensuring full lightning protection.

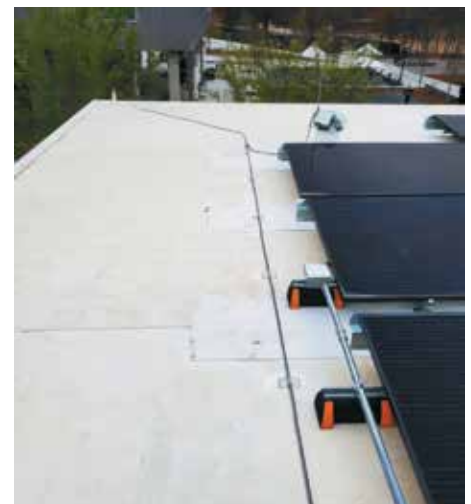


Figure 5. Roof-level interconnection of conductors with solar arrays.

in common: lightning risk threatens their ability to operate without interruption. A single strike can do more than damage a roof—it can ripple through networks, electrical grids, and critical systems that entire communities rely on. For example, a lightning strike to an unprotected fire station or emergency operations center can disrupt dispatch consoles, radio networks, and data links, slowing response times for fires, medical emergencies, and severe weather events precisely when the community needs them most.

Even a momentary disruption in a data center can jeopardize global connectivity and cloud services. As solar, wind, and electric vehicle (EV) charging infrastructure expands, new exposure points across the power grid make electrification projects increasingly vulnerable to lightning strikes. In manufacturing, highly automated production lines and robotics (Fig. 6) rely on uninterrupted power and communications, where downtime translates directly into costly delays. For hospitals, airports, and emergency response centers, continuous operation is not optional; it is mission-critical (Fig. 7-8).

When lightning protection is missing—or when existing systems are not properly maintained and inspected—the consequences extend beyond safety. Some of these consequences can include:

- **Resource Efficiency:** Without lightning protection systems, structures and systems can face premature failure, resulting in wasted materials and increased embodied carbon. A single lightning strike to an unprotected rooftop mechanical area may require replacing sections of roofing, conduit, and equipment years before the end of their expected service life.
- **Carbon Impact:** Damaged electronics and building systems often require full replacement, creating unnecessary emissions and landfill waste. For example, repeated loss



Figure 6. Automated manufacturing line with robotics. Lightning protection systems safeguard uptime and minimize costly downtime in advanced facilities.

of unprotected control panels, PV inverters, or building automation components means new manufacturing, shipping, and disposal each time a storm causes preventable damage.

- **Insurance Industry Lens:** Rising claims for lightning and other natural disasters have pushed insurers to prioritize resilience and sustainability. They recognize that proactive protection, including lightning protection systems, reduces both financial losses and risk exposure. Facilities with documented, well-maintained lightning protection are better positioned to avoid major claims after a severe storm, improving insurability and helping stabilize premiums over time.

Lightning protection systems directly support sustainability by reducing unplanned outages, extending the life of infrastructure, and preventing wasteful losses of equipment and resources.

LIGHTNING PROTECTION SYSTEMS AS PART OF THE CIRCULAR ECONOMY MINDSET

The circular economy in the built environment is about more than recycling. It focuses on keeping materials and systems in service longer, preserving their value, and avoiding unnecessary replacement. For building enclosure consultants, roofing professionals, and lightning protection specialists, this means coordinating early at design, reroofing,



Figure 7. (a) An example of a community/critical facility, this Fort Myers fire station is located in a high-lightning-density zone. Early design coordination enabled a fully enclosed lightning protection system. (b) The installation team did not get the call to rough in the system before the top pour of the walls. Adjustments were made to conceal the system in the parapet wall. (c) Conductors through the wall “to ground,” which connect to the ground loop.

and retrofit stages. This coordination ensures that penetrations, conductors, and rooftop equipment are installed correctly and maintained over time instead of being repeatedly torn out and replaced. When lightning protection is integrated with the enclosure strategy from the start, it supports circular-economy goals in several practical ways:

- **Inspection and recertification** (every 3 years under the Lightning Protection Institute – LPI Inspection Program, known as LPI-IP)⁴ ensure systems stay effective (Fig. 9). A scheduled LPI-IP inspection may catch a loose conductor and failing sealant at a roof penetration early, allowing a small, targeted repair instead of a larger tear-off later.
- **Preventative maintenance** extends usable life, reduces replacement cycles, and maximizes return on materials (Fig. 10). For example, replacing a corroded air terminal base or a few damaged clamps preserves the integrity of the entire system, avoiding premature replacement of long runs of conductor or larger sections of roofing.
- **Predictive monitoring** supports smarter operations to catch vulnerabilities before failure.

This proactive, coordinated approach mirrors sustainable practices: protect what is built, extend the lifespan of both the roof and the lightning protection system, and minimize waste over the life of the facility.

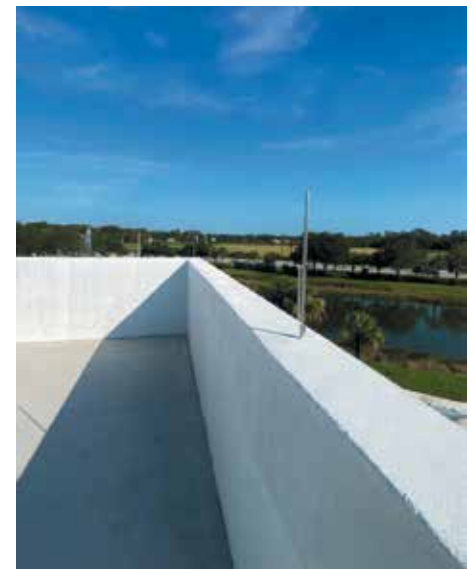


Figure 8. The result of early coordination is having an enclosed system. This picture shows the air terminal of the enclosed lightning protection system at a Fort Myers Fire Station/ Training Tower, coordinated with electrical and design trades. Courtesy of Lightning Protection Institute (LPI) member Lightning Protection Systems Inc.



Figure 9. Inspection can identify inappropriate repairs or repairs that are necessary to ensure that a system remains functional. Here, a conductor has been repaired using a noncompliant method of securing the conductor to the roof.



Figure 10. Rooftop equipment should be protected and monitored for damage due to possible other rooftop maintenance or issues.

THE COST OF NEGLECT

Lightning-related insurance claims in the US exceeded \$1.0 billion in 2023 and 2024. Those numbers reflect only homes; the stakes for large-scale industrial and municipal projects are far higher (**Fig. 11**). For facilities driving electrification and manufacturing, unprotected lightning strikes translate into the following:

- **Operational Downtime:** supply chain delays, halted EV charging, and interrupted digital services. For instance, a lightning strike to an unprotected manufacturing plant can halt automated lines and delay shipments, creating supply chain bottlenecks downstream.
- **Expensive Repairs:** damage to renewable energy installations, control systems, and structural integrity. A direct strike on an unprotected rooftop PV array can destroy inverters, surge protective devices, and portions of the roof assembly, which could result in costly replacement instead of minor repairs.
- **Community Impact:** disruption of emergency services, utilities, and business operations that people rely on daily.

BUILDING LIGHTNING RESILIENCE INTO A SUSTAINABILITY PLAN

Building true lightning resilience requires more than hardware; it demands adherence to recognized standards, a defined process, and qualified professionals. Sustainability is achieved through early collaboration of the design/build, facility management,



Figure 11. The US Air Force Academy's Hosmer Visitor Center in Boulder, Colorado. Courtesy of LPI member Mr. Lightning.

and lightning protection specialists. This disciplined approach enables the sharing of standards, expectations, and processes to ensure that all systems and materials are installed and maintained according to the standards and codes. This coordination safeguards operations but strengthens sustainability by preventing costly failures in the future (**Fig. 12**).

Assessment

Assessing an operation's risk to lightning involves more than just the location or the propensity for lightning in a particular area. It also includes:

- **Using NFPA 780-compliant risk assessments** to evaluate lightning exposure based on geography (flash density), building attributes (height, footprint, construction type, roof use, presence of PV), occupancy, contents, and system sensitivity. Even the simple assessment in NFPA 780 can quickly flag facilities where lightning protection should be a priority.
- **Checking in with multiple trades when applying the assessment.** Building enclosure consultants, electrical engineers, IT/controls, mechanical, and operations staff each see different vulnerabilities; these could include critical servers near exterior walls,



Figure 12. Close-up of the lightning protection system integrated into the roof of the US Air Force Academy's Visitor Center in Boulder, Colorado. Thorough assessment and coordination of trades are attributed to the design and sustainability of this structure.



Figure 13. All conductive systems and metal bodies likely to become energized by lightning must be bonded to the lightning protection system to eliminate potential differences and reduce the risk of a side-flash.

rooftop equipment clusters, or sensitive production lines.

- **Considering the interconnectivity of today's systems**, where a single point of failure can cascade into widespread downtime. Use the risk assessment as a framework for asking, "If this one component goes down, what else follows?" so that mitigation strategies address both direct and indirect strike risks on operations.

Design and Installation

A complete lightning protection system consists of five components: air terminals, conductors, grounding, surge protection, and bonding/potential equalization (Fig. 13). A complete system protects a facility from

both direct and indirect strikes, which may compromise the electrical system.

- Integrate lightning protection systems during initial design phases.
- Retrofitting historic (Fig. 14) or legacy facilities strengthens sustainability by extending usable life and preventing premature replacement. Many buildings that we encounter are *legacy facilities*: schools, hospitals, municipal buildings, and industrial plants. They may have been reroofed, re-clad, and retrofitted over decades without fully coordinating enclosure performance, lightning protection, or modern mechanical and electrical demands.
- Utilize certified lightning protection contractors who are skilled in the industry standards and installation practices.

Compliance

Design and construction of lightning protection systems should conform to national standards such as NFPA 780;¹ LPI 175, *Standard for the Design—Installation—Inspection of Lightning Protection Systems*;² IEC 62305, *Protection against lightning*;³ and UL 96A, *Standard for Installation Requirements for Lightning Protection Systems*.⁴ Consultants should avoid noncompliant "shortcuts" marketed as lightning protection; they undermine both safety and sustainability.

Inspections and Certification

When it comes to inspections and certifications, use accredited third-party inspections such as the LPI-IP to ensure objectivity and a thorough review.



Figure 14. (a) The Yorktowne Hotel by Hilton, located in York, Pennsylvania, is a historically significant building that was first opened in 1925. The 14-story building was completely renovated to re-open as a luxury hotel with a rooftop restaurant and bar. (b) The biggest challenges were the down conductors for this project. Placement of down conductors was complicated because of the age and design of the building. There was very little space in the ceiling and within the exterior walls; they did not want to place down conductors externally to change the aesthetic of the historic building. The conduits followed small "chases" from the top floor to the basement. There were multiple "pull boxes" on the path down to assist with pulling Class 2 wire through all of the building floors. (c) Once the conduits got to the basement, they were surface mounted to the interior of the exterior walls and a box was mounted to exit the building below grade. Courtesy of LPI Member Larson Lightning Protection Inc.

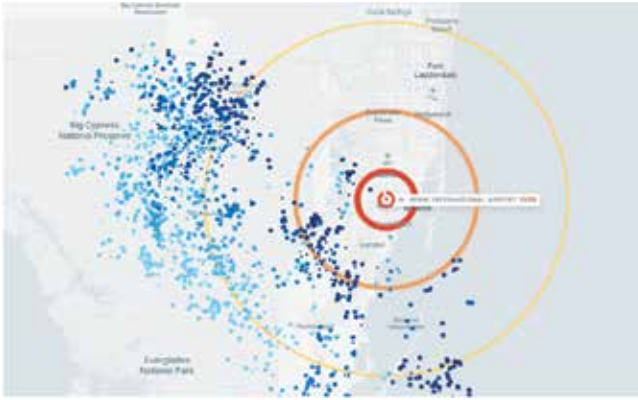


Figure 15. Vaisala's Xweather Protect showing live lightning monitoring near Miami International Airport. Alert radii determine when site-specific lightning alerts are triggered to safeguard operations. Courtesy of Vaisala Xweather.



Figure 16. Newark Liberty International Airport's consolidated rent-a-car facility is the largest single solar rooftop project at a US airport and includes a lightning protection system. Courtesy of Lightning Protection Institute member Lightning Prevention Systems.

Recertifying every 3 years ensures systems evolve with the facility's growth and existing components are intact.

Maintenance and Monitoring

Almost as important as the initial installation, preventative and predictive maintenance is critical to catch vulnerabilities early. Lightning protection systems can also be paired with lightning detection technology to track and respond to strikes impacting power grids or industrial sites. Vaisala Xweather^{6,7} is a trusted international source for monitoring lightning strikes (Fig. 15).


WHY LIGHTNING PROTECTION SYSTEMS MATTER TO KEY INDUSTRIES

Lightning protection systems play a critical role across today's most essential industries. In data centers, they safeguard operational continuity, where even brief downtime can result in lost revenue and eroded customer confidence. For power grids and renewable energy projects, protection of solar arrays, wind farms, and substations ensures that clean energy is reliably delivered without costly interruptions. In advanced manufacturing facilities, electrical stability is vital to keeping automation lines and robotics running without disruption. And for critical services such as fire stations, hospitals, and airports, lightning protection enables life-sustaining operations to continue seamlessly, even during severe weather (Fig. 16).

CONCLUSION: LIGHTNING PROTECTION IS SUSTAINABILITY AND COORDINATION IS VITAL

For the design-build community, facility managers, and consultants shaping the future

of cities and industries, sustainability must also mean survivability. With coordination among trades, lightning protection systems can be designed to meet the needs of both aesthetic and safety objectives. Lightning protection systems safeguard investments, protect lives, and prevent wasteful loss of energy and materials.

By including lightning protection systems in sustainability planning, we ensure that structures and infrastructure are resilient, reliable, and prepared for the challenges of tomorrow. 

For more information on how a lightning protection system works, or to find local certified lightning protection contractors, please visit www.lightning.org.

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