Understanding the Cal Fire

Solar Photovoltaic Installation Guideline

Prepared by:

Bill Brooks, P.E.
Brooks Engineering

Solar America Board for Codes and Standards

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Solar America Board for Codes and Standards Report

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EXECUTIVE SUMMARY

Photovoltaic (PV) systems present unique hazards for firefighters. In a building without a PV system, firefighters can often disconnect the utility alternating current (AC) service to protect themselves from electric shock during fire suppression activities. When a PV system is present, however, the situation is not as straightforward, and the PV system can pose dangerous risks to firefighters.

In August 2007, the California Department of Forestry and Fire Protection's (CAL FIRE's) Office of the State Fire Marshal began developing guidelines for the construction of PV systems in California to address these risks. It organized a task force of fire service and solar industry representatives, building officials, and codes and standards experts, which released the *Solar Photovoltaic Installation Guideline* on April 22, 2008. The *Guideline* is available as a free download at http://osfm.fire.ca.gov/pdf/reports/solarphotovoltaicguideline.pdf.

The purpose of the *Guideline* is to help firefighters identify PV systems, protect electrical wiring, and safely access roofs for vertical ventilation operations during fire suppression activities. The *Guideline* includes guidance about clearly marking conduit and equipment; access, pathways, and smoke ventilation; and the location of DC conductors in both residential and commercial buildings. Although the *Guideline* provides specific information that ensures compliance in these areas, there is little information about how the recommendations were developed.

In response to this information gap, this background document, *Understanding the CAL FIRE Solar Photovoltaic Installation Guideline,* was developed by the Solar America Board for Codes and Standards (Solar ABCs) to explain how the CAL FIRE task force developed the *Guideline* and why task force members recommended that PV systems be designed and installed to accommodate firefighting operations.

In May 2010, the International Code Council (ICC) approved a revised version of the CAL FIRE *Guideline* for inclusion in the 2012 version of the International Fire Code (IFC). 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. The 2012 IFC can be purchased from the ICC store in May 2012 at http://www.iccsafe.org/Store.

Without the information contained in this background document, local fire officials may be unwilling to consider alternative means and methods, choosing instead to rigidly implement the IFC. Rigid enforcement creates a process that lacks flexibility, and the complexities of the built environment require flexibility. CAL FIRE's intention in working with the PV industry was to facilitate the installation of PV systems while addressing the concerns of firefighters. A better understanding of the lengthy deliberations that went into the development of CAL FIRE's *Guideline* will encourage balanced and thoughtful enforcement.

In this document, each section of the *Guideline* is covered, indicating the corresponding section of the IFC in parentheses, repeating the language from the *Guideline* in italics, and including clarifications in plain text.

> "CAL FIRE's intention in working with the PV industry was to facilitate the installation of PV systems while addressing the concerns of firefighters."

Author Biography

Bill Brooks

Bill Brooks has worked with utility-interconnected PV systems since the late 1980s. He is a consultant to the PV industry on a variety of performance, troubleshooting, and training topics. Over the past 11 years, these training workshops have helped thousands of local inspectors and thousands of electricians and installers understand PV systems and how to properly install them.

His field troubleshooting skills have been valuable in determining where problems occur and to focus training on those issues of greatest need. Mr. Brooks has written several important technical manuals for the industry that are now widely used in California and beyond. His experience includes work on technical committees for the National Electrical Code, Article 690, and IEEE utility interconnection standards for PV systems. In 2008, the Solar Energy Industries Association appointed him to Code Making Panel 4 of the National Electrical Code.

Mr. Brooks holds bachelor and master of science degrees in mechanical engineering from North Carolina State University and is a registered professional engineer in both North Carolina and California.

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Solar America Board for Codes and Standards

The Solar America Board for Codes and Standards (Solar ABCs) provides an effective venue for all solar stakeholders. A collaboration of experts formally gathers and prioritizes input from groups such as policy makers, manufacturers, installers, and large- and small-scale consumers to make balanced recommendations to codes and standards organizations for existing and new solar technologies. The U.S. Department of Energy funds Solar ABCs as part of its commitment to facilitate widespread adoption of safe, reliable, and cost-effective solar technologies.

Solar America Board for Codes and Standards Web site:

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BACKGROUND

Photovoltaic (PV) systems present unique hazards for firefighters. In a building without a PV system, firefighters can often disconnect the utility alternating current (AC) service to protect themselves from electric shock during fire suppression activities. When a PV system is present, however, the situation is not as straightforward.

When utility power is interrupted, the AC output of the PV system inverter instantly shuts down, and the power flowing to the AC wiring in the building or to local utility lines stops. When the AC power stops flowing, the direct current (DC) power from the PV system also stops flowing.

The issue is that although the DC current isn't flowing, the PV array's DC voltage remains, and the PV system rests in an open-circuit condition awaiting the return of the utility power. This open-circuit condition is hazardous to anyone coming in contact with the circuits, and firefighters accustomed to conventional AC power systems but unfamiliar with PV systems can be exposed to dangerous and potentially fatal risks. For more details about why the load side of a DC switch in a PV array typically remains energized even when the power is off, see Appendix A.

In August 2007, the California Department of Forestry and Fire Protection's (CAL FIRE's) Office of the State Fire Marshal began developing guidelines for the construction of PV systems in California to address these risks. It organized a task force of fire service and solar industry representatives, building officials, and codes and standards experts, which met during a period of more than six months. This effort culminated in the release of the *Solar Photovoltaic Installation Guideline* on April 22, 2008. The *Guideline* is available as a free download at http://osfm.fire.ca.gov/pdf/reports/solarphotovoltaicguideline.pdf.

One of the first decisions CAL FIRE made was to develop a guideline rather than a regulation. The task force agreed with this approach because a guideline provides the flexibility to accommodate changes in response to lessons learned by local jurisdictions. In addition, regulations require a rulemaking, which would delay implementation by local jurisdictions.

The purpose of the *Guideline* is to help firefighters identify PV systems, protect electrical wiring, and safely access roofs for vertical ventilation operations during fire suppression activities. The *Guideline* includes guidance about clearly marking conduit and equipment; access, pathways, and smoke ventilation; and the location of DC conductors in both residential and commercial buildings. Although the *Guideline* provides specific information that ensures compliance in these areas, there is little information about how the recommendations were developed.

In response to this information gap, this background document, *Understanding the CAL FIRE Solar Photovoltaic Installation Guideline*, was developed to explain how the CAL FIRE task force developed the *Guideline* and why task force members recommended that PV systems be designed and installed to accommodate firefighting operations. The process of developing the *Guideline* involved numerous discussions, after which the text was circulated to task force members for comment and correction. The information provided here represents the author's understanding of the issues as a member of this task force, and is aimed to be useful to stakeholders including fire prevention officers, plans reviewers, firefighters, building officials, PV system designers, PV system installers, and PV equipment manufacturers.

From Guideline To Code

In May 2010, the International Code Council (ICC) approved a revised version of the *Guideline* for inclusion in the 2012 version of the International Fire Code (IFC). 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.

The revised wording of the IFC reminds local fire jurisdictions of their prerogative to provide alternative means and methods of compliance. In most cases, approving an alternative method of compliance requires an in-depth understanding of the original requirement. Although many PV installations easily comply with the IFC requirements, some installations require adaptations. Without the information contained in this background document, local fire officials may be unwilling to consider alternative means and methods, choosing instead to rigidly implement the IFC.

Rigid enforcement creates a process that lacks flexibility, and the complexities of the built environment require flexibility. CAL FIRE's intention in working with the PV industry was to facilitate the installation of PV systems while addressing the concerns of firefighters. A better understanding of the lengthy deliberations that went into the development of CAL FIRE's *Guideline* will encourage balanced and thoughtful enforcement.

There are two major fire codes used in the United States, the IFC published by the ICC and the Uniform Fire Code (UFC) published by the National Fire Protection Association (NFPA). The UFC is also known by its code designation, NFPA 1. Most U.S. jurisdictions use one of these two codes. The 2012 IFC includes provisions on PV installations in Section 605. NFPA is considering including provisions on PV installations in the 2012 UFC (see Appendix B). Both of these code changes include provisions very similar to those in the CAL FIRE *Guideline*, because both organizations used it as the template for their requirements.

The National Electrical Code (NEC®), which covers the fire safety requirements for electrical systems including PV systems, is also published by NFPA and can be referred to by its code designation of NFPA 70. The NEC is the basis for all electrical codes used in the United States.

> "Inclusion in the International Fire Code 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."

GUIDELINE LANGUAGE – RECOMMENDATIONS FOR ENFORCEMENT

The following provides an overview of each section of the *Guideline,* indicating the corresponding section of the IFC in parentheses, repeating the language from the *Guideline* in italics, and including my clarifications in plain text.

INTRODUCTION

The CAL FIRE *Guideline* begins with several pages of introductory information, including a history of the task force that developed the document, a short explanation of PV systems for stakeholders unfamiliar with the technology, a resource list for further study, and an explanation of what local governments must do to adopt the guidelines and enforce them as a local ordinance. The brief PV system background provides basic facts, including that PV systems only produce electricity during daylight hours, the typical locations of AC and DC disconnects, and that DC voltages can reach 600 volts. The introduction also describes other types of solar systems and notes that solar thermal systems for heating water or air may look similar to PV arrays, but do not present the electrical hazards of a PV system.

MARKING (IFC 605.11.1)

Marking is needed to provide emergency responders with appropriate warning and guidance with respect to isolating the solar electric system. This can facilitate identifying energized electrical lines that connect the solar modules to the inverter, as these should not be cut when venting for smoke removal.

Materials used for marking should be weather resistant. Use UL 969 as standard to weather rating (UL listing of markings is not required).

The section on marking covers the requirements for identifying PV circuits and the means for disconnecting them. The intent is to help ensure that firefighters are aware that a PV system is present and are not injured by PV-energized circuits.

The second paragraph related to weather resistance gives specific guidance on the requirement that circuits and equipment in outdoor locations be marked using weather resistant products. UL 969, "Marking and Labeling Systems," covers the resistance of labeling materials to UV radiation and moisture. It is common practice in the electrical industry to have placards custom-made by sign shops, using engraved plastic or metal materials. If the labels do not need to be customized, generic vinyl labels can be printed in volume. Vinyl labels should be specified as compliant with UL 969, but plastic and metal engraved labels do not require such a specification.

Main Service Disconnect (IFC 605.11.1.3)

For residential applications, the marking may be placed within the main service disconnect. If the main service disconnect is operable with the service panel closed, then the marking should be placed on the outside cover.

For commercial applications, the marking should be placed adjacent to the main service disconnect in a location clearly visible from the location where the lever is operated.

This section addresses the location of and specifications for identifying an electrical service that includes a PV system. Residential services often require opening a cover to access the main disconnect, and in those cases, the identification should be located inside the cover so that emergency personnel clearly see the labeling while operating the main service disconnect. If the main disconnect can be operated from outside the cover, the label should be mounted on or adjacent to the equipment.

The specifications for these labels indicate that adhesive-fastened labels are acceptable, although some jurisdictions require labels to be mechanically fastened. Mechanical fastening requirements often make it difficult or impossible to mount the label on outdoor equipment, because putting fasteners on outdoor equipment may violate the equipment listing to safety standards. A mechanical fastening requirement will often require the label to be mounted next to the equipment rather than on the equipment.

Some roofs have both PV and solar thermal systems. Solar thermal panels have no electrical components and pose no risk of electric shock. An array diagram located at the service panel may be used to illustrate the locations of the solar electric and solar thermal systems.

Marking Content and Format (IFC 605.11.1.1 and 605.11.1.2)

- *MARKING CONTENT: CAUTION SOLAR CIRCUIT (NEC® and IFC uses Warning: Photovoltaic Power Source")*
- *RED BACKGROUND*
- *WHITE LETTERING*
- *MINIMUM 3/8" LETTER HEIGHT*
- *ALL CAPITAL LETTERS*
- *ARIAL OR SIMILAR FONT, NON-BOLD*
- *REFLECTIVE, WEATHER RESISTANT MATERIAL (durable adhesive materials meet this requirement)*

CAUTION: SOLAR ELECTRIC SYSTEM

The intent of this section is to standardize the information, size and color, and construction of the warning labels on wiring systems and junction boxes. Some raised concerns that the CAL FIRE's preference for red labels with white lettering does not meet OSHA sign standards. The California and IFC requirements avoid the term "sign," because these labels are not used for the same purposes as OSHA signs. The IFC proposal that passed in May 2010 included slight wording changes to make the IFC consistent with the NEC. The message in the IFC proposal reads, "Warning: Photovoltaic Power Source."

1.2 Marking for DC Conduit, Raceways, Enclosures, Cable Assemblies, and Junction Boxes (IFC 605.11.1 and 605.11.1.4)

Marking is required on all interior and exterior DC conduit, raceways, enclosures, cable assemblies, and junction boxes to alert the fire service to avoid cutting them. Marking should be placed on all interior and exterior DC conduit, raceways, enclosures, and cable assemblies, every 10 feet, at turns and above and/or below penetrations and all DC combiner and junction boxes.

According to the *Guideline*, the DC side of the system requires specific visual identification of different kinds of solar panels (electric and thermal) and equipment such as inverters, combiner boxes, disconnects, and wiring systems. With a basic understanding of these major components, along with the labels covered in this section, it should be clear to firefighters and operations personnel that PV equipment is present and constitutes a hazard during daylight hours.

In commercial facilities, it is common practice to identify the contents of piping systems, including electrical conduit. Although there is no specific language exempting residential PV from identifying these circuits, it is less necessary, because non-metallic cables are more common in residential wiring. If a house has metal conduit installed, it is most likely either PV wiring or service entrance conductors, both of which firefighters should avoid. Simply said, commercial buildings have metal piping systems that require identification for various reasons. Metal conduit is less common in residential structures, and indicates a PV system.

In either case, firefighters should avoid touching the conduit. If a fire is present in the structure, these metal raceways may contain compromised conductors that could energize the conduit, shocking anyone who touches them. The labeling serves as an indicator that firefighters should avoid cutting the conduit and exercise caution when working near it.

The task force also discussed developing a complementary training program for fire service personnel. In this program, trainers cover aspects of the *Guideline* specifically and PV systems generally to help local fire departments develop standard operating procedures. This training program was introduced in November 2010 and will be available on the CAL FIRE website in 2011.

Inverters

The inverter is a device used to convert DC electricity from the solar system to AC electricity for use in the building's electrical system or the grid.

No specific markings are required by the California guidelines or the IFC requirements for the inverter, because the NEC already includes requirements for marking the PV power source disconnect, and that marking must be in the vicinity of the inverter.

ACCESS, PATHWAYS, AND SMOKE VENTILATION (IFC 605.11.3)

Section 2 of the *Guideline* addresses the access needs of fire departments that engage in vertical ventilation operations, which is a strategy for removing smoke from inside a burning structure. Although most fire departments engage in vertical ventilation operations, some are limiting this firefighting method depending on a structure's construction and the fire safety elements included in the building. For example, some types of roof construction may not be fire resistant enough to justify the risk of sending firefighters to the roof, and other buildings may have enough automatic vents that roof ventilation operations are unnecessary.

If manual roof ventilation is unnecessary, firefighters may require only access and egress to and from the roof to fight rooftop fires. Roof construction also plays a role in the decision process, because non-combustible roof decking such as concrete and metal may make ventilation operations impractical. Although a few fire departments may engage in vertical ventilation operations on metal and concrete decked roofs, they are the exceptions rather than the rule. In general, exceptions to access pathways and smoke ventilation must be approved by the fire jurisdiction, so the specifics of construction and operations are handled through the design review process.

Access and spacing requirements should be observed in order to:

- *Ensure access to the roof*
- *Provide pathways to specific areas of the roof*
- *Provide for smoke ventilation opportunities area*
- *Provide emergency egress from the roof*

Meeting the requirements of this section will limit the locations available for mounting PV modules, which is likely to make it a focus of concern for both solar professionals and firefighters. Understanding the requirements in this section is critical to properly enforcing the rules and enabling the flexibility to make adjustments to the rules when alternative means and methods can address the issues.

This list of bullets outlines why firefighters need clear spaces to work safely on a roof. The first bullet refers to firefighters' need to gain access to the roof with ladders or similar means. When they have achieved access to the roof, they must be able to get to the specific areas that require inspection or ventilation, as noted in the second bullet. As the third bullet points out, another reason to provide space on rooftops is so that the roof can be ventilated to help remove smoke from inside a burning structure. Lastly, firefighters require clear pathways to get off a roof quickly, as bullet four suggests. Typically, firefighters prefer to identify multiple pathways for egress so that if the fire cuts off one egress pathway, an alternative is available. The alternative pathways may not need to be as wide or structurally sound as the primary access and egress pathways.

Local jurisdictions may create exceptions to this requirement where access, pathway, or ventilation requirements are reduced due to:

- *Proximity and type of adjacent exposures*
- *Alternative access opportunities (as from adjoining roofs)*
- *Ground level access to the roof area in question*
- *Adequate ventilation opportunities beneath solar array (as with significantly elevated or widely-spaced arrays)*
- *Adequate ventilation opportunities afforded by module set back from other rooftop equipment (shading or structural constraints may leave significant areas open for ventilation near HVAC equipment, for example)*
- *Automatic ventilation device*
- *New technology, methods, or other innovations that ensure adequate fire department access, pathways, and ventilation opportunities*

The *Guideline* encourages local jurisdictions to exercise flexibility in the enforcement of these requirements in response to a variety of site-specific issues. The first three bullets describe circumstances that may allow fire departments to relax the setback options on a roof. PV arrays are often only mounted on one roof face (closest to south) so that other roof faces may be fully open for roof access and venting.

The next two bullets describe examples of PV array placement that allow for venting. In the first, the array is tilted above the roof pitch sufficiently to allow firefighters access to the roof below. In the second, gaps in the array intended to avoid shading from rooftop equipment such as HVAC units or the shrouds used to hide this equipment allow access for firefighters.

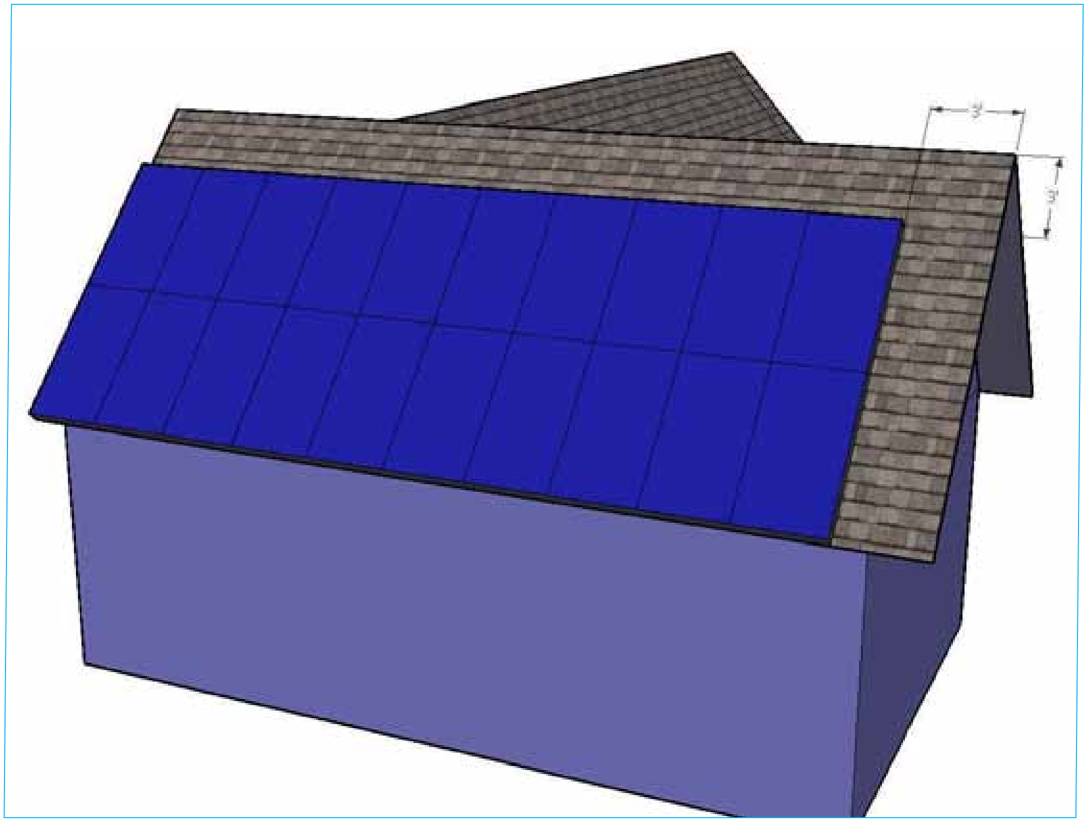
The last two bullets describe currently available ventilation options and potential new innovations that may allow easy removal of PV modules for roof ventilation access. In addition, some arrays include solar thermal panels that may be removable for roof ventilation access. The task force included these measures so that jurisdictional authorities would consider optional means and methods to meet the intent of adequate roof access and ventilation opportunities.

Designation of ridge, hip, and valley does not apply to roofs with 2-in-12 or less pitch. All roof dimensions measured to centerlines.

Roof access points should be defined as an area that does not place ladders over openings (i.e., windows or doors) and are located at strong points of building construction and in locations where it does not conflict with overhead obstructions such as tree limbs, wires, or signs.

An important distinction is made in this section with respect to residential low-slope (flat) roof construction. The guideline clarifies that requirements related to ridges, hips, or valleys do not apply to flat roofs. Simply stated, only a three-foot perimeter space would be required for flat residential roofs.

Example 1: Cross Gable Roof



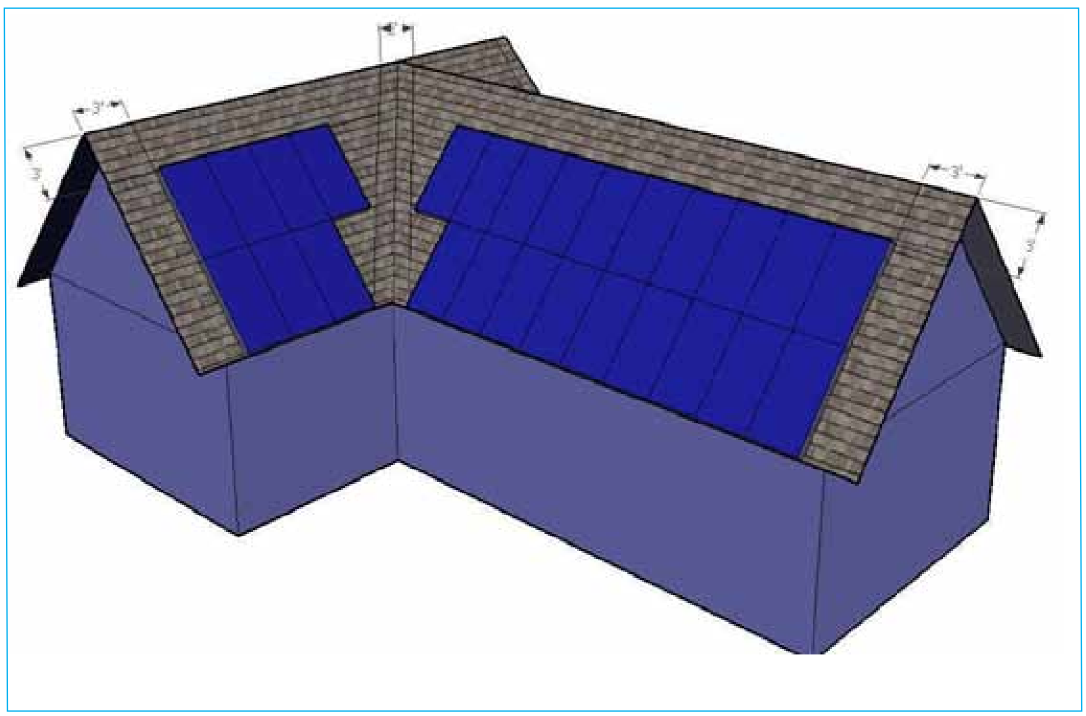
Residential Systems—Single and Two-Unit Residential Dwellings (IFC 605.11.3.2)

Plan review is required if a system is to be installed that will occupy more than 50% of the roof area of a residential building.

Examples of these requirements appear at the end of this guideline.

This statement suggests a relative PV system size that might trigger a plan review. Some jurisdictions have mistakenly interpreted this statement to mean that this applies to the area of the roof plane where the system will be installed. The intent of the task force was to minimize administrative review if the PV system will occupy no more than 50% of the total roof area. In order to achieve more than 50% of a residential sloped roof typically means mounting PV modules on multiple roof faces. This complicates the installation and increases the need for the fire department to review the plans to make sure that the PV system will still allow adequate access and ventilating opportunities. Systems that occupy less than 50% of a residence's roof area are generally simpler, and are likely to offer sufficient access and ventilation opportunities. This recommendation is not specifically mentioned in the IFC language.

Example 2: Cross Gable Roof With Valley



(IFC 605.11.3 and 605.11.3.1)

The three-foot access and ventilation requirements in 2.1.1. and 2.1.2 are among the most controversial items in the *Guideline* for both the solar industry and firefighters. The "three-foot rule" was the subject of lengthy deliberation and debate. Initially, the fire service requested four-foot setbacks and the solar industry preferred a two-foot setback. The three-foot setback was a compromise that could reasonably address the access needs of firefighters while allowing more room for larger solar arrays.

The wind loading on rooftops limits the roof area available for PV installations on many homes in high wind regions. The American Society of Civil Engineers (ASCE) publishes a standard ASCE-7, entitled "Minimum Design Loads for Buildings and Other Structures," which U.S. building codes reference. This standard includes tables for wind pressures based upon location, wind exposure, and location on the roof. The outer three-foot corners of a residential sloped roof structure has wind pressures that are double those three feet from the edge of the roof. PV modules are generally tested to withstand 30 pounds per square foot (PSF), and areas of the country with design wind speeds greater than 110 mph could experience wind pressures in excess of 30 PSF at roof corners. By staying away from the upper three-foot corners of a sloped roof, PV modules can be mounted safely and still provide firefighters the access they need to get to the ridge of the roof for ventilation operations.

This section does not discuss access to other roof faces, because each roof face must stand on its own. The reason for this distinction is that, during roof operations, adjacent roof faces may not be available for access or ventilation holes. One reason for a roof face to be unavailable for ventilation operations is that a strong wind on a roof face can make ventilation holes counterproductive.

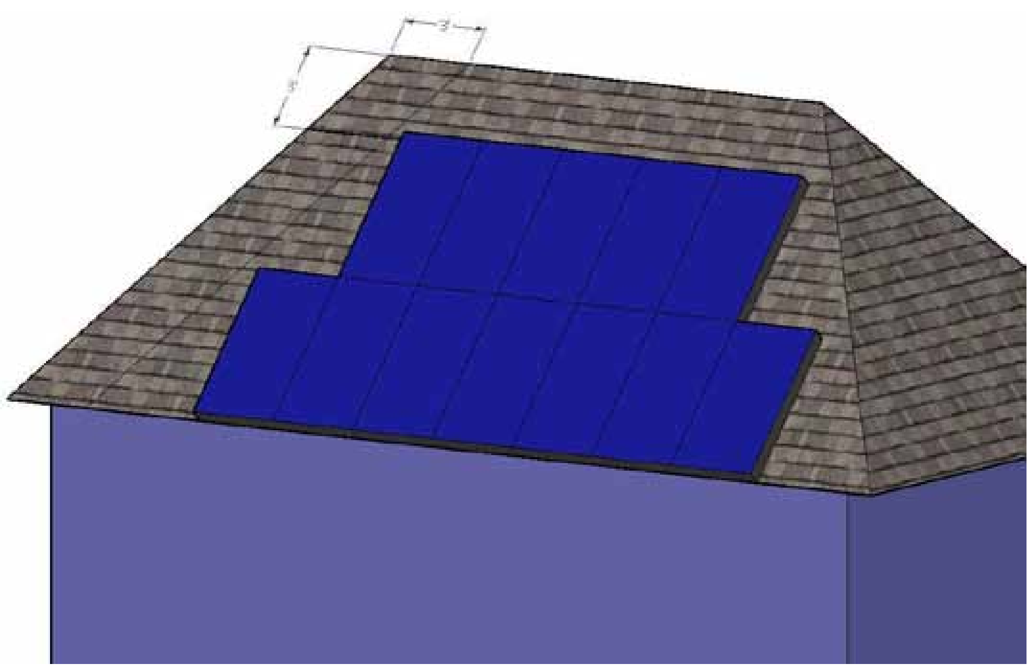
(IFC 605.11.3.2.1)

a. *Residential Buildings with hip roof layouts. Modules should be located in a manner that provides one (1) three-foot (3') wide clear access pathway from the eave to the ridge on each roof slope where modules are located. The access pathway should be located at a structurally strong location on the building (such as a bearing wall).*

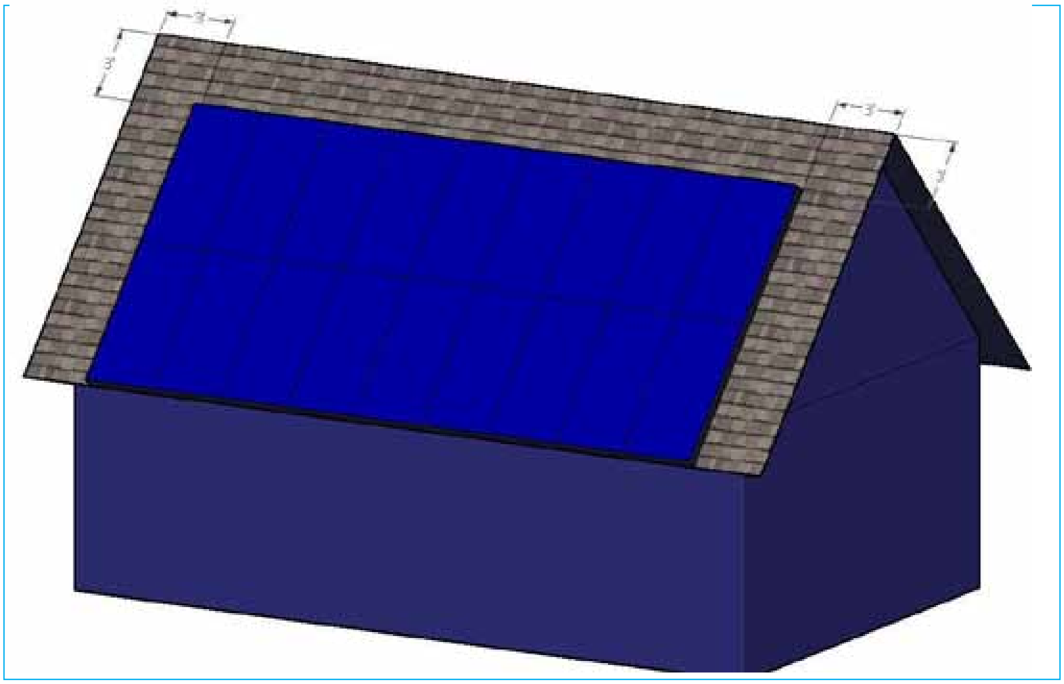
Hip roofs often have a relatively small center ridge section with side ridges (hips) that provide access to the corners of the building. These hips are not as structurally strong as single ridge gable ends. Only a single three-foot pathway is required, because it is necessary that at least one three-foot pathway be available on any roof slope with a PV array. This pathway is intended to be the primary access and egress for the roof. However, should this pathway be blocked or compromised during a fire, firefighters can make an emergency escape from the closest unaffected hip or slope to get to safety.

Although it is possible that a firefighter could walk on the opposing slope, there is a three-foot pathway on the PV slope in the event that a firefighter has to rapidly cross the hip slope to access a ladder against the PV slope at the corner. This would limit the total distance and time the firefighter would need to traverse the roof to get to a ladder.

Example3: Full Hip Roof



Example 4: Full Gable



(IFC 605.11.3.2.2)

b. *Residential Buildings with a single ridge. Modules should be located in a manner that provides two (2) three-foot (3') wide access pathways from the eave to the ridge on each roof slope where modules are located.*

Single ridge roofs, such as full gable construction, have structurally strong framed end walls that provide good access and egress for the firefighter to either end of the structure. Single ridge residences require two three-foot wide pathways to provide alternate means of access and egress for firefighters. As a related issue, these ridges can be long relative to the size of the structure so it is likely that one pathway is not accessible in a fire.

(IFC 605.11.3.2.3)

c. *Hips and Valleys: Modules should be located no closer than one and one half (1.5) feet to a hip or a valley if modules are to be placed on both sides of a hip or valley. If the modules are to be located on only one side of a hip or valley that is of equal length then the modules may be placed directly adjacent to the hip or valley.*

Roof types covered in (a) and (b) are common simple roof constructions. However, many roofs include a combination of ridges, valleys, and hips. Hips and valleys are treated differently from gable construction, because the hips and valleys often do not have structural walls under them. This makes hips and valleys less substantial than other access and egress options and therefore a lower priority during firefighting operations. However, hips and valleys may become a path for emergency egress should a fire prevent the firefighter from accessing the preferred structural access and egress location.

Ventilation (IFC 605.11.3.2.4)

Modules should be located no higher than three feet (3) below the ridge.

The purpose of the three-foot ridge setback for residential sloped roofs is twofold. First, it provides for access along the ridge for firefighters to move along the structurally stronger ridge. A minimum of 18 inches on either side of the ridge is generally used for a pathway so that firefighters can work their way along a roof ridge and step aside to allow another firefighter to pass without forcing either person too far away from the stronger ridge section.

Second, the three-foot space is intended to provide sufficient room for firefighters to cut a standard 16-square-foot vent hole two feet wide and eight feet long. This two-foot by eight-foot hole is in lieu of the more common four-foot by four-foot hole that is used for rafters or trusses on 24-inch centers. The four-foot by four-foot hole is cut with a rafter or truss at the centerline of the four-foot cut. This method only requires a single hinging action with 24-inch on center rafter or truss construction. A two-foot by eight-foot hole requires additional cuts and at least two louvered sections. This method of venting is commonly referred to as "dicing." It allows for a scalable hole by just lengthening the top and bottom cuts and "dicing" in between, completing new louvered sections. Another method is to make a four-foot by four-foot cut straddling the ridge of the roof. This last method may compromise an alternate escape route, but may be quicker than other methods and is used by some fire departments.

The ridge setback for PV modules assumes that they are energized and cannot be moved. Solar thermal panels, which are not energized and are removable for ventilation access, can be installed within 18 inches of the ridge, keeping the access pathway clear. In the future, as products are developed that automatically de-energize PV modules (see Appendix B), these special modules could also be removed safely, allowing systems to be installed as close as 18 inches from the ridge.

Some solar arrays are flashed into the roof. These flashing details should be allowed to extend into the three-foot setback areas, because this part of the array can be moved or removed during ventilation operations.

Commercial Buildings and Residential Housing with Three or More Units (IFC 605.11.3.3)

This classification covers all habitable structures that are not one- and two-family residences. The intent is to follow building code classifications, because there are many distinctions in building codes among single and two-family residences and other building types.

Exception: If a local fire department determines that the roof configuration is similar to residential (such as in the case of townhouses, condominiums, or single family attached buildings), the local fire department may make a determination to apply the residential access and ventilation requirements.

Examples of these requirements appear at the end of this guideline.

Access (IFC 605.11.3.3.1)

There should be a minimum six (6) foot wide clear perimeter around the edges of the roof.

Exception: If either axis of the building is 250 feet or less, there should be a minimum four feet (4') wide clear perimeter around the edges of the roof.

The access areas around the perimeter of a building are larger for commercial buildings than for single- and two-family residences for a variety of reasons. One is that firefighters must carry more gear and equipment for some roof operations on larger commercial buildings. Another is that more firefighters are generally dispatched for larger buildings, and they require extra space to maneuver around one another, particularly in the vicinity of access ladders. The exception acknowledges that smaller roofs will need fewer personnel and therefore less clearance.

For proper operation of a PV system, the perimeter area is often unusable because of shading and wind loads. Shading from parapet walls on flat roofs can be significant. Generally, a setback distance of twice the parapet wall height is necessary to prevent excessive shading by the wall. A three-foot parapet wall will require a six-foot setback to prevent shading. Higher wind speeds along the perimeter of a roof also make the edge of the roof unusable in many regions of the United States. In addition, the further the PV array is from the edge of a roof, the less likely construction workers will be exposed to the hazard of falling from the edge of the roof.

Pathways (IFC 605.11.3.3.2)

Pathways should be established in the design of the solar installation. Pathways should meet the following requirements:

- *Should be over structural members*
- *Centerline axis pathways should be provided in both axes of the roof. Centerline axis pathways should run on structural members or over the next closest structural member nearest to the centerlines of the roof*
- *Should be straight line not less than 4 feet clear to skylights and/or ventilation hatches*
- *Should be straight line not less than 4 feet clear to roof standpipes*
- *Should provide not less than 4 feet clear around roof access hatch with at least one not less than 4 feet clear pathway to parapet or roof edge*

The intent of pathway recommendations for commercial roofs is to place the walkways in locations firefighters would most likely use during rooftop operations if no solar array were present. Generally, firefighters will find a major structural member and follow that member across the roof when it is necessary to leave the roof edge. While following structural members is not always possible because the member may not be obvious, these provisions were intended to make those preferred paths available. The IFC language only requires that the pathway be on parts of the roof capable of supporting the weight of a firefighter. Skylights, ventilation hatches, and standpipes are key ventilation and access locations that must have clear pathways from the edge of the roof. These pathways ensure that the firefighter is free to move around the perimeter and to access the ventilation location closest to the fire. Roof hatches may also be used for ventilation or building access, depending on the source and type of the fire.

Ventilation (IFC 605.11.3.3.3)

a. *Arrays should be no greater than 150 by 150 feet in distance in either axis*

b. *Ventilation options between array sections should be either:*

   1. *A pathway 8 feet or greater in width*
   2. *4 feet or greater in width pathway and bordering on existing roof skylights or ventilation hatches*
   3. *4 feet or greater in width pathway and bordering 4' x 8' "venting cutouts" every 20 feet on alternating sides of the pathway*

The reason the size of the array is discussed in the ventilation section is to allow for ventilation opportunities no further apart than 150 feet. This assumes that a large building that could accommodate multiple 150-foot by 150-foot array blocks is fairly open so that smoke can travel to an available venting location. The more compartmentalized the space below the roof is, the more firefighters will prefer multiple venting opportunities. Some buildings make ample use of skylights, which can greatly facilitate venting opportunities during a fire. Of course, these skylights and ventilation hatches need to be accessible. Maintenance personnel also need access to these locations to repair and maintain skylights and hatches. The third option is an attempt to allow for a four-foot wide walkway and yet take up less room than an eight-foot pathway that would also be used for ventilation purposes. The alternating areas for ventilation are to provide venting options on either side of a structural member in case that structural member is over a partition wall. While this option helps meet the needs of firefighters, alternating sides of the pathway would not be a preferred method for the effective layout of a PV array, so it is less likely to be used by PV system designers.

LOCATION OF DC CONDUCTORS (IFC 605.11.2)

Conduit, wiring systems, and raceways for photovoltaic circuits should be located as close as possible to the ridge or hip or valley and from the hip or valley as directly as possible to an outside wall to reduce trip hazards and maximize ventilation opportunities.

Conduit runs between sub arrays and to DC combiner boxes should use design guidelines that minimize the total amount of conduit on the roof by taking the shortest path from the array to the DC combiner box. The DC combiner boxes are to be located such that conduit runs are minimized in the pathways between arrays.

To limit the hazard of cutting live conduit in venting operations, DC wiring should be run in metallic conduit or raceways when located within enclosed spaces in a building and should be run, to the maximum extent possible, along the bottom of load-bearing members.

Since the development of these guidelines in early 2008, several additions have been made to the 2011 NEC to address firefighters' concerns in the routing of conductors. In most residential rooftop systems, conduit is run exterior to the structure. Conduit runs generally proceed from the edge of the array closest to the location of the inverter, and the shortest possible path is taken to get to the inverter. Ridges, hips, and valleys may be used to run conduit as recommended in this section.

If conduit is run inside the structure, it is usually in attic spaces, so the last paragraph recommends running conduit along the bottom of load-bearing members to the extent possible. Firefighters are not going to cut through load-bearing members, making them safer locations to route conduit. However, other options may be as good or better in reducing the likelihood of conduit damage from firefighter operations. A series of requirements adopted by the 2011 NEC more specifically clarifies the acceptable options. I include these sections here for reference:

690.4 (E) (New)

(E) Circuit Routing. Photovoltaic source and PV output conductors, in and out of conduit, and inside of a building or structure, shall be routed along building structural members such as beams, rafters, trusses, and columns where the location of those structural members can be determined by observation. Where circuits are imbedded in built-up, laminate, or membrane roofing materials in roof areas not covered by PV modules and associated equipment, the location of circuits shall be clearly marked.

690.31(E) (New)

Wiring methods shall not be installed within 25 cm (10 in.) of the roof decking or sheathing except where directly below the roof surface covered by PV modules and associated equipment. Circuits shall be run vertically from the roof penetration point to supports a minimum of 25 cm (10 in.) below the roof decking.

Informational Note: The 25 cm (10 in.) requirement is to prevent accidental damage from saws used by firefighters for roof ventilation during a structure fire.

Where flexible metal conduit (FMC) or metal clad cable (MC) smaller than metric designator 21 (trade size 3/4) containing PV power circuit conductors is installed across ceilings or floor joists, the raceway or cable shall be protected by substantial guard strips that are at least as high as the raceway or cable. Where run exposed, other than within 1.8 m (6 ft) of their connection to equipment, these wiring methods shall closely follow the building surface or be protected from physical damage by an approved means.

NON-HABITABLE BUILDINGS (IFC 605.11.4)

This guideline does not apply to non-habitable structures. Examples of non-habitable structures include, but are not limited to, parking shade structures, solar trellises, etc.

GROUND-MOUNTED PHOTOVOLTIAC ARRAYS (IFC 605.11.4)

Setback requirements do not apply to ground-mounted, free standing photovoltaic arrays. A clear brush area of 10' is required for ground mounted photovoltaic arrays.

Clear brush areas are required around ground-mounted systems to reduce the safety hazard of fuel from brush that could start a fire that would propagate beyond the limits of the PV array.

Appendix A: Information Intentionally Omitted From the *Guidelines*

PV ARRAY DC DISCONNECTS TO PROTECT FIREFIGHTERS

During the past decade, the fire service has been tasked with developing installation guidelines for PV systems. One of the most common of their draft requirements relates to disconnects on rooftops. The history of service disconnects for fire operations is to protect firefighters from energized conductors. One of the first activities of a team of firefighters is to control the energy utilities to a structure (typically utility electrical and gas). The addition of a PV system on the roof of the structure poses a unique challenge to firefighting operations. It seems logical that adding disconnects at the source of power—the PV array—will effectively eliminate that source from the building, but that is not the case.

The task force intentionally omitted a requirement to install rooftop DC disconnects at PV module arrays, because they may not de-energize the circuits associated with the switch and can give firefighters a false sense of safety. If the circuits are not de-energized, and a firefighter believes that it is safe to move a raceway associated with that switch, it is possible that the firefighter could be severely shocked or electrocuted. For this reason, the CAL FIRE draft *Solar Photovoltaic Installation Guideline*, dated April 2008, does not include any language related to rooftop PV array switches.

The *Guideline* also does not explain why the requirement was omitted. This has caused various jurisdictional authorities and fire enforcement representatives to believe that the omission was accidental and to introduce an additional requirement. This was evidenced in the wording of the initial IFC proposal, which has subsequently been withdrawn:

> 611.6 Power disconnects. A power disconnect shall be located within 3 feet of the photovoltaic array to provide for de-energizing the DC circuit(s) from the array to the inverter. The disconnect shall be labeled with reflective lettering.

THE PROBLEM

Turning off a rooftop DC disconnect in a PV system does not de-energize the conductors on either side of the switch. Because of this concern, the NEC requires a warning label on these types of switches. This label must read substantially

> WARNING. ELECTRIC SHOCK HAZARD.
> DO NOT TOUCH TERMINALS. TERMINALS ON BOTH THE LINE AND LOAD SIDES MAY BE ENERGIZED IN THE OPEN POSITION.

This warning is primarily for electricians performing work on the equipment as a reminder that normal electrical conventions do not apply to this equipment. Normally, a safety disconnect has energized conductors to the line side of the switch, but the load side of the switch is always de-energized when the switch is off. This is because no other source of power typically exists on the load side of a switch. With PV systems, this assumption is wrong in almost every case, thus the requirement for a warning label.

To understand why the load side of a DC switch in a PV array is typically energized, we must look at how PV systems work. The majority of rooftop PV systems are connected directly to an electrical converter, called an inverter, that takes the DC power from the PV array, converts it to AC power compatible with the utility system, and then supplies that power to existing distribution equipment in the building. On the AC side, if the utility power is shut down for any reason, the AC output of the PV system inverter instantly shuts down to prevent a hazardous condition on the AC wiring in the building or on local utility lines. If the AC side is shut down, the DC power from the array instantly stops flowing. The DC current also stops, but the DC voltage remains—the PV array rests in an open-circuit condition awaiting the return of utility power.

Although power isn't flowing, this open-circuit condition is still hazardous to anyone coming in contact with the circuits. That is the fundamental reason firefighters want to shut the voltage off in that circuit. In small residential rooftop PV systems, all the circuits from the roof are typically run into a single raceway, so it seems logical to install a DC disconnect to de-energize this conduit. Although it is possible to interrupt the circuit from the roof to the inverter, the voltage on the load side of the switch is coming from the inverter—specifically from the input capacitors for the array.

All PV inverters without battery systems include large input capacitors, which store "half-wave" power from the PV array so that the inverter can produce AC power, which fluctuates at 60 cycles per second, and keep the power from the PV array at a constant DC voltage. These capacitors have "bleed resistors" to gradually deplete the charge to zero volts when the voltage is removed from them. This bleed-down process takes five to 15 minutes and is intended to make the equipment safe for servicing. This five- to 15-minute time period is fine for maintenance work, but far too long for fire operations. A firefighter, thinking this circuit is de-energized, could easily be shocked by these large capacitors. While the shock on a small PV system is unlikely to be fatal, the involuntary muscle reaction to the shock could easily cause the firefighter to lose balance and fall off the roof, resulting in serious injury or death.

On larger commercial PV systems, there can be dozens of electrical distribution boxes electrically combined at a large inverter at ground level. Although the 2011 NEC will require DC disconnects for each rooftop combiner box, turning off these disconnects may not de-energize any of the circuits or conduit. For the same reason small systems are not de-energized, large inverters have massive capacitor banks that are capable of causing a severe burn or even electrocution. These capacitor banks have bleed resistors, but the large inverters require the same five- to 15-minute waiting period as small inverters and the capacitors will only start to discharge after all the rooftop disconnects are switched off.

IMPACT ON FIRE OPERATIONS

A utility AC service disconnect provides protection that does not exist with DC disconnects in a PV system. Electricians and firefighters who are accustomed to the conventional AC frame of reference and are unfamiliar with PV systems can be exposed to dangerous and potentially fatal risks. This is why the code requirement for warning labels on all PV disconnects is so important. For example, if 15 disconnects exist on a roof—one at the location of each subarray combiner box—and only one of the 15 is left on, the entire array wiring system can be fully energized and lethal. In the smoke and confusion of a fire, it is likely that one or more of the disconnects will not be identifiable or accessible because the fire is blocking access. Firefighters in daytime operations must always assume that the equipment is energized and potentially dangerous.

The 2011 NEC has established several new requirements for PV systems in the routing of wiring systems, marking, arc-fault detection systems, and disconnects for combiner boxes. These improvements in safety will not solve all current hazards, but they will reduce the danger to firefighters and maintenance personnel. Basic education on the hazards of PV systems is the key to safe and effective firefighting operations. Although disconnects on combiner boxes will help isolate circuits during overhaul operations, they should not be the focus during fire suppression operations.

From a fire safety point of view, requiring disconnects is not adequate protection for firefighters. Staying clear of PV modules and the associated raceways is the only way to guarantee the safety of firefighters.

TECHNOLOGY ADVANCES THAT MAKE PV SYSTEMS SAFER

Although the use of DC disconnects in current PV system designs does not provide protection for firefighters, several new technologies show promise in addressing some or all of firefighters' major electrical concerns with PV installations. These new technologies place communications and control features directly into each module, allowing individual modules to shut down instantly. These module-level electronics, sometimes called module-level control or smart modules, could easily communicate with the inverter and shut each module off in response to a utility outage or a shutdown of the main AC service. By controlling the voltage at the module level, the electrical hazards of the PV array are eliminated, and firefighters can concentrate on their main goal of fire suppression rather than energy control for the PV system. One of the challenges of developing new safety measures is how to make them easily identifiable to firefighters. Without a clear indication that safety measures have been employed, the firefighter must assume that typical PV system hazards exist.

Appendix B: New IFC and UFC Regulations Under Development

There are two primary fire codes used in the United States today. The first is the International Fire Code (IFC) published every three years by the International Code Council (ICC). The second is the Uniform Fire Code (UFC) published by the National Fire Protection Association (NFPA). The UFC is often referred to by the code designation of NFPA 1.

Both draft documents for the 2012 code cycle include language related to solar photovoltaic (PV) system regulation that is based upon the CAL FIRE *Guideline*. One significant difference between the California document and these fire regulations is the emphasis of the language. The California document is a recommended practice—not a requirement—and words like "must" and "shall" are not used. The IFC and UFC are standards written as requirements, however, and the word "shall" is used in place of "should."

IFC F30 Code Compared to the CAL FIRE *Guideline*

Comparing the IFC F30 code and the CAL FIRE *Guideline* side by side, it becomes clear that the IFC regulation is largely based upon the California document, but with the increased emphasis of code requirements. Several important differences do exist, however. Rather than cover all the similarities here, I will only address the significant differences. The reasoning behind issues such as access, pathways, and ventilation has not changed, but the language has. To summarize the differences:

- All instances of "should" were changed to "shall" to make the statements code requirements rather than recommendations.
- The recommendation to have access pathways on top of structural members of a building is amended to require only that the roof be capable of handling the live load of a firefighter.
- The exception for fire departments to amend the three-foot rule for residences is prominently featured at the beginning of the section on access, pathways, and smoke ventilation.
- The NEC is referenced for additional requirements for marking, labeling, and routing of wiring methods.
- Residential structures shall be designed so that each array is no greater than 150 feet by 150 feet in either axis.
- The word "Caution" is replaced with "Warning" on signage.

The following is the new language for the 2012 IFC:

> **605.11 Solar Photovoltaic Power Systems.** Solar photovoltaic power systems shall be installed in accordance with this code, the International Building Code and NFPA 70.
>
> > **Exception:** Detached Group U non-habitable structures such as parking shade structures, carports, solar trellises, and similar type structures are not subject to the requirements of this section.
>
> **605.11.1 Marking. Marking** is required on all interior and exterior DC conduit, enclosures, raceways, cable assemblies, junction boxes, combiner boxes, and disconnects.
>
> **605.11.1.1 Materials**. The materials used for marking shall be reflective, weather resistant and suitable for the environment. Marking as required in sections 605.11.1.2

through 605.11.1.4 shall have all letters capitalized with a minimum height of 3/8 inch (9.5 mm) white on red background.

605.11.1.2 Marking content. The marking shall contain the words WARNING: PHOTOVOLTAIC POWER SOURCE.

605.11.1.3 Main service disconnect. The marking shall be placed adjacent to the main service disconnect in a location clearly visible from the location where the disconnect is operated.

605.11.1.4 Location of marking. Marking shall be placed on all interior and exterior DC conduit, raceways, enclosures and cable assemblies every 10 feet (3048 mm) within 1 foot (305 mm) of all turns or bends and within 1 foot (305 mm) above and below all penetrations of roof/ceiling assemblies and all walls and /or barriers.

605.11.2 Locations of DC conductors. Conduit, wiring systems, and raceways for photovoltaic circuits shall be located as close as possible to the ridge or hip or valley and from the hip or valley as directly as possible to an outside wall to reduce trip hazards and maximize ventilation opportunities. Conduit runs between subarrays and to DC combiner boxes shall be installed in a manner that minimizes total amount of conduit on the roof by taking the shortest path from the array to the DC combiner box. The DC combiner boxes shall be located such that conduit runs are minimized in the pathways between arrays. DC wiring shall be installed in metallic conduit or raceways when located within enclosed spaces in a building. Conduit shall run along the bottom of load bearing members.

605.11.3 Access and pathways. Roof access, pathways, and spacing requirements shall be provided in order to ensure access to the roof; provide pathways to specific areas of the roof; provide for smoke ventilation operations; and to provide emergency egress from the roof.

Exceptions:

1. Requirements relating to ridge, hip, and valleys do not apply to roofs slopes of two units vertical in twelve units horizontal (2:12) or less.
2. Residential structures shall be designed so that each array is no greater than 150 feet (45 720 mm) by 150 feet (45 720 mm) in either axis.
3. The fire chief may allow panels/modules to be located up to the ridge when an alternative ventilation method acceptable to the fire chief has been provided or where the fire chief has determined vertical ventilation techniques will not be employed.

605.11.3.1 Roof access points. Roof access points shall be defined as an area that does not place ground ladders over openings such as windows or doors, and are located at strong points of building construction in locations where the access point does not conflict with overhead obstructions such as tree limbs, wires, or signs.

605.11.3.2 Residential systems for one- and two-family residential dwellings. Access shall be provided in accordance with Sections 605.11.3.2.1 through 605.11.3.2.4.

605.11.3.2.1 Residential buildings with hip roof layouts. Panels/modules shall be located in a manner that provides a 3 foot (914 mm) wide clear access pathway from the eave to the ridge on each roof slope where panels/modules are located. The access pathway shall be located at a structurally strong location on the building capable of supporting the live load of firefighters accessing the roof.

605.11.3.2.2 Residential buildings with a single ridge. Panels/modules shall be located in a manner that provides two 3 foot (914 mm) wide access pathways from the eave to the ridge on each roof slope where panels/modules are located.

605.11.3.2.3 Hips and valleys. Panels/modules shall be located no closer than 18 inches (457 mm) to a hip or a valley if panels/modules are to be placed on both sides of a hip or valley. If the panels are to be located on only one side of a hip or valley that is of equal length then the panels shall be permitted to be placed directly adjacent to the hip or valley.

605.11.3.2.4 Smoke ventilation. Panels/modules shall be located no higher than 3 feet (914 mm) below the ridge in order to allow for fire department smoke ventilation operations.

605.11.3.3 All other occupancies. Access shall be provided in accordance with Sections 605.11.3.3.1 through 605.11.3.3.3.

> **Exception:** Where it is determined by the *fire code official* that the roof configuration is similar to a one- or two-family dwelling, the *fire code official* may *approve* the residential access and ventilation requirements provided in 605.11.3.2.1 through 605.11.3.2.4.

605.11.3.3.1 Access. There shall be a minimum 6 foot (1829 mm) wide clear perimeter around the edges of the roof.

> **Exception:** If either axis of the building is 250 feet (76 200 mm) or less, there shall be a minimum 4 foot (1290 mm) wide clear perimeter around the edges of the roof.

605.11.3.3.2 Pathways. The solar installation shall be designed to provide designated pathways. The pathways shall meet the following requirements:

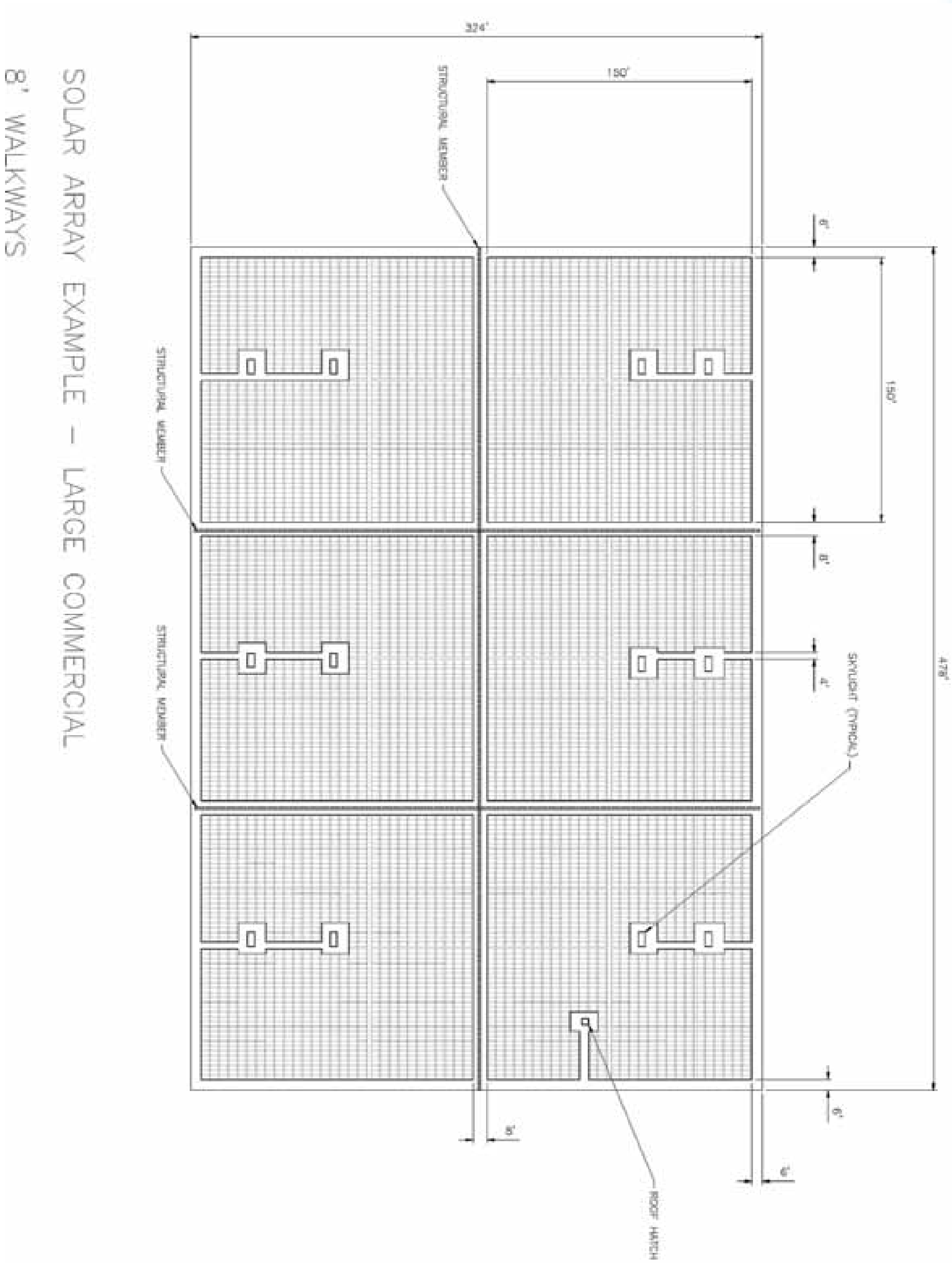
1. The pathway shall be over areas capable of supporting the live load of firefighters accessing the roof
2. The centerline axis pathways shall be provided in both axes of the roof. Centerline axis pathways shall run where the roof structure is capable of supporting the live load of firefighters accessing the roof.
3. Shall be straight line not less than 4 feet (1290 mm) clear to skylights and/or ventilation hatches
4. Shall be straight line not less than 4 feet (1290 mm) clear to roof standpipes
5. Shall provide not less than 4 feet (1290 mm) clear around roof access hatch with at least one not less than 4 feet (1290 mm) clear pathway to parapet or roof edge

605.11.3.3.3 Smoke ventilation. The solar installation shall be designed to meet the following requirements:

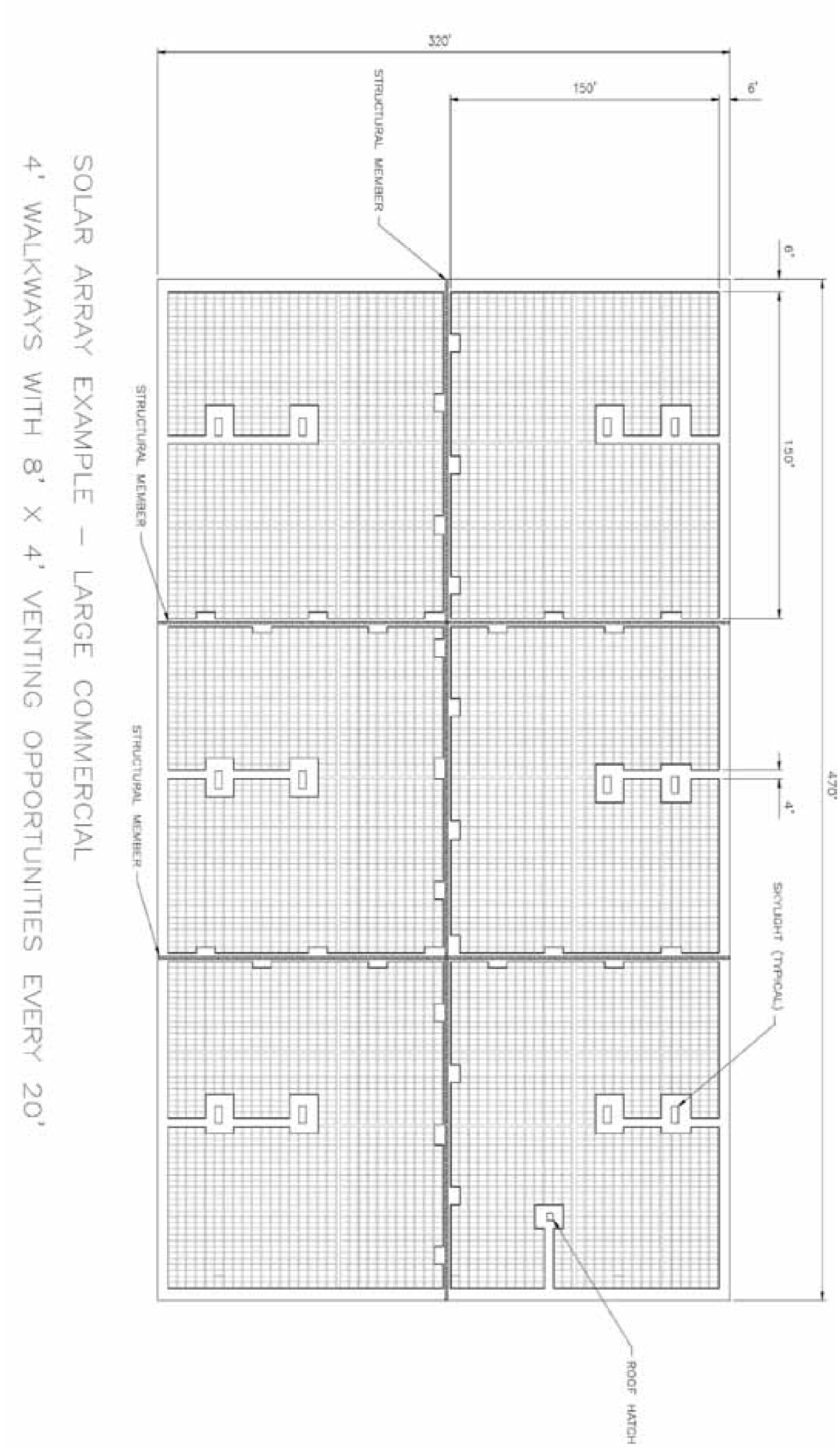
1. Arrays shall be no greater than 150 feet (45 720 mm) by 150 feet (45 720 mm) in distance in either axis in order to create opportunities for smoke ventilation operations.
2. Smoke ventilation options between array sections shall be one of the following:
   - 2.1. A pathway 8 feet (2438 mm) or greater in width
   - 2.2. A 4 feet (1290 mm) or greater in width pathway and bordering roof skylights or smoke and heat vents
   - 2.3. A 4 feet (1290 mm) or greater in width pathway and bordering 4 foot (1290 mm) x 8 foot (2438 mm) “venting cutouts” every 20 feet 6096 mm) on alternating sides of the pathway

605.11.4 Ground mounted photovoltaic arrays. Ground mounted photovoltaic arrays shall comply with Sections 605.11 through 605.11.2 and this section. Setback requirements do not apply to ground-mounted, free standing photovoltaic arrays. A clear brush area of 10 feet (3048 mm) is required for ground mounted photovoltaic arrays.

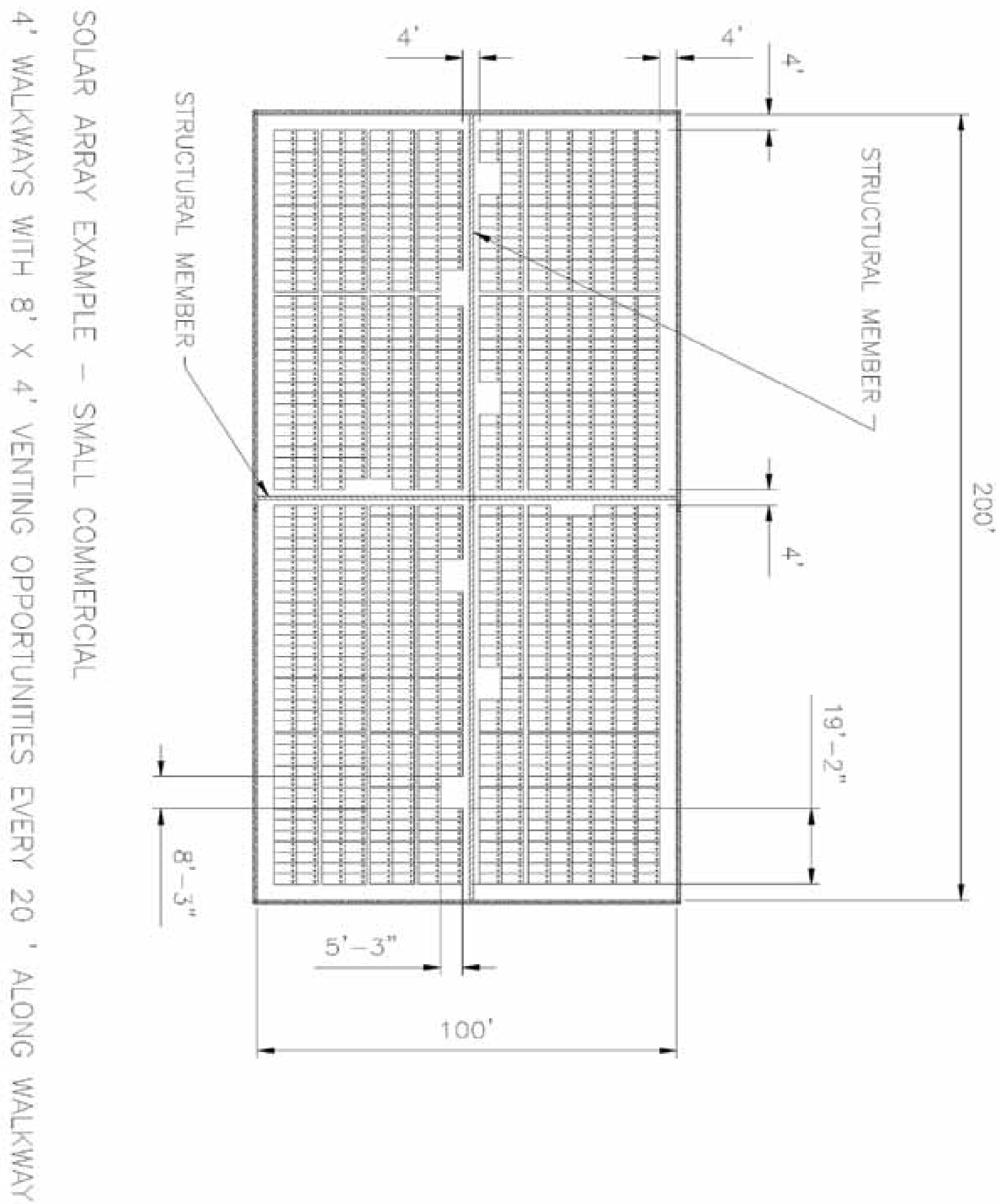
Example 5 – Large Commercial 8-Foot Walkways



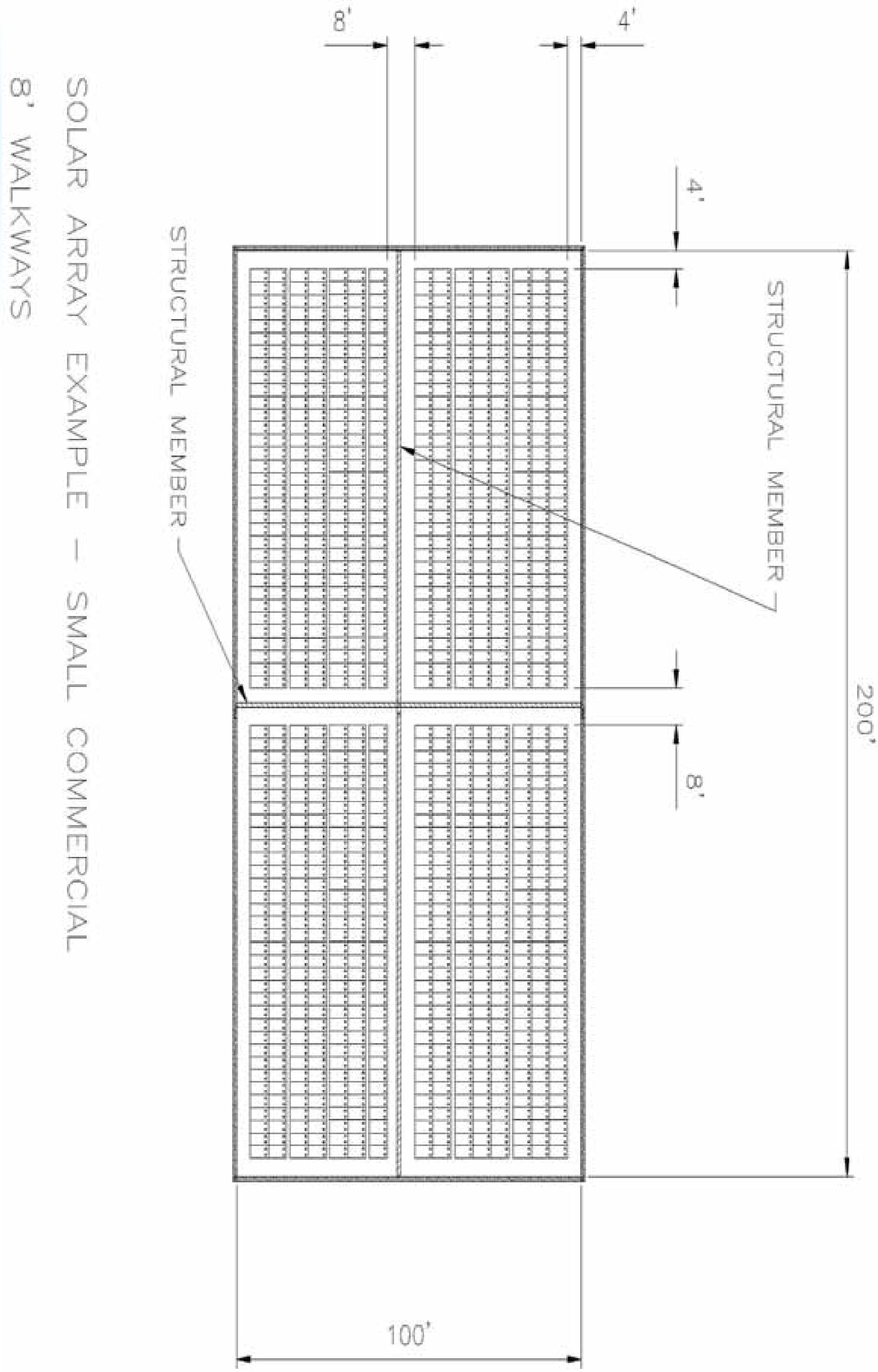
Example 6 – Large Commercial 4-Foot Walkways



Example 7 – Small Commercial 4-Foot Walkways



Example 8 – Small Commercial 8-Foot Walkways



ACRONYMS

AC	alternating current
ASCE	American Society of Civil Engineers
CAL FIRE	California Department of Forestry and Fire Protection
DC	direct current
ICC	International Code Council
IFC	International Fire Code
NEC	National Electrical Code
NFPA	National Fire Protection Association
PSF	pounds per square foot
PV	photovoltaic
Solar ABCs	Solar America Board for Codes and Standards
UFC	Uniform Fire Code

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