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Pitched Roof Array Layout for Fire Code Compliance

By: Fortunat Mueller (/Profile/Fortunat-Mueller)

Design & Installation (/design-installation)

While the fire code requirements for steep-slope roofs nominally apply to one- and two-family dwellings, AHJs are allowed to enforce these requirement in nonresidential applications, such as the roof...
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While the fire codes contain marking requirements ... bodies, enclosures, junction boxes, combiner boxe... and so forth, installers can meet these requiremen...
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INSIDE THIS ARTICLE

The latest fire code editions include requirements that could have far-reaching implications for residential PV installations.

In this article, I provide background on the two primary fire codes enforced in the US and the process that added PV system requirements to these codes. I focus specifically on fire code requirements that pertain to array layout on single- and two-unit residential dwellings. I discuss why these particular requirements, which may be new to you and your system designers, could have a negative impact on solar markets around the country. I then summarize some possible compliance strategies for companies that sell and install residential PV installations. Finally, I illustrate how proactive engagement with AHJs can help minimize the disruptive potential of these new requirements.

PV Systems in the Fire Codes

In July 2007, the California Department of Forestry and Fire Protection (CAL FIRE) established a task force consisting of fire service and solar industry stakeholders, as well as building code officials and codes and standards experts, to develop a set of PV system installation guidelines. This collaborative effort culminated in the April 2008 release of the *Solar Photovoltaic Installation Guideline.* (See Resources.)

While CAL FIRE originally developed the *Guideline* as an optional means of writing a local ordinance, its language was subsequently revised and incorporated into the 2012 editions of the two primary fire codes adopted and enforced in the US: the *International Fire Code (IFC),* published by the International Code Council, and the *NFPA 1: Fire Code,* published by the National Fire Protection Association, which also publishes *NFPA 70,* more commonly known as the *National Electrical Code.* As with the *NEC,* the issuing organization revises both fire codes every 3 years. While local regulatory agencies across the country vary in terms of which code or edition they enforce, the requirements related to PV systems are very similar in both the *IFC* and the *NFPA 1.*

Subsection 11.12 of *NFPA 1* follows the format of the CAL FIRE *Guideline* and organizes requirements for photovoltaic systems into two main content areas: requirements for marking and requirements for access, pathways and smoke ventilation. Subsection 605.11 of the *IFC* includes these primary content areas, but also adds a third related to locations of dc conductors. The fire code content related to marking and wiring methods for PV power systems is generally harmonized with requirements in the 2014 *NEC.* AHJs and PV installers around the country should therefore be familiar with these requirements.

The goal of the CAL FIRE *Guideline* is to "increase public safety for all structures equipped with solar photovoltaic systems." To achieve this principal objective, the *Guideline* places restrictions on rooftop PV installations to accommodate emergency response and fire suppression activities. The CAL FIRE *Guideline* is the only precedent for the PV array layout restrictions now found in the fire codes. These requirements may therefore be new to AHJs and PV system installers outside California and neighboring states such as Arizona and Oregon.

Bill Brooks is the principal at Brooks Engineering and a noted codes and standards expert. He was among the solar industry representatives who worked on the CAL FIRE *Guideline,* and he subsequently wrote the 2011 Solar America Board for Codes and Standards (Solar ABCs) report, "Understanding the CAL FIRE *Solar Photovoltaic Installation Guideline."* (See Resources.) In this report, Brooks explains why revising the CAL FIRE *Guideline* for inclusion in the fire codes is significant: "This elevates the importance of the *Guideline* from a recommendation to a legally binding code, and makes a thorough grounding in the reasoning behind the *Guideline* even more important."

Residential Array Layout Restrictions

The fire code requirements for PV arrays on steep-slope residential rooftops are in some ways more challenging to meet than those pertaining to low-slope commercial roofs. (See "Designing for Fire Code Compliance: Commercial Rooftop PV Arrays (https://solarprofessional.com/articles/design-installation/designing-for-fire-code-compliance)," *SolarPro* magazine, August/September 2014.) Residential rooftops tend to be more varied in shape than commercial roofs. In addition, residential roofs are generally smaller and more space constrained than commercial roofs.

System designers and owners often aim to fit as many modules as possible on a south-facing roof surface; the fire codes' array layout restrictions ensure that every design also meets the needs of firefighters. In some ways it is more challenging to fight fires at one- and two-unit buildings than at commercial facilities. This is due in part to the variety and complexity of residential roofs. More important, local fire departments often have predetermined strategies for fighting fires at commercial buildings, whereas at a residence, incident commanders must make strategic and tactical decisions about how to fight a fire on the fly.

The code-making panels intend the codes' roof layout restrictions to minimize the impact that roof-mounted PV arrays have on firefighter operations and safety. Specifically, the requirements ensure that firefighters can access the roof, that they have pathways to move about, that they have room to conduct smoke ventilation operations and that they have egress pathways in the event of an emergency.

Subsections 605.11.3.2 of the *IFC* and 11.12.2.2.2 of *NFPA 1* establish array layout restrictions for one- and two-unit dwellings—specifically, those with a roof pitch greater than 2:12 units. These subsections detail array layout setback requirements for hip roofs, single-ridge roofs, roofs with hips and valleys, and roof ridges. Further, both fire codes require suitable roof access points, which are defined as structurally strong areas of the building that do not require firefighters to place ground ladders over openings, such as windows or doors, and that do not conflict with overhead obstructions, such as power lines or tree limbs. Note that AHJs can also apply these requirements to other types of buildings where they have determined that the roof configuration is similar to that of a one- or two-unit dwelling.

Hip roofs. The fire code requirements for access pathways on hip roofs are fairly simple. As shown in Figure 1, subsection 605.11.3.2.1 of the *IFC* requires a 3-foot-wide "clear access pathway from the eave to the ridge" on any roof slope with PV modules. Further, it must be located "at a structurally strong location on the building capable of supporting the live load of firefighters accessing the roof."

While subsection 11.12.2.2.1.1 of *NFPA 1* includes the same general requirements, it provides an exception that allows AHJs to relax these requirements "where adjoining roof planes provide a 3-foot-wide clear access pathway." Per this exception, in scenarios where the roof slopes adjacent to the array area provide a 3-foot-wide clear access pathway to the ridge, AHJs may not require the side access pathway shown in Figure 1.

Single-ridge roofs. While a hip roof provides at least four roof planes for firefighter access, a single-ridge roof—like those typically found on Cape Cod or Colonial-style homes—usually has a relatively long ridge and two roof planes. The gable ends of single-ridge roofs provide structurally strong access pathways for firefighters because they are located over framed end walls.

Because each roof plane requires more available pathways, the fire codes call for an additional access pathway for single-ridge roofs. Specifically, subsection 605.11.3.2.2 in the *IFC* requires the configuration of arrays on single-ridge roofs to provide two 3-foot-wide access pathways from the eave to the ridge, as shown in Figure 2. Subsection 11.12.2.2.2.1.2 of *NFPA 1* includes the same basic requirement.

Roofs with hips and valleys. Homes with complex roofs often include a combination of ridges, hips and valleys. Subsection 605.11.3.2.3 of the *IFC* and subsection 11.12.2.2.2.1.3 in *NFPA 1* address array layouts for roofs with hips and valleys. Where the system design positions PV modules on both sides of a hip or valley, the fire codes generally require an 18-inch setback on either side of the hip or valley, as shown in Figure 3. However, in a design with modules on one side only, installers can place them directly adjacent to the hip or valley, as firefighters should be able to use the abutting uncovered roof slope as an access pathway.

Firefighters are trained to identify and prioritize the use of structurally strong roof access pathways. Since hips and valleys are often not located directly over structural framing, they are generally lower-priority access pathways compared to a gable located over a framed end wall. However, firefighters can use pathways at hips or valleys for emergency egress if a better option is not available.

Ridge setbacks. The fire codes generally require setting back PV arrays at least 3 feet from steep-slope roof ridges. In *NFPA 1,* this unembellished requirement appears in subsection 11.12.2.2.2. Meanwhile, subsection 605.11.3.2.3 in the *IFC* clarifies that the intent of the 3-foot-wide ridge setback is to “allow for fire department smoke ventilation operations.”

Firefighters use vertical ventilation to remove fire, heat and toxic gases from a burning building, thus reducing the immediate danger to victims and to firefighters on the attack crew. When ventilating residential structures and similar buildings, firefighters typically cut open a 16-square-foot vent hole in the decking and punch down through the attic space to drop the sheetrock or plaster ceiling below, thus giving hot gases and flames an exit. Alternatively, a 3-foot-wide ridge setback allows firefighters to open up a 2-by-8-foot vent hole. Access pathways must extend to ridge setback areas to make these rooftop operations possible.

Exceptions

Access, pathway and smoke ventilation requirements generally restrict the total roof area that can accommodate a PV array, which potentially puts them at odds with system integrators’ design goals or owners’ energy goals. However, the CAL FIRE *Guidelines* and both fire codes allow AHJs to grant exceptions that reduce these requirements.

In his SolarABCs report, Brooks notes that the revised CAL FIRE *Guideline* language that was codified “reminds local fire jurisdictions of their prerogative to provide alternative means and methods of compliance.” He goes on to explain the importance of this allowance: “Rigid enforcement creates a process that lacks flexibility, and the complexities of the built environment require flexibility.”

In the *IFC,* subsection 11.12.2.2.1.1 contains the exceptions to the access, pathway and smoke ventilation requirements; in *NFPA 1,* they appear in subsection 11.12.2.2.1.1. While exceptions to array residential layout restrictions are often specific to a site or a jurisdiction, AHJs will relax array setback requirements in two common scenarios. The first is where open roof faces provide adequate access pathways and ventilation opportunities for firefighters. The second applies to jurisdictions in which fire departments do not deploy vertical ventilation for fire suppression.

Open roof areas are adequate. The CAL FIRE *Guideline* authors recognized that residential plan review creates an administrative burden. To minimize this burden, they suggested using the ratio of the PV array to total roof area as a plan review trigger. This is why the *Guideline* states: “Plan review is required if a system is to be installed that will occupy more than 50% of the roof of a residential building.”

While neither of the fire codes formally adopted language related to the plan review trigger, language in *NFPA 1* specifically empowers AHJs to reduce access, pathway or ventilation requirements based on “proximity and type of adjacent exposures” or “alternative access opportunities, as from adjoining roofs.” In other words, if other roof areas (especially those adjoining the proposed array area) meet firefighters’ needs, AHJs can grant exceptions to the array layout restrictions.

While AHJs can grant these exceptions on a case-by-case basis, they can also standardize certain exceptions to streamline the permitting process. As an example, the *Oregon Solar Installation Specialty Code* (see Resources), which contains provisions based on the CAL FIRE *Guideline,* generally requires 3-foot pathways along three sides of a solar roof. However, it provides two exceptions for structures with PV arrays smaller than 1,000 square feet, as shown in Figures 4a and 4b. Standardizing these exceptions provides installers with specific design guidelines, expedites the permit review process and still accounts for firefighters’ needs.

Roof ventilation is unnecessary. Code-making panels write all of the fire codes with the assumption that vertical ventilation is a common fire suppression tactic. In a classic residential firefight, the first responding engine company stretches a water-charged hose to the building to support search and rescue and interior fire attack operations. Meanwhile, the first responding ladder company accesses the roof to perform vertical ventilation. While this operation improves visibility and survivability inside the building, it can also accelerate air-limited fires. Therefore, it is critical that ventilation and attack crews coordinate their activities.

Modern fire science, including research on fire flow paths conducted at UL and the National Institute of Standards and Technology, has increasingly called into question the appropriateness of vertical ventilation for some residential fire attack scenarios. Because modern homes are relatively airtight, fires in these structures are generally underventilated or air limited. Once firefighters ventilate the building, the fire can burn hotter and faster, which can cause rapid expansion or even flashover. Because of the risk of sudden roof collapse, many fire departments no longer use ground or roof ladders to access the roofs of wood-framed buildings constructed with lightweight framing techniques, which includes buildings constructed using attic trusses rather than rafters. Instead, they might ventilate these roofs only where they are accessible from an aerial ladder truck.

In some cases, fire departments simply do not ventilate residential roofs, whether due to concerns about roof collapse, insurance liability or equipment or personnel training limitations. In these scenarios, Exception 2 under subsection 605.11.3 of the *IFC* specifically allows AHJs to waive the 3-foot ridge setback requirement “where the fire chief has determined vertical ventilation techniques will not be deployed.” The exception also allows location of arrays “up to the ridge line where an alternative ventilation method approved by the fire chief has been provided.”

Impact on System Design and Sales

At first glance, system designers and installers may find the residential array layout restrictions that fire codes impose intimidating. Many of these professionals are used to trying to cover as much of the available south-facing roof as is practical. Applying access pathway and ridge setbacks to each roof face can dramatically reduce the available array area and thus the potential system capacity. In some cases, a strict reading and enforcement of the fire codes effectively eliminates the possibility of installing a PV system.

Dan Yechout is the sales director at Namasté Solar, an employee-owned PV systems integrator based in Boulder, Colorado. When Boulder's city council conducted public hearings prior to adopting the 2012 editions of the international codes, Yechout testified that a strict enforcement of the *IFC* could result in a 50% reduction in PV adoption in the city. Case studies conducted by Namasté Solar on behalf of the Colorado Solar Energy Industries Association (COSEIA) and presented to the Fire Marshal's Association of Colorado illustrated this point. Compared to unrestricted roof layouts, the fire code requirements reduced array capacity by anywhere from 15% to 37% for typical roof configurations. This not only reduced the potential electric bill offset, but also increased customers' up-front payments—in the case of a lease or power purchase agreement, by as much as $3,500. Yechout concludes: "In many cases, the fire code is so restrictive that it can make PV unviable because you can't use enough of the good roof for the system to make financial sense."

While fire code compliance poses a challenge for both residential and commercial projects, it can place a disproportionate burden on residential projects. The residential sales cycle is relatively short compared to that of commercial projects. Further, the residential market is extremely competitive. Meeting fire code requirements can drive up soft costs associated with system design and permitting. While detailed design and permit review are a routine part of commercial project deployment, residential sales personnel are often expected to complete preliminary system designs and close sales at the customer's kitchen table. This obviously makes it difficult to discuss each array layout with an AHJ prior to producing a proposal.

Compliance Strategies

Residential solar service providers, especially those active in multiple markets, should consider strategic options for reducing operational inefficiencies and mitigating potential risks associated with fire code compliance. On the one hand, system integrators have neither the time nor the budget to complete a detailed design or permit review for every residential proposal before presenting it to a client. On the other, it is not ideal to have system designers and sales staff prepare proposals without knowing which fire code or fire code edition applies, or how likely a particular AHJ is to grant exceptions.

After speaking to colleagues across the country, I identified three strategies for fire code compliance. The first option is to harmonize your company's internal design standards with the fire code so that your designs are universally compliant with the default requirements. The second option is to design systems on a case-by-case basis to the spirit of the fire code, taking full advantage of the available exceptions. The third option is to proactively engage code enforcement and fire department officials and develop jurisdiction-specific requirements for compliance.

Design for universal compliance. Perhaps the simplest strategy is to assume universal enforcement of the fire codes' array layout restrictions and to design every system around those limitations. This strategy likely makes the most sense for companies operating primarily in jurisdictions that have already adopted and are rigidly enforcing the 2012 *IFC* or *NFPA 1.*

Kevin Koch is the president and co-founder of Technicians for Sustainability, based in Tucson, Arizona. He explains: “We have been designing our permit submittals to the new fire code requirements since January 1, 2014. We have just accepted it and lived with the limitations. It does not affect the low-slope roofs we work on, which is probably 60% of our jobs. However, it does restrict, sometimes significantly, the steep-slope roofs we work on, including quite a few tile roofs.”

To implement the new design standards internally, Technicians for Sustainability trained its sales and design teams to take the new rules into account. Koch explains: “To help our staff understand the new design rules, we posted a drawing on the wall at the office that shows various roof conditions and the corresponding fire code setbacks. If everyone is not on board, you run the risk not only of costly rework and change orders but also of disappointing your customers.”

Compared with the other compliance strategies, designing for universal compliance is relatively easy to implement and requires minimal investment of resources on the part of the solar contractor. However, you always run the risk of losing projects to competitors that do not follow the same design standards. Koch acknowledges: “Even in Tucson, where code enforcement is pretty consistent, we occasionally encounter competitors’ proposals that do not appear to comply with the fire code requirements. It is unclear whether permitting and inspection officials are bringing these systems into compliance.”

Design to the spirit of the code. Designing for universal compliance may not be an option for companies that work across multiple jurisdictions, especially if code adoption and enforcement is patchwork. “There are hundreds of fire jurisdictions in Colorado,” notes Yechout at Namasté Solar, “and fully a dozen fire protection districts in Boulder County. Since these fire jurisdictions all operate independently, code adoption and enforcement is not uniform across the state.”

James Hasselbeck, the operations manager for ReVision Energy in Exeter, New Hampshire, elaborates: “We install solar projects in four states and hundreds of jurisdictions. While it would be nice to compile a comprehensive database of every town in Maine, Massachusetts, New Hampshire and Vermont so that we could understand exactly what each code enforcement officer and fire chief expects in terms of roof layout in their town, it simply isn’t realistic to do that at this stage of the industry’s development.”

If designing for universal compliance is not a good fit for your company, consider training your staff to design arrays with the intent of the fire code in mind. This requires training them to understand the basic fire code rules, as well as how to apply the exceptions. To the extent that your sales and design teams understand the logic of the fire code, they should be able to design systems that are consistent with the spirit of its requirements. In other words, they should produce defensible array designs that are likely to pass muster if subjected to a detailed code review.

While this strategy can be resource intensive, it has generally proven successful for ReVision Energy. Hasselbeck explains: “If a code official has questions about fire code compliance during their permitting review, I walk them through our design logic in detail, including our thoughts about alternative viable access pathways and ventilation options. Occasionally, an AHJ disagrees with our design logic, and we have to modify our design to meet its requirements.”

In many cases, code officials are not familiar with the fire code requirements or their discretion to grant exceptions. In addition to providing exceptions that apply specifically to PV array layouts, both fire codes broadly provide AHJs with enforcement flexibility and latitude—specifically, subsection 104.9 of the *IFC,* “Alternative materials and methods,” and subsection 1.4 of *NFPA 1,* “Equivalencies, Alternatives, and Modifications.” These subsections permit an AHJ to accept an alternative method of compliance as long as the designer can show that it provides the same level of protection as the original code requirement.

One potential downside to this strategy is that it can be time consuming to bring a rejected design into compliance. Further, if designing for compliance requires a change order, you will need to have a delicate conversation with your customer to explain why the array just got smaller. There may also be additional soft costs associated with this approach, which companies may want to track and evaluate on a cost-benefit basis.

Yechout clarifies: “Submitting a design for approval via ‘Alternate methods and materials’ takes additional effort compared to simply designing for compliance. It can also delay the permitting process while you wait for approval. In the worst-case scenario, the design is rejected and the project becomes unviable.”

Engage proactively with jurisdictions. While a case-by-case fire code review process can improve enforcement flexibility, it also increases administrative burdens for AHJs and solar contractors. This is why Namasté Solar and COSEIA proactively engaged the City of Boulder to amend its local fire code requirements for residential PV arrays. While this type of effort requires a significant up-front investment, it has the potential to improve operational efficiency in the long term compared to a case-by-case review process. The Boulder compromise, for example, resulted in clearly defined alternative design standards that installers and designers can easily follow and apply.

Yechout explains: “Because the City of Boulder has a stated goal of reducing carbon emissions, its planning board directed the fire department to work with COSEIA on a compromise that would protect firefighters without substantially reducing PV adoption.” This collaboration resulted in a proposed amendment to the 2012 *IFC,* relaxing some of its residential array layout restrictions. As both the fire service and the solar industry supported these alternative standards, the Boulder city council voted to approve them. (See “The Boulder Compromise”.)

This compliance strategy likely makes the most sense for companies that work in just a few jurisdictions and have cultivated good working relationships with code enforcement entities. Even if the process of proactive engagement does not result in a blanket modification of enforcement policies, it can still serve an important purpose in terms of educating firefighters about PV systems and educating solar contractors about fire suppression tactics. Ultimately, solar contractors, firefighters and code enforcement officers all benefit from rational and consistently enforced code requirements.

Design Responses for Space-Constrained Roofs

As more AHJs adopt and enforce the 2012 fire codes, application of those codes will reduce the size of optimal array areas on residential rooftops, except where solar contractors can negotiate alternatives on a case-by-case basis or via blanket code amendments. The most obvious design response to these array layout restrictions is to reduce PV system capacity. However, this is not the only strategy available. Other options include increasing module efficiency, installing modules on secondary roof surfaces or moving the array off the roof altogether.

Upgrading to higher-efficiency modules may enable designers to reduce the physical footprint of a PV array for fire code compliance without reducing overall system capacity or annual energy production. According to Koch, Technicians for Sustainability regularly employs this approach on residential projects, using either Sunpower E-Series or LG Mono X NeON modules. While higher-efficiency modules command a premium price, the client's total cost increase is generally modest compared to the overall system cost. Further, this approach gives solar contractors a competitive advantage when customers are shopping based on PV system capacity.

Alternately, system designers may be able to install modules on secondary roof surfaces. While the solar orientation or exposure of these other roof surfaces may be less attractive than that of the primary roof, designers can use these additional array areas to increase capacity and production in compensation for fire code setbacks. In some cases, this design approach requires the use of module-level power electronics, such as ac modules, microinverters or dc-to-dc converters. However, manufacturers increasingly offer residential string inverters with multiple MPPT inputs, which can independently optimize PV source circuits with different operating characteristics.

Where meeting rooftop code requirements is especially onerous, system designers may wish to consider options for ground- or pole-mounted PV arrays. In addition to outlining the fire code restrictions for rooftop PV arrays, the 2014 code cycle includes rapid shutdown requirements for PV systems installed on buildings. These and other new code requirements increase the cost and complexity of deploying roof-mounted PV systems, which decreases the cost premium for ground- or pole-mounted designs. If your customer has a good site at ground level—one with good solar exposure and easy access to the electrical interconnection point—a ground- or pole-mounted PV array may be a viable alternative to one that is roof mounted.

CONTACT:

Fortunat Mueller / ReVision Energy / Portland, ME / revisionenergy.com (http://revisionenergy.com)

RESOURCES

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