# The Nuts and Bolts of Resilient and Sustainable Roofs


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## Introduction

Resiliency. Sustainability. These terms get tossed around a lot in the roofing industry. These terms, to most of us, are more nebulous than practical when it comes to buildings and roofing. Of course, dictionary definitions trend to the common uses of the words. Simply put, resilience is the ability to bounce back, and sustainability is the ability to continue over time.

ASTM Committee E60 on Sustainability developed standard E3341, General Principles of Resilience, which includes a definition of "resilience". It states: "resilience, n—the ability to prepare for anticipated hazards, adapt to changing conditions, to withstand and limit negative impacts due to events, and to return to intended functions/services within a specified time after a disruptive event." Also, E60 developed standard E2114, Terminology for Sustainability, which defines sustainability as "the maintenance of ecosystem components and functions for future generations."

The dictionary and ASTM definitions are certainly correct, but, honestly, not all that helpful when it comes to designing a roof. So, how does one implement resiliency and sustainability when it comes to buildings, and specifically roof systems? The roof on a building is arguably one of the key elements required for a building to remain usable for long periods of time and after extreme weather events, i.e., sustainable and resilient. So, again, what does all this mean when it comes to designing roof systems?

In the author's opinion, the most sustainable roof is one that performs properly for a very long time, almost irrespective of materials choices. (Almost. See Material Choices section near the end of this article.) And the most resilient roof system is one that stays in place (think durability and wind resistance), provides efficient and effective thermal protection for the long term, and is usable if there is no power. Yes, these are simple and focused ideas, but they

**Resilience is the ability to bounce back, and sustainability is the ability to continue over time.**

are very practical concepts that allow us to lay the foundation for design concepts that then can be translated into roof system designs and construction details–all of which should be easily implemented. In other words, these simple and focused ideas allow us to discuss the nuts and bolts of roof design that results in a roof that is sustainable and resilient.

## Wind Resistance

Wind resistance really means two things–are we designing a roof system that is able to withstand the increased frequency and intensity of storms, and are we designing the edge metal system (and the all-important load path) with the same look to the future?

The standards we use to determine loads acting on a roof have become more conservative and detailed with our growing experience of storm related damage and ability to assess wind loads. However, and very importantly, the standards we use to design roofs are based on historical data, not on the anticipated needs of the future. Anticipating future needs is a key element of sustainability. So from a practical standpoint, a designer could use a higher wind speed than current standards require (e.g., +10mph, +20mph), or a designer could use a more conservative risk category. Either will increase the design wind pressures, and therefore, increase the wind resistance of the installed roof system.

Canada is putting this concept into practice. A new Canadian Standard on Performance Requirements of Climate Resilience of Low Sloped Membrane Roofing Systems (CSA A123.26) was released in 2021. It provides a scaled framework (i.e., bronze, silver, gold) for increasing the resilience of roofing systems; one of the topics is wind resistance. For example, to reach silver, a roof's design wind loads are to be increased by 30%, and to reach gold, design wind loads are to be increased by 50%. These increases are based on anticipating future climate conditions.

The same wind-resistance concepts can be applied to designing edge metal. The industry knows that a large majority of failures from wind originate at the perimeters and corners. Increasing the wind speed increases the design wind pressures required for edge metal, resulting in stronger, more wind-resistance systems. A designer could also specify a heavier gauge cleat, and use an L-shaped cleat to ensure the cleat and the fascia's drip edge are well engaged. Recent testing, as presented in this article, showed that cleat-drip edge engagement is critical wind resistance of edge metal. Prefabricated edge metal can also be a practical solution for ensuring strong and well-aligned edge metal systems.

Additionally, a peel-restraint bar (aka, peel-stop bar) can be installed 1 foot to 2 foot inboard of the perimeter edge as a secondary measure to prevent a roof membrane and insulation from being lifted if the edge metal does fail. A peel-restraint bar can simply be a standard termination bar that is commonly used to secure the top edge of flashings. Fasten it through the roof into the structural deck and cover it with a stripping ply. A peel-restraint bar can be used on new roofs, and can be easily retrofitted on *existing roofs*, too! Consider this idea for any existing roof that is potentially vulnerable to high winds.

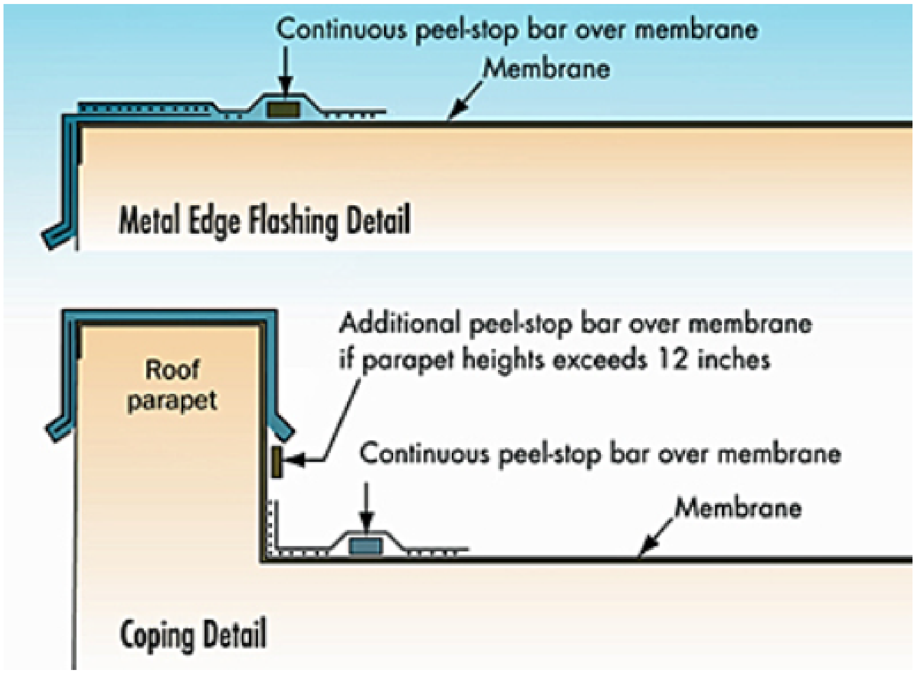
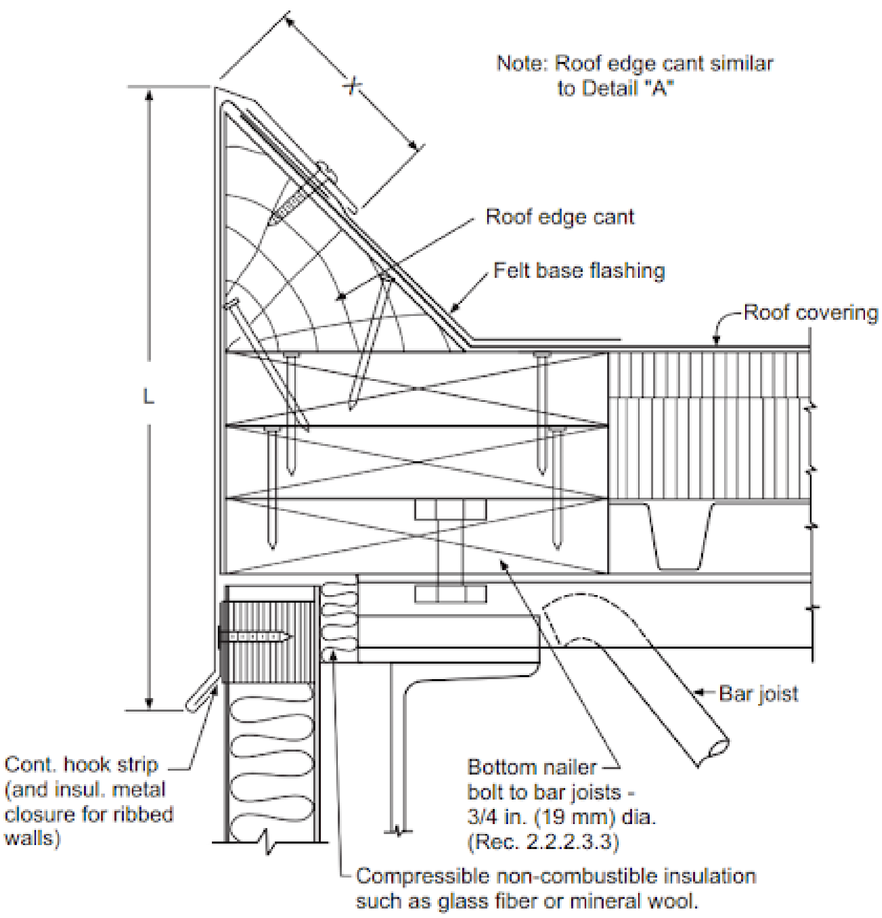



*Figure from the NIST Whole Building Design Guide titled, Wind Safety of the Building Envelope, that can be found here.*




For edge metal that is properly attached to the substrate, the attachment of the substrate (e.g., wood blocking) to the structure is, without question, a key factor in keeping the edge metal on the building. The fastening method of the substrate / wood blocking should be engineered to ensure there's adequate capacity and a continuous load path from the blocking to the structure. FM Global's Property Loss Prevention Data Sheet, 1-49, Perimeter Flashing, includes a number of ideas on how to ensure a proper load path exists, but the key is to connect the wood blocking to the structure such that the wood blocking stays in place during high wind events.

*Figure from FM Global LPDS 1-49, Perimeter Flashing, showing an example of the fastening of the edge metal substrate (i.e., the wood blocking) to the metal deck to create a proper load path.*

## Impact Resistance

Impact resistance, often referred to as hail resistance, is another factor for longevity. The industry recognizes that using a coverboard adds durability and can certainly extend service life. Hail, foot traffic, and debris from a storm can damage a roof. A tough membrane (e.g., a 2-ply granule-surfaced SBS membrane) over a rigid coverboard can provide much-improved impact resistance. Very importantly for long term resilience and sustainability of a roof, don't let the coverboard get removed because of the dreaded "value engineering". Traditional gypsum, cementitious, and HD polyiso coverboards provide toughness and durability, and now there are a few coverboards on the market that are specifically manufactured to provide resistance to very severe hail.

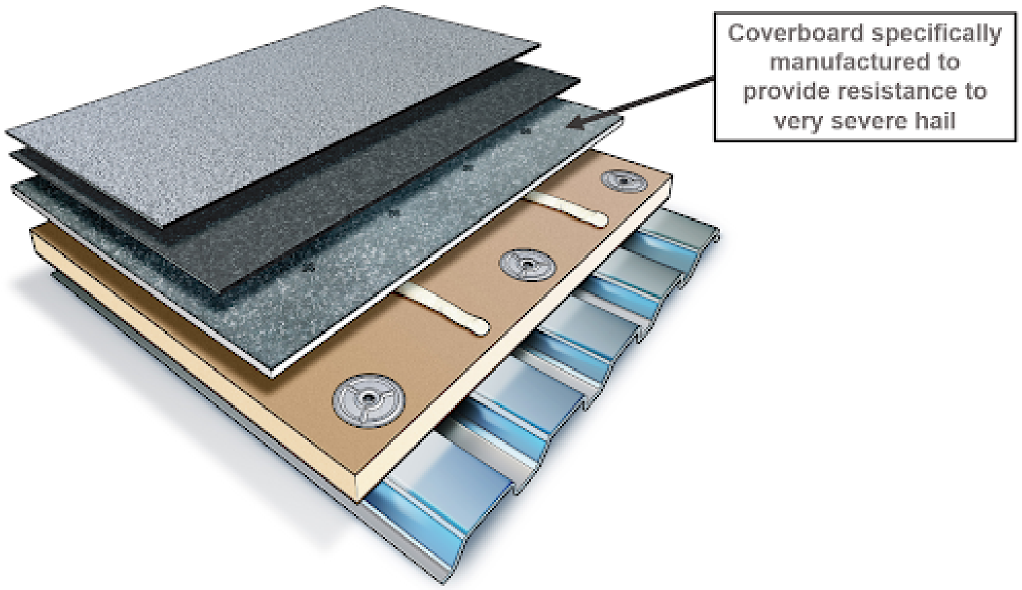



*Figure showing a coverboard specifically manufactured to provide resistance to very severe hail*

Another practical idea to increase impact resistance are paver systems. Pavers above membranes essentially completely protect the roof from impacts. Pavers can add a lot of weight, so determining the structural capacity of the roof structure is definitely important.

Often overlooked is what can happen when rooftop units (e.g., HVAC units) are displaced during high winds and tumble across a roof. Sharp corners can tear roofs and the impact can crush insulation. A practical solution is to strap or tether rooftop units to the curbs they sit on. Consider this–even if the rooftop unit doesn't damage the roof, displacing a rooftop unit leaves a large opening in the roof! And what often comes with high winds? Rain. Once rain is freely entering the building, it often renders the building uninhabitable, and that's not sustainable or resilient. And similar to peel-restraint bars, tethers and straps can be added to new roofs and to existing roofs at any time.

## Roof Insulation and Color

Roofs are required by the IECC to have minimum levels of roof insulation. Oftentimes this insulation is installed continuously above the deck–using multiple layers of rigid insulation. The most efficient way to retain R-value and prevent thermal bridging is to adhere all layers of insulation. At a minimum, the upper layer or layers of insulation should be adhered with the lowest layers fastened. Deck type and building requirements certainly affect the installation of insulation. Modeling performed a few years ago, presented in this paper, showed that various installation methods can have significant effect on the as-installed R-value of a roof system.

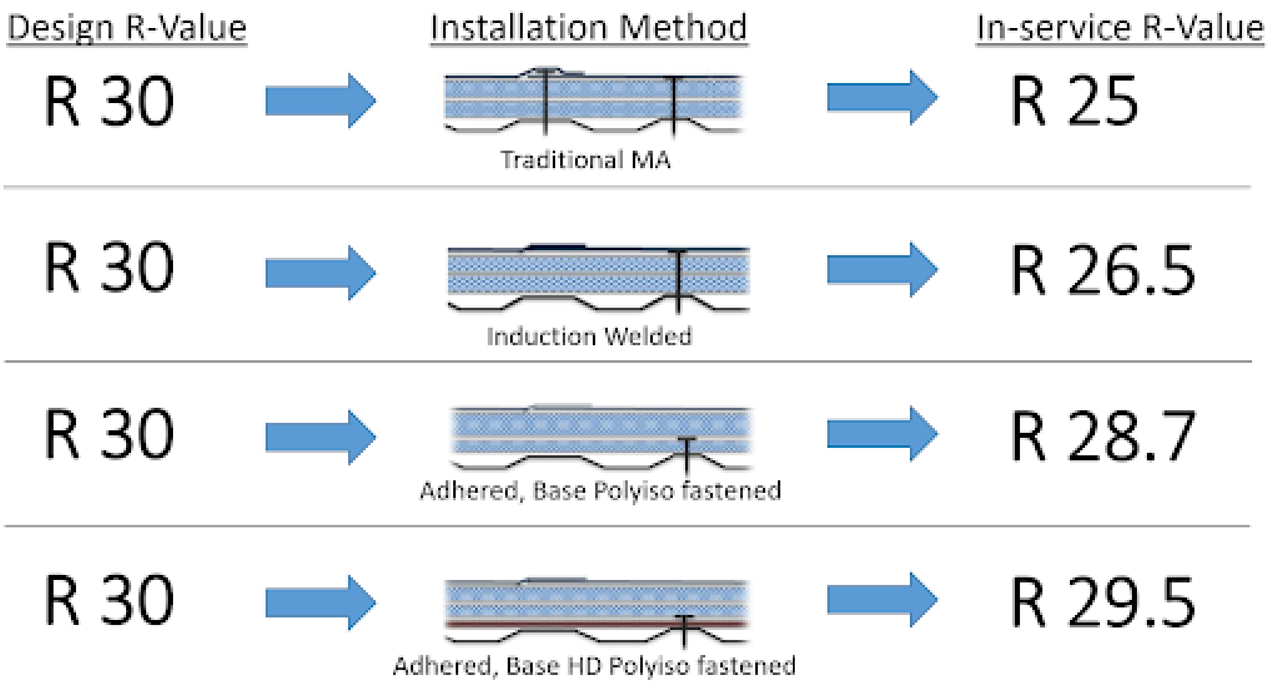



*Figure showing In-Service R-value based on modeling a 15,000 square foot roof with a 120mph wind speed used to determine the fasteners quantities and densities.*

Another type of insulation that is sustainable due to its longevity and ability to be reused is lightweight insulating concrete. Various LWIC system types exist, but simply put, an insulation board (typically EPS) is installed within a cementitious-based slurry that results in a substrate the resembles concrete but is much lighter weight per cubic foot and provides high R-value. LWIC's sustainability characteristic comes from the fact that it can be reused when the roof is re-roofed; there is generally no need to tear off the LWIC when replacing the roofing membrane.

Many locations have reflective roof requirements, stemming from local policy or implementation of the International Energy Conservation Code (IECC). A reflective roof helps with the urban heat island effect as well as energy efficiency of the building. But a reflective roof can also increase the resilience of a building when there is no power (e.g., after high winds occur) because it can reduce the solar gain and lower interior temperatures when the air conditioning isn't operating. Keeping interior temperatures at a more comfortable level helps ensure occupant comfort and continued use of the building.

From a sustainability and resiliency standpoint, coupling roof reflectivity with an efficient thermal insulation layer can keep a building comfortable and usable if there is no power. And, regardless, a reflective roof coupled with efficient insulation reduces the amount of energy required to cool and heat a building. In other words, roof color and insulation provide benefits 24/7/365, regardless of resiliency needs.

## Rooftop Energy Production

Typically tied to any sustainability discussion is the use of renewable energy, and for buildings, that predominantly means rooftop solar. If done correctly, rooftop solar can add to a building's resilience after extreme weather events. First and foremost, the solar arrays need to remain in place and be functional after a weather event. Similar to roofs in general, the corners and perimeters of solar arrays are the most vulnerable to damage. A practical solution is to mechanically fasten the corners and perimeters of the racking system to the structure, or at least attach the racking system to the membrane in some fashion. An often used, but less conservative approach to wind resistance of rooftop solar is the use of ballasted solar racking systems. Ballasted systems have zero mechanical attachment to the roof membrane or structure. If we're suggesting that rooftop HVAC or mechanical units be tethered, so should a solar array on a rooftop. Keeping solar panels on the roof is step one for a correctly installed rooftop solar.

This photo is showing a large solar array that is mechanically attached to the structure at the corners and the quarter points along the leading edge.

The second step for resiliency for rooftop solar is storage (e.g., a battery). What is not commonly known is that solar arrays require a battery at all times, and the majority of rooftop solar installations (i.e., those without a dedicated storage) use the utility grid to act as the battery. Therefore, when the power is off, a rooftop solar array will not work without an on-site dedicated battery. In other words, if you put solar panels on your roof without a battery and the power goes out, the solar panels will not provide power to the building. In order to be truly sustainable and resilient, rooftop solar requires dedicated storage (a battery) so that the building can be powered when the local utility is not providing electricity.

## Material Choices

Yes, material choices are important for resiliency and sustainability. There are many ways to evaluate materials choices–EPDs, HPDs, product datasheets, safety datasheets, and third party certifications, such as UL's GreenGuard certification, and more.  However, if we choose materials that get removed and replaced often ("Often" might be defined for a roof as every 12-15 years), the energy and resources needed to remove and replace those materials is definitely not good for the environment. We are not at the point where manufacturing, transporting, installing, removing, and disposing of materials is net-zero. So, it behooves us to design and install roofs with very long service lives regardless of the material we chose to construct the roof with.

## Initial versus Annualized Costs

Initial cost is clearly an important factor when it comes to roofing and reroofing. However, for many building owners, assessing annualized costs may often tell a different story and could lead to a longer lasting roof with lower costs per year of service life. From a cost perspective, adding 10% to 15% for the initial cost might add 25% or more time to the service life. For example, a $150k roof that lasts for 15 years is more expensive per year than a $170k roof that lasts 20 years. The nuts and bolts that lead to a resilient and sustainable roof can add costs, but the extended life can offset those costs when annualized. And, a more efficient and effective thermal insulation layer will lower annual heating and cooling costs. Longer life, reduced energy costs, and little or no interruption to a building's operations are factors that should be included in the discussion about a roof's long term resilience and sustainability.

## Conclusion

In addition to the nuts and bolts of designing roofing systems and their associated details, there is a larger concept that leads to longevity of all roofing systems. This concept has four components, which is called "The 4 Tenets of Roofing". They are good design, quality materials, proper installation, and regular maintenance. Roofs are being asked to be a lot of things in today's world, but let's not forget how important these four tenets are to long-term success, and ultimately to the resiliency and sustainability of our roofs and ultimately our buildings.

## More About the Author

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Jim Kirby, AIA, is an architect for Siplast. His focus is Building Science, Industry Relations, and Compliance. He has a Masters of Architecture—Structures Option and is a licensed architect. His 30+ years in the roofing industry have covered low-slope, steep-slope, metal, and SPF roofing, as well as green roofs and rooftop solar. Jim writes and speaks about building science topics related to roofing, represents Siplast across numerous segments of the roofing industry, and helps manage Siplast's compliance documents and information. He is a board member for CRRC and SPRI, an active committee member for ARMA and ASTM, and a member of AIA, ICC, IIBEC, NRCA, and WSRCA.

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