CODES AND STANDARDS ENHANCEMENT INITIATIVE (CASE)

Nonresidential Solar-ready Buildings

2013 California Building Energy Efficiency Standards

California Utilities Statewide Codes and Standards Team September 2011

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1. Introduction

Through Codes and Standards Enhancement (CASE) Studies, the California Investor Owned Utilities (IOUs) provide standards and code-setting bodies with the technical and cost-effectiveness information required to make informed judgments on proposed regulations for promising energy efficiency design practices and technologies.

The IOUs began evaluating potential code change proposals in fall 2009. Throughout 2010 and 2011, the IOU CASE Team (Team) evaluated costs and savings associated with each code change proposal. The Team engaged industry stakeholders to solicit feedback on the code change proposals, energy savings analyses, and cost estimates. This CASE Report presents the IOU code change proposal for nonresidential solar-ready buildings. The contents of this report, including cost and savings analyses and proposed code language, were developed taking feedback from the solar and building industries and the California Energy Commission (CEC) into account.

All of the main approaches, assumptions and methods of analysis used in this proposal have been presented for review at three public Stakeholder Meetings hosted by the IOUs. At each meeting, the CASE team asked for feedback on the proposed language and analysis thus far, and sent out a summary of what was discussed at the meeting, along with a summary of outstanding questions and issues.

A record of the Stakeholder Meeting presentations, summaries and other supporting documents can be found at www.calcodesgroup.com. Stakeholder meetings were held on the following dates and locations:

- First Stakeholder Meeting: April 29, 2010, San Ramon Conference Center, San Ramon, CA
- Second Stakeholder Meeting: November 2, 2010, Webinar
- Follow-up Discussion from Second Meeting: January 11, 2010, Webinar
- Third Stakeholder Meeting: April 6, 2011, Webinar

2. Overview

2.1 Measure Title

Nonresidential Solar-ready Buildings.

2.2 Description

The nonresidential solar-ready buildings measure would require new low-rise nonresidential buildings to be designed such that it will be technically feasible to install, at a future date, a photovoltaic (PV) or solar water heating (SWH) system of the size specified in the code. The solar-ready requirements would apply for major retrofits if the retrofit would increase the total roof area by more than 20 percent. The required design features include: 1) an un-shaded and un-obstructed Solar Zone of a specified area, 2) inclusion of the as-designed maximum dead load and live loads for the Solar Zone in compliance forms and building drawings; and 3) inclusion of design for interconnecting the PV or SWH to the building electrical or plumbing system in building drawings.

This code change proposal does not require solar equipment to be installed, nor does it propose a means of using renewable energy generation to reach a specified energy budget.

2.3 Type of Change

The proposed change could be incorporated into the building code in two ways: as a new mandatory requirement in Part 6 of Title 24, or by replacing the existing voluntary PV-ready requirement in Part 11 of Title 24 with the proposed mandatory solar-ready requirement. Changes to modeling software, calculation procedures or assumptions used in performance calculations are not recommended. The proposed code would not add a compliance option, nor would it affect the way that trade-offs are made.

If the solar-ready measure is incorporated into Part 6 of Title 24, the proposed language would become a mandatory measure in Subsection 2: All Occupancies—Mandatory Requirements for the Manufacture, Construction, and Installation of Systems, Equipment and Building Components. Subsection 2 applies to all building types, so the language would clearly indicate the measure would only apply to low-rise nonresidential buildings. To implement the proposed measure as a mandatory measure in Part 6, the nonresidential Title 24 envelope compliance forms would also need to be modified. A section would be added to form ENV-1C: Certificate of Compliance and Field Inspection Energy Checklist. A new form, ENV-5C, would be used to ensure the area of the Solar Zone has been calculated correctly and to ensure the interconnection plan and the Solar Zone have been designed according to code.

If the solar-ready measure is incorporated into Part 11 of Title 24, the proposed language would be added as a mandatory measure in Chapter 5 Division 5.2: Nonresidential Mandatory Measures - Energy Efficiency. Alternatively, the proposed language could be added into a new division to Chapter 5, Division 5.6: Nonresidential Mandatory Measures – Renewable Energy. To implement the proposed measure as a mandatory measure in Part 11, a new compliance form would need to be added. The form would likely be called EE-1: SOLAR-READY or RE-1: SOLAR-READY, depending on whether the proposed language would appear in the energy efficiency (EE) division or the renewable energy (RE) division. The new form would be used to ensure the area of the Solar Zone has been calculated correctly and to ensure the interconnection plan and the Solar Zone have been designed according to code.

While the proposed solar-ready requirement does not expand or modify the scope of Title 24, incorporating a requirement that buildings actually *install* renewable electricity generation systems could require modifications to the scope of Title 24. Considering California's goal of achieving zero-net energy residential and nonresidential building by 2020 and 2030, respectively, it is reasonable to assume that renewable energy requirements could be incorporated into Title 24 in forthcoming code change cycles. Items pertaining to modifying the scope of Title 24 to incorporate renewable energy requirements are outside of the scope for this CASE Report.

2.4 Energy Benefits

Surveys of the existing building stock indicate that fewer than 30 percent of existing buildings are suitable locations for PV or SWH installations (Harvey 2010). The primary goal of the solar-ready measure is to enable virtually all low-rise commercial buildings to be suitable for PV or SWH systems. The code would not require PV or SWH systems to be installed, so energy savings from this measure are attributed to an increase in the number of systems that would be installed voluntarily at some point in the life of the building. The code change would provide assurance that all buildings with access to solar resource will allocate space on the building site for solar equipment and that the building is designed with the interconnection of the PV or SHW system in mind. The code will effectively lead to a higher percentage of buildings that will be suitable for PV and SHW installations. The energy benefits presented in the Analysis and Results section of this report provide the savings that could be expected if PV systems of the size specified by the code were installed on new buildings.

As discussed in Section 3.3 of this report, it is difficult to predict the number of systems that will be installed on a voluntary basis, and it is therefore difficult to predict how much energy will be saved because of the measure. Section 4 of this report presents the prospective energy and energy cost savings if all buildings install solar systems sized according to the proposed code and extrapolations to show savings if smaller subsets of the building stock install systems.

Time Dependent Valuation (TDV) savings were not calculated because the code change would not lead to direct energy savings because, as mentioned previously, the code does not require PV or SWH installations. Assuming systems are installed, TDV benefits will vary based on system design. Many PV and SWH systems are optimized so the majority of electricity is generated in the afternoon when demand is the highest. Modules generate the most electricity or are most effective at heating water when they have the most direct access. Since western-facing aspects get direct sunlight in the afternoon, modules oriented towards the west or southwest are optimized to offset peak energy demand.

Per unit energy savings are presented below:

	Electricity Savings (kwh/yr)	**Demand Savings (W)**	**Natural Gas Savings (Therms/yr)**	**TDV Electricity Savings**	**TDV Gas Savings**

Savings per square foot	4.8	3.0	0	n/a	n/a

If 5 percent of all the buildings install PV systems of the specified size on a voluntary basis, the savings from this measures would results in the following statewide first year savings:

Statewide Power Savings (MW)	**Statewide Electricity Savings (GWh)**	**Statewide Natural Gas Savings (million Therms)**	**TDV Cost Savings ($ million)**
21.2	33.6	0	n/a

2.5 Non-Energy Benefits

There are many benefits of distributed renewable energy. Electricity generated from renewable sources produce far fewer greenhouse gas emissions than electricity generated from coal or natural gas power plants. Distributed generation effectively offsets grid electricity demand, thereby alleviating the necessity of building new power plants. Some also argue that a distributed generation provides enhanced system reliability; if there are many small systems generating electricity, the grid is not impacted as severely if one or more large power plants go off-line.

2.6 Environmental Impacts

The proposed code change does not have any potential adverse environmental impacts. Water consumption would not increase and there is no impact on water quality. There are no environmental or energy impacts associated with material extraction, manufacture, packaging, shipping to the job site, installation at the job site, or other activities associated with implementing the measure.

The proposed changes have no direct impact on water consumption or water quality.

Material Increase (I), Decrease (D), or No Change (NC): (All units are lbs/year)

	Mercury	Lead	Copper	Steel	Plastic	Others (Identify)
Per Prototype Building	NC	NC	NC	NC	NC	NC

Water Consumption:

	On-Site (Not at the Power plant) Water Savings (or Increase) (Gallons/Year)
Per Prototype Building	NC

Water Quality Impacts:

	Mineralization (calcium, boron, and salts)	Algae or Bacterial Buildup	Corrosives as a Result of PH Change	Others

Impact (I, D, or NC)	NC	NC	NC	NC
Comment on reasons for your impact assessment				

2.7 Technology Measures

While the measure does aim to enable more PV and SWH installations, the proposed code change does not require the installation of any particular technology or equipment. If a building owner decides to install solar equipment at a future date, they may choose to install any equipment that is available at the time.

2.8 Performance Verification of the Proposed Measure

The solar-ready measure will not require performance verification or commissioning. No acceptance tests are recommended.

2.9 Cost Effectiveness

As mentioned, the proposed code change does not require equipment installation, so there are no equipment costs associated with the change. A building that is constructed to be solar-ready will remain solar-ready for the lifetime of the building, and there are no costs associated with maintaining the solar-readiness of the building. With no equipment costs and no maintenance costs, the only costs associated with the measure are design costs. Initially designers will need to familiarize themselves with the solar-ready requirement, but over time design will become streamlined and the costs of complying will be minimal. The CEC's Life Cycle Costing (LCC) Methodology does not include design costs in the costs of a measure, so for LCC purposes the measure has no costs. Since the proposed code will enable energy savings and there are no LCC costs, the proposed change is cost-effective.

The cost of installing systems on solar-ready buildings (as defined in the recommended code language) could be 10 percent less expensive than installing on buildings that are not solar-ready (C&S Stakeholder Process; Solar Stakeholder Meeting II Follow-up Jan. 11, 2011). Savings will result when equipment is easily interconnected to the buildings electrical or plumbing system. Installation cost savings are only realized if the system is installed as a retrofit (i.e. the system was not installed as part of the original building construction). If the system is installed during initial construction it is assumed that the PV or SHW system would be integrated into the initial building designs the costs of installing the system are already minimized.

Both energy cost savings and cost savings from equipment installation only when PV or SWH systems are installed voluntarily. None of the cost savings were included in the cost effectiveness calculations because not all buildings will install systems so savings are not universal across the entire building stock.

2.10 Analysis Tools

The proposed measure would be a mandatory requirement that does not include performance trade-offs, so changes to the performance modeling software are not required. However, one method to determine the area of the Solar Zone would require using a CEC-approved PV modeling tool.

2.11 Relationship to Other Measures

This CASE proposes PV and SWH “solar-ready” requirements for nonresidential buildings. This CASE is related to three other solar PV and solar water heating measures. The multifamily SWH CASE proposes solar water heating and sola-ready requirements for *multifamily* homes. The cross-cutting SWH CASE proposes to increase the existing solar fraction requirement for single family residential buildings with electric water heating, and to add a new solar fraction requirement for restaurants with both electric and natural gas water heating above a certain square footage. The Solar Oriented Development and Solar-ready Homes CASE proposes solar-ready requirements for PV and SWH for *single-family* residential buildings and proposes requirements for building orientation. These CASEs were developed collaboratively, with each CASE addressing distinct areas of the code.

The Nonresidential Daylighting CASE proposes increasing the daylighting requirement, which would result in more roof space being occupied by skylights. The solar-ready measure was developed taking the proposed daylighting requirements into consideration. As discussed in section 3.2.2 of this report, the Solar Zone would not compete for roof space with skylights. The proposed solar-ready requirement would not supersede the proposed or existing daylighting or cool roofing requirements. All buildings would need to comply with daylighting, cool roofing, and solar-ready requirements.

3. Methodology

3.1 Existing Conditions

3.1.1 Buildings Suitable for Solar Installations

Surveys of the existing building stock indicate that less than 30 percent of existing nonresidential buildings are suitable for PV or SWH installations (Bryan 2010). Common features that make buildings unsuitable include:

- Shading both from external sources, such as neighboring buildings, or self-shading (e.g. from HVAC equipment or a taller part of the building);
- Roof obstructions like mechanical equipment, pipes, vents, ducting, antennas, satellite dishes, or weather monitoring equipment;
- Unfavorable roof shape such as domed roofs;
- Unfavorable roof orientation or slope such as the entire roof sloping towards the north; and
- Insufficient structural integrity to accommodate solar equipment.

Figure 1 shows a building with self-shading and roof obstructions. The tallest portion of the building is located on the southern edge of the building site and it shades the rest of the site. If the tallest portion of the building were located on the northernmost edge of the site, the majority of the building site would be un-shaded. Even if shading were not an issue on this building, it is not be feasible to place collectors on the roof that is covered with ducting.

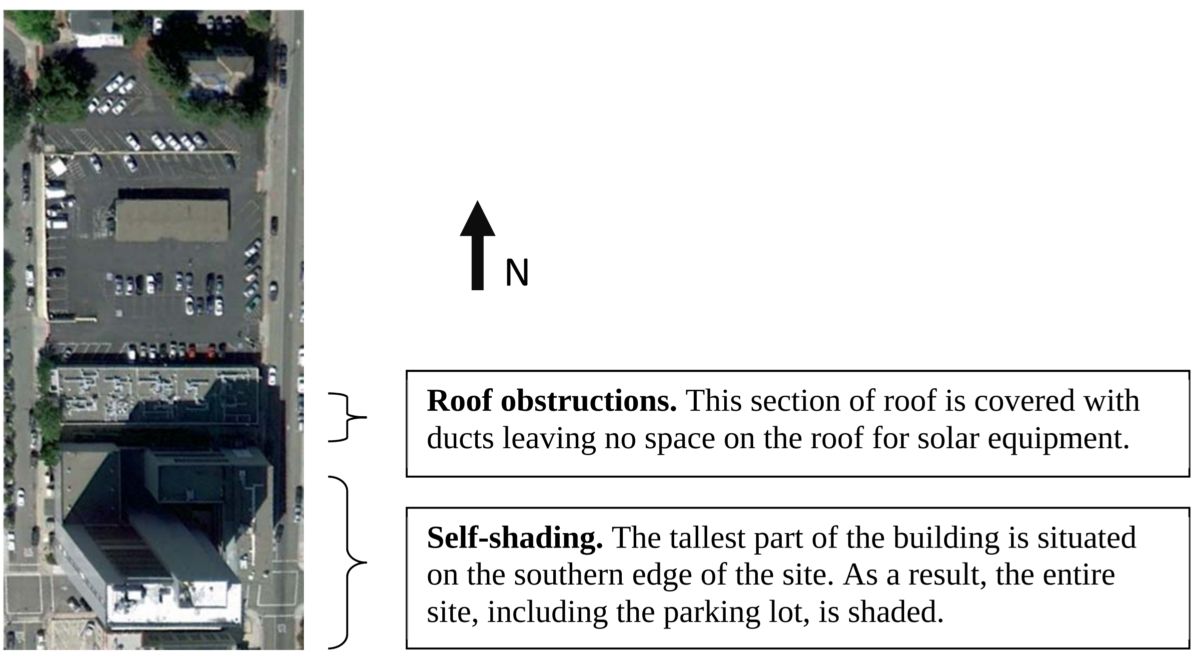
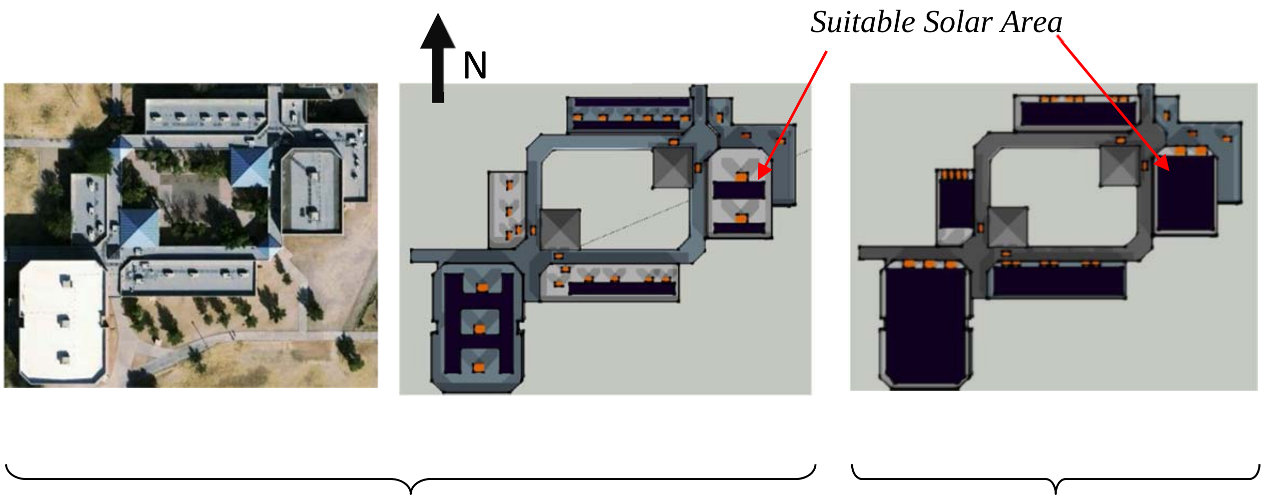


Figure 1. Example of Building that is Not Suitable for PV or SWH

As shown in Figure 2, it is possible to design rooftops so a much larger portion of the roof area is suitable for PV or SHW installations. As a general rule of thumb, due to shading constraints solar modules are set back to the east, west, and north of any obstruction at a distance equal to two times the height of the obstruction. For example, an obstruction that is one square foot in area and one foot high would render an area of 15SF of roof area unsuitable for solar collectors (i.e.an area two square feet on each side of the obstruction and two SF to the south of the obstruction – 5'x 3' = 15SF). So even when buildings have an area that is un-shaded and unobstructed and suitable for solar, the area is often not as large as it could have been if the building was designed to optimize solar potential.



Standard Design Practice. Rooftop equipment in the center of roof and parapits are high. Limited un-shaded and unobstructed space available for solar.

Optimized Solar Design. Rooftop equipment on north side of roof. Significantly more un-shaded and unobstructed space available for solar.

Figure 2. Standard and Optimized Rooftop Design

Source: Bryan

Many existing buildings are unsuitable because they lack ample structural integrity to accommodate PV or SWH equipment. This is especially true of older buildings that were constructed before California's stringent structural and seismic building requirements took effect. Structural retrofits are possible, but they are oftentimes costly. After factoring in the cost of the required structural retrofits into the project cost, the project becomes prohibitively expensive.

As structural requirements have become more stringent, buildings have become better suited for solar installations. Researchers have found that, in general, inadequate structural integrity is not a limiting factor for installing solar systems in buildings constructed after the 2007 California Building Standards took effect (Binkley). The 2007 code requires most nonresidential buildings to accommodate a uniform live load of 20 psf and a concentrated load of 300 psf (Part 2, Section 1607A.11), which is strong enough to hold typically 4 - 8 psf crystalline or thin-film PV system or lightweight SWH systems with some remaining strength to account for wind or snow loading. During the second public stakeholder meeting held on November 2, 2010, industry stakeholders confirmed that California's current structural requirements for nonresidential buildings are sufficient to accommodate PV systems. Furthermore, some jurisdictions have adopted supplemental structural requirements to account for snow loading or excessive wind loads caused by relatively high local wind speeds.

3.1.2 Current Solar-ready Design Practices

The standard practice is to locate rooftop equipment in the center of the roof and to install screens or tall parapits to hide equipment. This is not ideal for solar because the shadows from equipment and screens make the areas to the east, west, and north of the obstruction unsuitable. An alternative design, which maximizes the space suitable for PV, is to install rooftop equipment on the north side of the roof. By pulling equipment away from the parameter of the building, equipment becomes less visible from the ground level eliminating the need for tall parapits and/or screens (see Figure 2).

3.1.3 Current Market Penetration of Solar

Currently, only a small percentage of suitable buildings actually install PV systems. California Solar Initiative (CSI) data indicates that the market penetration of PV installations on newly constructed buildings is low. Between 2007 and 2010, fewer than fifty PV systems were installed on newly constructed nonresidential buildings per year (see Figure 3). CSI program administrators have indicated CSI data may not accurately represent the number of systems that are installed on newly constructed buildings; some systems that are labeled as retrofit installations were installed within months of completing construction. From a practical perspective, installations that occur within the first months of building occupancy should be considered new construction as opposed to retrofits. While this is a valuable insight into discrepancies in the data, even if it is assumed that *all* PV systems installed on nonresidential buildings were installed on newly constructed buildings as opposed to retrofits (a very conservative estimate), still fewer than 5 percent of newly constructed buildings are currently installing PV systems. This is a low overall market penetration rate of PV installations, especially considering California's impending zero-net energy goals. The market penetration of on-site renewable electricity generation needs to increase rapidly if all newly constructed nonresidential buildings in California are going to be zero-net energy by 2030.

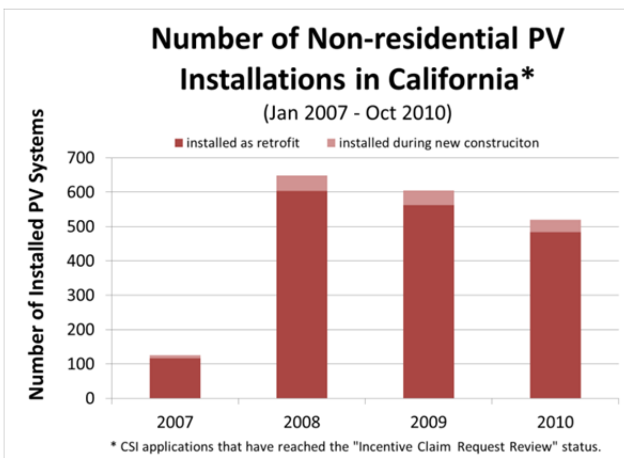


Figure 3. Number of Installed PV Systems on Nonresidential Buildings, 2007-2010

Source: CSI 2010

As shown in Figure 4, the capacity of installed PV systems varies significantly. The smallest systems are under 1kW and the largest systems are larger than 1 MW.[1] It is not possible to determine whether the PV systems are typically offsetting 1 percent of the electricity demand or 100 percent of the electricity demand, however CSI data indicates that some customers are installing relatively large systems that are likely offsetting most or all of their electricity demand.

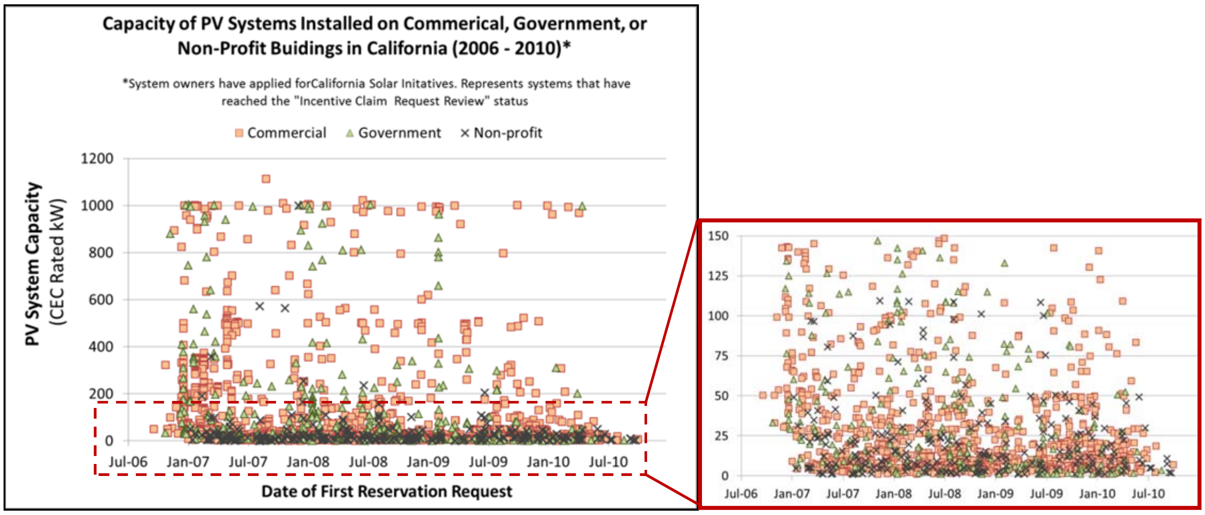


Figure 4. Capacity of PV Systems Installed in California (2007 - 2010)
Source: CSI

3.1.4 PV and SWH Market Trends

The current cost of PV or SWH systems does not have a direct impact on the cost of the solar-ready measure because the code would not require systems to be installed, but system costs will have an impact on the number systems that are installed at some point during the life of the building. As shown in Figure 5, the installed cost of solar PV is decreasing steadily. With rapid technology advances, it is practical that costs could fall to $2/Watt within the decade (McKinsey). As the cost of solar falls and the cost of grid electricity increases, building owners are going have a growing incentive to install solar systems.

[1] CSI does not provide incentives for systems over 3 MW, and it only provides rebates for up to 1MW of a system. There are other incentive programs available for larger system sizes, so in general the CSI database does not capture data on systems larger than 1 MW in capacity

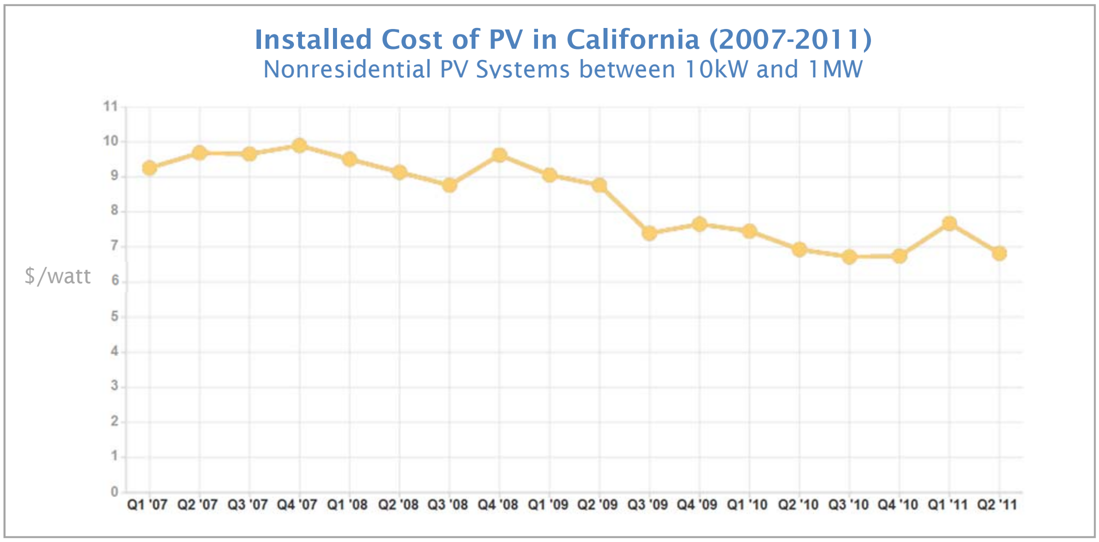


Figure 5. Installed Cost of Nonresidential PV Systems in California (2007 - 2011)

Source: CSI 2011

3.2 Proposed Code Change

3.2.1 Summary of Proposed Change

By addressing the common limitations that render solar infeasible or excessively costly, the proposed code change would enable a larger number of solar installations in the future and will ensure that buildings that have access to solar resource are able to accommodate PV or SWH systems. It would also encourage building designers to provide a larger un-shaded and unobstructed area thereby enabling the installation of larger PV and/or SWH systems. As discussed in the previous section, key factors that make buildings unsuitable for solar include external shading, shading by features of the building project itself, obstructions like pipes and ducts, and inadequate structural integrity. Requiring designers to consider how PV or SWH systems would be integrated into the building will help eliminate some of the common constraints. Incorporating solar readiness as a primary design consideration may also will encourage building owners to consider the option of installing PV or SWH systems more seriously.

The proposed code would apply to new low-rise nonresidential buildings and major alterations and additions to low-rise nonresidential buildings if the planned addition or alteration would increase the total roof area by more than 20 percent. Buildings would be required to have an allocated Solar Zone on the roof or elsewhere on the building site. The Solar Zone would be sized according to the code requirements. The zone also needs to be un-shaded by objects on the building site (e.g. HVAC equipment, trees, other sections of the building), and free of obstructions (e.g. pipes, vents). The code would require designers to plan for the interconnection of the PV or SWH system to the buildings electrical or plumbing system. The interconnection point to the building electrical or plumbing system would need to be identified as would space for key equipment such as inverters, metering equipment, and storage tanks. Pathways for running conduit or piping to connect the system components would also be need to be established during the building design phase. To address structural integrity issues, the proposed code would require that the as-designed maximum dead load and live load for the Solar

Zone be clearly labeled on the record drawings and the Title 24 compliance forms. Each of the components of the proposed solar-ready code is discussed in more detail in the following sections.

3.2.2 Allocated Solar Zone

The proposed code requires designers to include a Solar Zone on the roof of the building that covers at least 40 percent of the roof area (net of the area covered by skylights). Alternatively, the area of the Solar Zone can be determined using a design-based method that would allow building designers to use a CEC-approved modeling software and follow CEC guidelines to demonstrate that a PV system installed in the allocated Solar Zone would be capable of generating at least 20 percent of the expected electricity demand.[2] The Solar Zone could be located somewhere other than the roof, but to locate the Solar Zone elsewhere on the building site the designer would need to use the design-based approach to determine the size of the Solar Zone.

The CASE Team took a number of factors into consideration when defining the requirements for the allocated Solar Zone. The key considerations are discussed below.

Defining Size of Solar Zone

The Team explored three ways to define the minimum area of the Solar Zone. Each approach has its benefits and drawbacks, but all approaches will lead to the same result: space available for future solar. Using the first method, called the Area Method, the designer would simply take the total roof area, subtract the area covered by skylights, and multiply the remaining area by 40 percent. This basic method to calculate the area of the Solar Zone is well suited for simple roof designs that are common for many nonresidential buildings including warehouses, grocery stores, and retail buildings. However, this approach does not provide as much leeway for architectural creativity as the Design Method.

For the second method, called the Design Method, the code would specify the percentage of the building's expected electricity demand that would need to be supplied by the future system (i.e. 20 percent of expected demand). The designer would then design the system and provide documentation to show the Solar Zone was appropriately sized. The Design Method would require a more comprehensive design effort than the Area Method, but it allows more aesthetics freedom. It would also allow the system to be specifically modeled for the building and will yield more accurate energy savings estimates.

The third method, called the Multiplier Method, uses unique multipliers for each building type to calculate the area of the Solar Zone based on the total building floorspace. The multipliers would be calibrated so the resulting Solar Zone would be capable of generating approximately 20 percent of the expected electricity demand. See the Appendix for more information about the Multiplier Method.

When vetting code language that incorporated all three methods during a public meeting, stakeholders provided feedback that the code language was too complicated and that they preferred a simplified approach (see Appendix for draft language that includes all three options). This was not the only time

[2] The modeling software and the modeling guidelines would be established after the code is adopted.

the CASE Team received feedback to simplify the code. Throughout the course of developing the dozens of the code change proposals for the 2013 rulemaking, many similar requests were received. The CASE Team deliberated the pros and cons of a relatively complex solar-ready code that allows for more flexibility in how to comply versus a simplified code with fewer compliance options. Ultimately, the Team decided to eliminate the option of using the Multiplier Method to determine the area of the Solar Zone. While some wanted the Design Method eliminated as well, the CASE Team recommends keeping the Design Method in place to provide a compliance option for designers who desire more architecturally unique rooftops. The final proposed language would allow designers to size the Solar Zone using the Area Method or the Design Method.

Desired System Capacity

The Solar Zone needs to be large enough to accommodate a system that could offset a reasonable portion of the building's electricity or hot water demand. Initially, the Team based the target capacity on the existing voluntary reach code requirement (Title 24, Part 11, section A5.211) that calls for buildings to generate 1 percent of electricity demand from a renewable source. After calculating the area of the Solar Zone such that it could provide 1 percent of the building's demand, stakeholders provided feedback that the Solar Zone was too small and that requiring such a small Solar Zone would not result in changes to current design practices. Taking this feedback into account, the next iteration of the proposed language set the Solar Zone size based on the target system capacity of 20 percent of the expected electricity demand. The multipliers that were created to size the Solar Zone, which as described above are not included in the final proposed language, were calibrated so that the Solar Zone would be capable of generating about 20 percent of the expected load. The Design Method for calculating the Solar Zone also required the system to generate enough electricity to offset 20 percent of the expected building demand. When vetting language that sized the Solar Zone based on 20 percent of electricity demand, the Team did not receive any feedback that this was an unreasonable goal.

The capacity of a PV system that occupies 40 percent of the roof area will offset various percentages the building's electricity demand depending on the energy intensity of the building (kWh/SF) and the number of stories the building has – in addition to the efficiency of the particular PV system that is installed. If all the low-rise nonresidential buildings constructed in 2014 install a PV system that covered 40 percent of the roof area, it is estimated that on average, 36 percent of a building's electricity demand would be offset by PV systems. Table 4 in Section 4.1 of this report shows an estimated generation potential per square foot by building type. For each building type, Table 4 also presents the average percentage of electricity demand that would be offset by a system covering 40 percent of the roof space

The CASE Team relied on California Commercial Energy-use Survey (CEUS) data to determine the statewide average energy intensity (kWh/SF floorspace) for various building types. CEUS data was collected in 2002 and it is based on electricity used in existing buildings. Thanks to steady improvements in building practices and strengthening of the California's building energy code over the last two decades, newly constructed buildings in 2014 or later will generally consume less energy than the existing building stock in 2002. The implication is the estimates of the percentage of electricity demand offset by the PV systems may be underestimated.

To achieve the State's zero-net energy goals, the amount of electricity generated from distributed generation, like PV, needs to be maximized. Although the minimum goal of the solar-ready measure is to allocate space for systems that can offset 20 percent of demand, the CASE Team found that many buildings could generate much more than 20 percent of demand. Low energy density buildings like warehouses have enough roof space to generate more than 100 percent of their expected demand. There is little reason to install SWH systems that produce more hot water than there is on-site demand, but if a PV system generates more electricity than there is on-site demand, the remaining electricity generated can offset demand from another building.

Available Space on Rooftop or Building Site

The Draft CASE study for Nonresidential Daylighting, which was also prepared for consideration during the 2013 code change cycle, includes an analysis of the percentage of roof space occupied by obstructions such as rooftop equipment and ducting. The CASE author surveyed a sample of 70 general commercial, shopping centers, retail stores, grocery stores, and industrial buildings. Results of the study are summarized as follows:

> "(O)f the 70 buildings surveyed, the maximum obstructed area was 11%. However, most buildings had much lower amounts of rooftop obstructions. The average was 2% roof obstruction, though 18 of the 70 buildings (26%) had no obstructions at all, and 50 of the 70 buildings (71%) had 2% or less obstructed area," (CUSCST 2011).

These results indicate there is plenty of space on roofs for both skylights and solar equipment. Figure 6 shows a warehouse in Southern California that has both skylights and solar equipment. The solar panels are situated between the rows of skylights (the skylights appear as small white boxes in the photograph). The Figure also shows the building site for a typical shopping complex in Northern California. There would have plenty of room available to install solar equipment on an area equal to 40 percent of the roof space, especially considering the Solar Zone could be located anywhere on the building site – not just on the roof.

b. Warehouse with PV system a. Typical shopping center

Figure 6. Typical Roof Layouts
Source: Google Earth. 2011; Image © 2001 Digital Globe, © 2011 Google

There is some concern that high energy density buildings with relatively small roof areas, such as restaurants, may not have enough roof space to allocate 40 percent of the roof space to the Solar Zone or accommodate a system capable generating 20 percent of the building's electrical demand. To address this concern, the PV system can be located elsewhere on the building site, such as in the parking lot. Designers of these buildings could incorporate a portion of the Solar Zone on the roof and dedicate a portion of the landscaped area to the Solar Zone. PV parking shade structures are also an option. However, buildings that choose to comply with this standard with a Solar Zone that is not on the building roof must use the Design Method to determine the area of the Zone, thereby putting more time into the system design.

In high-rise buildings, which are particularly space constrained, the amount of electricity the system could generate would not make a dent in offsetting the building's annual consumption. High-rise buildings also tend to be in high density areas where the building occupies much of the total building site so the rooftop is the only feasible location on the building site to install solar collectors. In part because of constraints about available space, the proposed code change excludes high-rise buildings. High-rise buildings tend to encounter more shading constraints than low-rise buildings, which also contributed to the decision to exclude high-rise building from the code requirement.[3] Although about 20 percent of the floorspace built in 2014 is expected to be in buildings with more than four floors, less than 5 percent of the new roof space will be on high-rise buildings. Omitting high-rise buildings from the code reduces the potential statewide PV generation by less than 5 percent.[4]

Daylighting

The preferred strategy for achieving zero-net energy buildings is to conserve energy first, then to use energy efficiently, and finally to use renewable energy sources to meet the buildings energy demand. Daylighting helps achieve energy conservation objectives, and it is important that the solar-ready requirement does not encourage designers to sacrifice installing skylights, and the immediate energy savings they will enable, in order to provide space for future solar panels. To avoid incorporating a disincentive for installing skylights, the area of the Solar Zone is calculated based on roof area net of area covered by skylights. Designers can install as many skylights as desired and 40 percent of the *remaining* roof space would need to be allocated to the solar zone.

Contiguous Area

It is more favorable to have a solar array cover a small number of contiguous areas as opposed to many smaller discontinuous areas. While the proposed code language does not specify how many sub-areas the Solar Zone can be comprised of, it does require that an area has to be at least 5 feet wide

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3 ASHRAE has received feedback that due to space constraints it is challenging or impossible for high-rise buildings to adhere to the renewable-energy-ready measure in ASHRAE 189. Stakeholders have also provided feedback that rooftops in dense urban areas are often shaded by neighboring buildings, so solar resource is very limited.

4 If high-rise buildings were included in the proposed code change, the total generation potential would increase by 36.5 GWh to 708.4 GWh. This assumes that all buildings would install a PV system that would cover 40 percent of the roof area (net of skylights).

in the narrowest dimension to count towards the Solar Zone requirement. This 5 foot minimum is in place so that typical solar modules can easily fit within the zone.

Shading

Shading of solar modules and arrays can cause disproportional reductions in power output: in extreme cases, 10 percent shading can reduce power output by as much as 90 percent. As mentioned, typical shading constraints include rooftop equipment, trees, and sections of the building shading the lower roofs. To address shading constraints, the code requires that the Solar Zone be set back two times the height of any obstruction to the south, east or west of the zone. Using Solar Pathfinder or a similar tool to determine the shading constraints was not recommended because the tools are better suited for evaluating the shading on existing buildings. Alternatively, the code language specifies that the Solar Zone has to be set back two times the height of any obstruction to the south, east, or west of the Zone.

Architectural Leeway

During public meetings about the proposed measure, stakeholders expressed concern that the solar-ready requirement would limit the amount of leeway architects would have when designing buildings. The requirement is not intended to limit the flexibility designers have to use architectural footprints that enhance natural ventilation, windows, and daylighting. Nor does it intend to preclude architectural elements such as complex roof structures, roofs sloped towards the north or domed roofs. To address stakeholder concerns about architectural leeway, the CASE Team included the Design Method for determining the area of the Solar Zone. This Design Method allows designers to model systems that use less common products such as PV glazings and laminates, systems that use less traditional array orientations or tilts, or systems that are otherwise less traditional. The Design Method also allows the Solar Zone to be located anywhere on the building site, not just on the rooftop.

Fire Marshal Guidelines

Fire safety was an important consideration when developing the code change proposal. The solar industry has been presented with the challenge of designing systems that are compatible with current fire suppression techniques and that provide enough space on the roof for fire fighters to move around the roof safely. The 2012 International Fire Code (IFC) includes a new solar PV provision (section 605.11), which will be used as the basis for a solar PV provision in the 2013 revision of the California Fire Code (Title 24, Part 9).[5] At the time of writing, the 2013 revisions to the California Fire Code had not been adopted, so the CASE Team used the IFC provision and the California Office of the State Fire Marshal guidelines to inform decisions about the impact of future fire codes on the amount of space that would be available for solar equipment (CDFFP 2008). Key considerations include setting the Solar Zone back from the edges of the roof, from ventilation hatches and from skylights.

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5 Section 605.11 of the 2012 International Fire Code provision was based on guidelines the California Office of the State Fire Marshal published in 2008 (CDFFP 2008).

3.2.3 Allocated Space for System Equipment

The proposed code change requires designers to allocate a space for key system components such as inverters, metering equipment and storage tanks. The amount of space the equipment requires will depend on the building size and the building end use. The compliance manual could provide additional guidance on how to size equipment appropriately.

3.2.4 Pathway for Wiring or Piping

The CASE Team considered requiring buildings to be pre-wired or pre-plumbed, which would allow solar equipment to be connected to the building electrical or plumbing system easily. However, after stakeholders expressed concerns about this option, this option was taken off the table. One concern stakeholders had was that to pre-plumb or pre-wire a building, the designers would need to decide on the capacity of the system that would be installed. If the system that is installed at a future date is a different capacity than was originally planned, the wiring or plumbing may not be appropriately sized and new wires or pipes would need to be reinstalled. In this case, the code change could result in an increased installed system cost, which is counterproductive.

Another concern stakeholders expressed is that the solar installation company that installs the solar equipment bares the liability of ensuring the entire system functions properly. They may not feel comfortable using wiring or piping they did not design and install. Finally, every building owner would incur the cost of pre-wiring or pre-piping the building, but only a portion of building owners who voluntarily install systems would benefit from the potential cost savings of easily connecting equipment to the building electrical or plumbing system.The discrepancy in the number of people that would incur the cost of pre-wiring or pre-plumbing and the number of people who would benefit from the cost savings is large enough that a pre-wiring requirement would not be a cost effective.

The proposed code change language specifies that designers have to identify the path that conduit or piping would follow if a solar system were installed. Wiring or piping would need to take the most direct route from the Solar Zone to the inverter and from the inverter to the electrical interconnection or from the Solar Zone to the storage tanks and plumping interconnection. Requiring designers to establish the direct path for wiring or piping encourages the building designer to consider the practical implications of designing a building that is well suited for solar generation. For example, the designer may locate the Solar Zone directly above the electrical room, which would minimize the length of DC wiring required and would thus result in a simplified and lower cost PV system. Stakeholders indicated that installing a system on a building with direct pathways for wiring and piping could reduce the installed cost of a PV system by as much as 10 percent.

3.2.5 Disclosure of Structural Specifications

To address structural integrity issues, the proposed code would require that the as-designed maximum dead load and live load for the Solar Zone be clearly labeled on the record drawings, and Title 24 compliance forms. One challenge PV and SWH companies face is that the roof's structural capacity is not always known, and it is challenging to get a structural engineer to sign off on the structural condition if they were not involved in the initial design process or if they do not know how the building was modified after construction was complete. Requiring structural engineers to provide the maximum as-designed load for the Solar Zone will enhance communication about the future solar system amongst the design team and may encourage designers to add structural capacity on the Solar Zone.

3.2.6 Interaction with Existing Code Language

The solar-ready requirement would not supersede or be superseded by the cool roofing requirements or the skylight requirements. All buildings would need to comply with cool roofing, daylighting and solar-ready requirements.

3.3 Energy Savings Methodology

The primary goal of the solar-ready measure is to enable PV and SWH systems to be installed at a future date. The code would not require PV or SWH systems to be installed, so energy savings from this measure are attributed to systems that are voluntarily installed at some point in the life of the building. The energy benefits presented in Section 4 of this report provide a reference point for the savings that could be achieved if solar PV systems of the recommended size were actually installed. PV or SWH systems effectively offset demand for electricity at the building site. For the energy savings estimates, it is assumed that the electricity generated from a PV system is equivalent to site energy savings.

To calculate the potential statewide energy savings, the CASE Team first estimated the total area that would be part of a Solar Zone in newly constructed low-rise nonresidential building during the year the code would take effect (2014). The nonresidential construction forecast was used to determine the total projected nonresidential floorspace built in 2014. [6] Data from the Energy Information Administration's Commercial Buildings Energy Consumption Survey (CBECS) was used to estimate the portion of nonresidential buildings constructed in 2014 that would be three stories or fewer.[7] CBECS data indicates that 98 percent of the commercial buildings in the western region have fewer than three stories. Since high-rise buildings have more floorspace than low-rise buildings, only 80% of the total floorspace is found in low-rise buildings (EIA 2006). The construction forecast is presented in Table 1.

Combining the nonresidential construction forecast with CBECS data yields a projection of the newly constructed floorspace that would be in one, two, and three story buildings. With this information, it is possible to estimate the total area of roof space that would be allocated as a Solar Zone. For one-story buildings, the total roof space is equal to the total floorspace of the building, so if 40 percent of the roof space is allocated to a Solar Zone then the area of the Solar Zone is 40 percent of the projected floorspace in one-story buildings. For two-story buildings, the roof area is half the total floorspace, so the Solar Zone would be 40 percent of the total floorspace divided by two {40% x (total SF/2)}. Similarly, the Solar Zone on a three-story building would be 40 percent of the total floorspace divided by three (40% x (total SF/3)}. Table 2 presents the estimated Solar Zone area for all low-rise nonresidential construction in 2014. The Team estimated that 2 percent of the total newly constructed

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6 Nonresidential construction forecast data is provided by the Demand Forecast office at the California Energy Commission. Moshen Abrishami compiled total construction floor space (in ft^2) for 1964 – 2020 in the following nonresidential space types: off-small (offices less than 30,000 ft^2), off-large (offices larger than 30,000 ft^2), restaurants, retail, food service, non-refrigerated warehouse, refrigerated warehouse, schools (K-12), colleges, hospitals, hotel and lodging, and miscellaneous. In addition, the CEC provides estimates in each space type category for additional floor space each year, indicating the total new construction added annually. The data was provided to the CASE Team on August 23, 2010.

7 In using CBECS data, the analysis assumes the distribution of low-rise and high-rise buildings in California is the same as the distribution in the Western region of the United States.

roofs pace would be occupied by skylights, so 2 percent of the roof area was subtracted before multiplying by 40 percent.

Table 1. Forecasted Low-rise Nonresidential Construction in 2014

Building Type	**Forecasted New Nonresidential Construction in 2014** [(a)] (million SF)	**Forecasted New LOW-RISE Nonresidential Construction in 2014** [(b)] (million SF)	**Forecasted New Nonresidential Construction by Number of Floors** [(c)] (million SF)			
			One Floor	Two Floors	Three Floors	Four or More Floors
Small Office	9.1	4.9	1.8	1.7	1.3	4.2
Large Office	27.7	14.8	5.6	5.1	4.1	12.9
Restaurant	5.1	4.6	2.9	1.2	0.5	0.5
Retail	32.4	30.7	20.6	7.0	3.1	1.7
Grocery	8.5	8.5	6.5	1.8	0.2	0.0
Warehouse	32.1	32.1	21.1	8.5	2.4	0.0
Refrigerated Warehouse	1.8	1.8	1.2	0.5	0.1	0.0
School	10.0	8.3	3.7	2.9	1.7	1.6
Colleges	7.4	6.2	2.8	2.2	1.2	1.2
Lodging	9.1	4.0	1.2	1.7	1.1	5.1
Other	31.6	25.1	13.9	8.7	2.5	6.5
TOTAL	**174.7**	**140.9**	**81.2**	**41.3**	**18.4**	**33.8**

a) Source: Nonresidential construction forecast data provided by the Demand Forecast office at the California Energy Commission for use in 2013 code change cycle.

b) Assumed to be all buildings under with three or fewer floors.

c) Source: EIA 2006 (CBECS). Table B10. Number of Floors, Number of Buildings and Floorspace for Non-Mall Buildings.

Table 2. Area of PV Zones in New Nonresidential Low-rise Construction in 2014

Building Type	Area of PV Zone on LOW-RISE Buildings Constructed in 2014 (million SF)	Area of PV Zone on Buildings Constructed in 2014 (million SF)			
		One Floor	Two Floors	Three Floors	Four or More Floors
Small Office	1.2	0.7	0.3	0.2	n/a
Large Office	3.7	2.2	1.0	0.5	n/a
Restaurant	1.4	1.1	0.2	0.1	n/a
Retail	9.9	8.1	1.4	0.4	n/a
Grocery	2.9	2.6	0.3	0.0	n/a
Warehouse	10.3	8.3	1.7	0.3	n/a
Refrigerated Warehouse	0.6	0.5	0.1	0.0	n/a
School	2.3	1.5	0.6	0.2	n/a
Colleges	1.7	1.1	0.4	0.2	n/a
Lodging	0.9	0.5	0.3	0.1	n/a
Other	7.5	5.5	1.7	0.3	n/a
TOTAL	**42.3**	**31.8**	**8.1**	**2.4**	---

Next, the Team multiplied the total statewide Solar Zone area (42.3 million SF) by the assumed generation potential per SF. The assumed generation potential was determined using a statewide average PV system efficiency value. To calculate the statewide average PV system efficiency value, the Team modeled the annual electricity generation per kW (kWh/kW) for two representative systems: a high efficiency and a low efficiency system. For each system, the electricity generation was modeled in all 16 climate zones. Using data from the nonresidential construction forecast, the forecast used in all cost effectiveness calculations for code changes proposed for the 2013 code cycle, the Team weighted the high and low kWh/kW values by the percentage of new nonresidential construction forecasted for each climate zone the year the code would take effect (2014). The result is two statewide average kWh/kW values that are weighted by the forecasted square footage of new building construction in 2014. Table 3 presents the findings from modeling representative systems. To be conservative about the generation potential from systems on the Solar Zone, the Team used the weighted average system efficiency for the lower efficiency system (1,587 kWh/kW) to estimate the generation potential of systems placed on Solar Zones. The industry rule-of-thumb sizing factor of 100 kW/SF was used to estimate the kWh generation per square foot of Solar Zone area.

Table 3. Representative PV System Annual Electricity Generation per kW: 16 Climate Zones

Building Type	Representative Systems: Electricity Generation per kW Capacity (kWh/kW)		Percent of Nonresidential Buildings Forecasted for Construction in 2014
	Low Result	**High Result**	
Climate Zone 1	1,220	1,475	0.2%
Climate Zone 2	1,420	1,660	2.2%
Climate Zone 3	1,515	1,885	8.7%
Climate Zone 4	1,560	1,920	5.5%
Climate Zone 5	1,570	1,965	1.1%
Climate Zone 6	1,590	1,980	8.2%
Climate Zone 7	1,545	1,940	10.7%
Climate Zone 8	1,565	1,965	9.9%
Climate Zone 9	1,570	1,870	19.7%
Climate Zone 10	1,560	1,880	5.7%
Climate Zone 11	1,595	1,905	2.9%
Climate Zone 12	1,670	1,975	15.0%
Climate Zone 13	1,705	2,000	6.8%
Climate Zone 14	1,790	2,140	1.3%
Climate Zone 15	1,755	2,085	0.5%
Climate Zone 16	1,560	1,860	1.6%
Statewide Weighted Average	**1,587**	**1,926**	---

Lifetime savings was estimated by multiplying the first year saving by the 20-year system life. This calculation does not account for the fact that systems will degrade and generate less electricity over time. With the installed cost of PV expected to drop and uncertainty about whether state and federal incentives for solar will remain over time, it is difficult to predict how many buildings will install PV systems at some point during the building life. The margin of error in predicting the percentage of buildings that will install systems far outweighs other assumptions used in the analysis, including the degradation of the PV system resulting in reduced electricity generation over time.

Since it is difficult to predict the percentage of buildings that will install solar at some point, the analysis section of this report (section 4.1) provides a range of savings assuming between 1 and 100 percent of buildings install the appropriately sized PV system.

Per unit energy savings were calculated by taking the statewide savings and dividing by the forecasted new construction rates.

3.4 Cost Savings Methodology

Cost savings associated with the code change are realized on buildings where solar equipment is installed voluntarily and the equipment is installed as a retrofit (i.e. the system was not installed as part of the original building construction). There are no cost savings expected when systems are installed during initial construction because it is assumed that if designers know the PV or SWH system is going to be installed before or shortly after the building is first occupied, the designers will have already planned for easy (and inexpensive) installation. Cost savings from retrofits will result when PV or SWH equipment is easily interconnected with the building electrical or plumbing systems. Installing PV or SWH systems on solar-ready buildings (as defined in the recommended code language) could reduce the installed cost of the system by as much as 10 percent (C&S

Stakeholder Process, January 11, 2011). Energy cost savings will result when PV or SWH equipment is installed. Energy cost savings are presented in Table 6.

Both cost savings from equipment installation and energy cost savings apply only when PV or SWH systems are installed voluntarily. None of the cost savings were included in the cost effectiveness calculations because not all buildings will install systems so savings are not universal across the entire building stock.

3.5 Cost Effectiveness Methodology

The proposed code change does not require equipment installation nor does it have any incremental maintenance costs. The only costs associated with the measure are design costs. Initially designers will need to familiarize themselves with the solar-ready requirement, but over time design will become streamlined and the costs will be minimal. The LCC Methodology does not include design costs in the costs of a measure, so for LCC purposes the measure has no costs.

4. Analysis and Results

4.1 Energy Savings

Table 4 shows an estimated generation potential per square foot and the average percentage of electricity that would be offset for each building type. For example, if all the small offices built in 2014 installed a PV system that covered 40 percent of their roof space, 31 percent of the total expected electricity use from all small offices would be offset by generation from the PV systems.

Table 4. Average Energy Intensity of Various Building Types and Percent of Total Statewide Electricity Demand that could be Offset by PV Systems on Solar Zones

Building Type	**Statewide Average Energy Intensity** (kWh/SF floorspace)*	**Average PV Generation per Total Projected Floorspace** (kWh/SF/yr)	**Average PV Capacity per Total Projected Floorspace** (W/SF)	**Statewide Average Percent of Demand Offset by Generation from PV Systems** (%)
Small Office	13.1	4.0	2.5	30.5%
Large Office	17.7	4.0	2.5	22.6%
Restaurant	40.2	4.9	3.1	12.3%
Retail	14.1	5.1	3.2	36.2%
Grocery	41.0	5.5	3.4	13.3%
Warehouse	4.5	5.1	3.2	114.2%
Refrigerated Warehouse	20.0	5.1	3.2	25.4%
School	7.5	4.3	2.7	57.6%
Colleges	12.3	4.3	2.7	35.1%
Lodging	12.1	3.7	2.3	30.7%
Other	9.8	4.7	3.0	48.0%
Statewide Average		**4.8**	**3.0**	**35.3%**

* Source: CEC 2006, CEUS Data

Table 5 presents the maximum potential statewide savings if all nonresidential low-rise buildings constructed in 2014 install PV systems that cover the Solar Zone. Demand reduction would be 4 424 MW and annual electricity savings would be approximately 672 GWh. Throughout the 20-year equipment lifetime, PV systems installed on 2014 vintage buildings would save about 13,439 GWh.

Table 5. Electricity Savings and Demand Reduction if All New Nonresidential Buildings Built in 2014 Install PV System of Recommended Size during Initial Construction

Building Occupancy	**All New Buildings Install PV System of Recommended Size**		
	Annual Electricity Savings (GWh)	**Lifetime Electricity Savings*** (GWh)	**Demand Reduction** (MW)
Small Offices	19.4	388.8	12.3
Large Offices	59.2	1,184.7	37.3
Restaurants	22.6	452.9	14.3
Retail	156.4	3,128.5	98.6
Food	46.5	930.2	29.3
Warehouse	162.9	3,258.7	102.7
Refrigerated Warehouse	8.9	178.1	5.6
School	35.8	716.1	22.6
College	26.5	529.8	16.7
Hotel	14.7	294.7	9.3
Other	118.8	2,376.3	74.9
Total	671.9	13,438.7	423.5

* assumes 20-year lifetime

The actual savings resulting from the code change will be much lower than the values presented in Table 5. At least 10 percent of new buildings will likely still be unsuitable for PV due to external shading constraints including shading from nearby topography. Additionally, only some portion of new buildings that are suitable for PV will elect to install. Table 6 presents a range of energy savings if only a portion of the buildings install PV systems. The lower end of the range represents the current market trends of ~1 percent of newly constructed buildings installing PV.[8]

[8] About 1 percent of newly constructed nonresidential buildings install PV systems, but the system capacity – as a percentage of total building electricity demand – is not known. In this case, the assumption is that buildings will install systems capable of offsetting 20 percent of demand.

Table 6. Electricity Savings and Demand Reduction if Subset of Nonresidential Buildings Built in 2014 Install PV System of Recommended Size during Initial Construction

Percentage of Buildings that Install PV Systems	PV Capacity Installed (MW)	Annual Electricity Savings (GWh)	Annual Energy Cost Savings ($million/yr)*	20-year Electicity Savings (GWh)	20-year Energy Cost Savings ($million)*
1%	4.2	6.7	$1	134.4	$16
5%	21.2	33.6	$4	671.9	$81
10%	42.3	67.2	$8	1,343.9	$161
25%	105.9	168.0	$20	3,359.7	$403
40%	169.4	268.8	$32	5,375.5	$645
50%	211.7	336.0	$40	6,719.3	$806
100%	423.5	671.9	$81	13,438.7	$1,613

* assumes $0.12/kWh

Time Dependent Valuation (TDV) savings were not calculated because the code change would not lead to direct energy savings because, as mentioned previously, the code does not require PV or SWH installations. Assuming systems are installed, TDV benefits will vary based on system design. Many PV and SWH systems are optimized so the majority of electricity is generated in the afternoon when demand is the highest. Modules generate the most electricity or are most effective at heating water when they have the most direct access. Since western-facing aspects get direct sunlight in the afternoon, modules oriented towards the west or southwest are optimized to offset peak energy demand.

4.2 Cost Savings

Industry stakeholders estimated the installed cost of PV or SWH, if installed as a retrofit, could be reduced by 10 percent if installed on a solar-ready building, as defined. The cost savings result from a more simple design process and a more straight forward installation, which reduces labor costs. For example, the pathway to rough wires from the Solar Zone to the electrical interconnect has already been designed in a solar-ready building. Instead of starting from square one, the system designer will only need to verify that the pre-designed pathway is suitable for the planned system. Provided the pathway has not been obstructed between the time of initial construction and the time the system is installed, there will be clear pathway to install conduit and run wires, which will minimize the cost of installing the wiring.

Figure 7 provides a breakdown of the installed costs of PV systems. Currently, about 50 percent of the installed cost is associated with the PV modules and 50 percent is associated with the balance-of-system (BOS). Module costs are projected to be cut in half, dropping below $1/watt in the coming years. The BOS costs (inverters, wiring, electrical installation, site prep, racking, structural installations, design and overhead) account for half of the installed cost of PV. Looking more closely at the BOS costs, the cost of wiring fluctuates with the market price of raw materials and industry dictates the cost of inverters and racking. The solar-ready measure will address the remaining BOS costs including the cost of the electrical installation, site prep, structural alterations, and the "Business Process" including design costs.

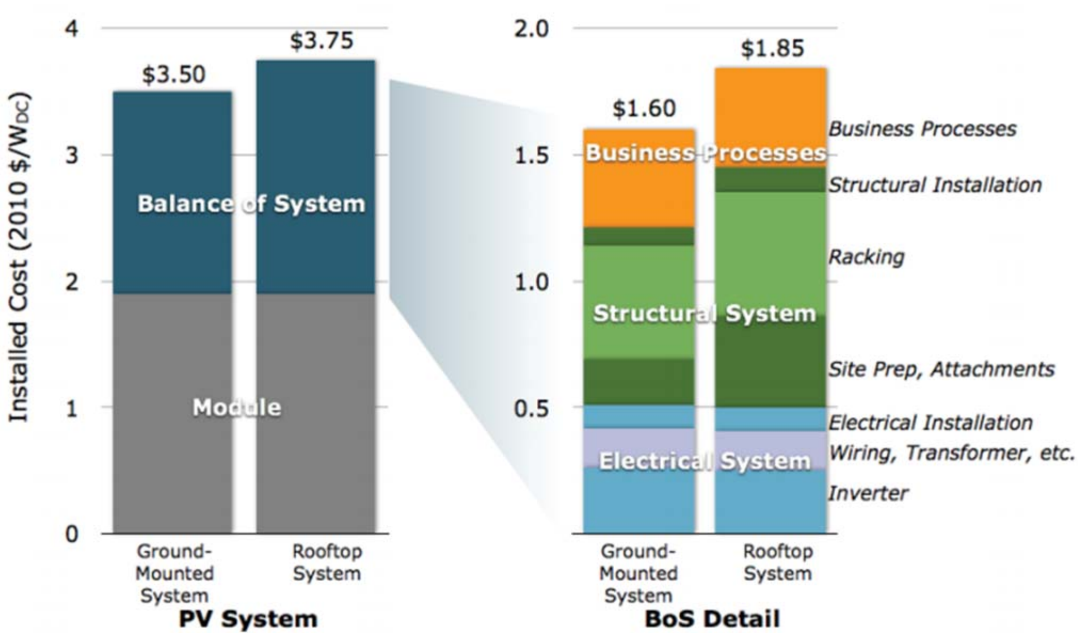

Figure 7. Cost Breakdown of PV System (2010$/Wdc)

Source: Boney et al. 2010

4.3 Cost Effectiveness

The proposed code will result in energy savings and there are no LCC costs associated with it, so the proposed change is cost effective.

5. Proposed Code Change Language

5.1 Where Code Language Would Appear

The language presented in this section is formatted in two ways: 1) for inclusion in Part 6 of Title 24, and 2) for inclusion in Part 11 of Title 24. The language is the same but the section numbers and formatting vary to accommodate the formats of the two documents. The section numbers in the code language presented in section 5.2 correspond to the sections in Part 11 of Title 24. If the language ends up in Part 6 of Title 24, the section headings and references to compliance form would be modified accordingly.

If the solar-ready measure is incorporated into Part 6 of Title 24, the proposed language would be a mandatory measure in Subsection 2: All Occupancies—Mandatory Requirements for the Manufacture, Construction, and Installation of Systems, Equipment and Building Components. Subsection 2 applies to all building types, so the language would clearly indicate the measure would only apply to nonresidential buildings. To implement the proposed measure as a mandatory measure in Part 6, the nonresidential Title 24 envelope compliance forms would also need to be modified. A section would be added to form ENV-1C: Certificate of Compliance and Field Inspection Energy Checklist. A new form, ENV-5C, will be used to ensure the area of the Solar Zone has been calculated correctly and to ensure the interconnection plan and the Solar Zone have been designed according to code.

If the solar-ready measure is incorporated into Part 11 of Title 24, the proposed language would be added as a mandatory measure in Chapter 5 Division 5.2: Nonresidential Mandatory Measures - Energy Efficiency. Alternatively, the proposed language could be added into a new division to Chapter 5, Division 5.6: Nonresidential Mandatory Measures – Renewable Energy. To implement the proposed measure as a mandatory measure in Part 11, a new compliance form would need to be added. The form would likely be called EE-1: SOLAR-READY or RE-1: SOLAR-READY, depending on whether the proposed language would appear in the energy efficiency (EE) division or the renewable energy (RE) division. The new form will be used to ensure the area of the Solar Zone has been calculated correctly and to ensure the interconnection plan and the Solar Zone have been designed according to code.

5.2 Proposed Code Change Language

SECTION 5.202: DEFINITIONS

SECTION 5.203: SOLAR READINESS

Low-rise nonresidential buildings shall provide for the future installation of on-site solar photovoltaic (PV) or solar water heating (SWH). Record drawings shall show allocated Solar Zone and the designs for interconnecting the PV or SWH system with the building electrical or plumbing system. Section 5.203 applies to major alterations or additions of low-rise nonresidential buildings that would increase the total roof area by more than 20 percent.

5.203.1 Allocated Solar Zone.

The building must have an allocated Solar Zone located on the roof of the building. The Solar Zone must be clearly marked on the record drawings, and the total area of the Solar Zone must be documented and on the EE-1 SOLAR-READY compliance form.[9] The Solar Zone must comply with the following:

1. **Minimum Area. The minimum area of the Solar Zone shall be determined by either a) or b):**
    a. **Percent of roof area: Minimum area of Solar Zone = 40% x [(total roof area) – (area covered by skylights)]**
    b. **Design method: Use a CEC approved calculator tool to determine the area required to generate at least 20 percent of the electrical contribution to the estimated annual building energy budget, as defined by Section 101 of Title 24 Part 6. Calculations must be completed according to CEC guidelines.**

    EXCEPTION: The Solar Zone can be located elsewhere on the building site, aside from the roof, but designers must use the design method (option b) to determine the size of the Solar Zone.
2. **Obstructions. The Solar Zone must be free of pipes, vents, ducts, HVAC equipment and other obstructions.**
3. **Shading. The Solar Zone must be set back a distance of at least two times the height of any objects (including features of the building itself, parapets, rooftop equipment, vegetation, or any other feature) located south, east, or west of the Solar Zone.**
4. **Contiguous Area. The Solar Zone may be comprised of smaller sub-zones. All sub-zones must be at least 5 feet wide in the narrowest dimension.**

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9 If code change is added as a mandatory measure in Part 6, the nonresidential Title 24 envelope compliance forms would also need to be modified. A section would be added to form ENV-1C: Certificate of Compliance and Field Inspection Energy Checklist. A new form, ENV-5C, will be used to ensure the area of the Solar Zone has been calculated correctly and to ensure the interconnection plan and the Solar Zone have been designed according to code.

5. **Fire Code. The Solar Zone should be designed in accordance with current Fire Code Requirements (see Title 24, Part 9).[10]**
6. **Structural Integrity. If the Solar Zone is on the roof of the building or a parking structure, the as-designed dead load and live load for the Solar Zone must be clearly marked on the record drawings and on EE-1 SOLAR-READY compliance form.[11]**

EXCEPTION to 5.203.1:

1. **Buildings that have PV or SWH systems installed may count the area occupied by the system towards the Solar Zone requirement.**

5.203.2 Designed PV or SWH Interconnection.

Buildings must design for the interconnection of a PV system or a solar water heating system, as specified by (1) and (2) below:

1. **PV System Interconnection Design. The building electrical drawings must indicate the plan for connecting the PV system of the specified capacity to the building's electrical system. The interconnection must be designed such that the sum of the supply feeders from inverter(s) serving the busbar is no more than 20 percent of the busbar rating and wiring follows the shortest feasible pathway between the Solar Zone to the inverter location and from the inverter location the dedicated electrical interconnection point. Drawings must clearly label the:**
   a. **Solar Zone**
   b. **location for inverters and metering equipment**
   c. **electrical interconnection**
   d. **pathway for wiring**
2. **SWH System Interconnection Design. The building plumbing drawings must indicate the plan for connecting the SWH system of the specified capacity to the building's plumbing system. The interconnection must be designed such that piping follows the shortest feasible pathway between the Solar Zone and the plumbing interconnection point. Drawings must clearly label the:**
   a. **Solar Zone**
   b. **location for hot water storage tanks**
   c. **plumbing interconnection**
   d. **pathway for piping**

[10] When the 2013 revisions to the fire code have been adopted, the reference to Title 24 Part 9 will be updated with the section of the fire code that addresses solar installations.

[11] If code change is added as a mandatory measure in Part 6, the nonresidential Title 24 envelope compliance forms would also need to be modified. A section would be added to form ENV-1C: Certificate of Compliance and Field Inspection Energy Checklist. A new form, ENV-5C, will be used to ensure the area of the Solar Zone has been calculated correctly and to ensure the interconnection plan and the Solar Zone have been designed according to code.

6. Bibliography and Other Research

Barbose, G., N. Darghouth, & R. Wiser. 2010. *Tracking the Sun III: The Installed Cost of Photovoltaics in the U.S. from 1998-2009.* LBNL-4121E. Berkeley, CA. Lawrence Berkeley National Laboratory. Available online at: http://eetd.lbl.gov/ea/emp/reports/lbnl-4121e.pdf

Binkley, A. & D. Fisher. "Distributed Solar's Deployment Obstacle: Sufficient Solar-Ready Roofs." *Solar Industry Magazine.* 3 (9) 1, 10-13. Available online at: http://www.solarindustrymag.com/editorial/archive.php

Boney, L., S. Doig, C. Hart, E. Maurer & S. Newman. 2010. "Achieving Low-Cost Solar PV: Industry Workshop Recommendations for Near-Term Balance of System Cost Reductions". Rocky Mountain Institute (RMI). Available online at: http://www.rmi.org/rmi/SolarPVBOS.

Bryan, Harvey, Hema Rallapalli, and Jin Ho Jo. "Designing a Solar Ready Roof: Establishing the Conditions for a High-performing Solar Installation". American Solar Energy Society Solar 2010 Conference Proceedings. 2010. Available online at: http://www.ases.org/papers/046.pdf

[BSC] California Building Standards Commission. "2010 California Green Building Standards (CALGreen) Code". Available online at: http://www.documents.dgs.ca.gov/bsc/CALGreen/2010_CA_Green_Bldg.pdf.

[CDFFP] California Department of Forestry and Fire Protection and Fire Protection Office of the State Fire Marshal. "Solar Photovoltaic Installation Guideline". April 22, 2008. Available on line at: http://osfm.fire.ca.gov/training/pdf/photovoltaics/solarphotovoltaicguideline.pdf

[CEC] California Energy Commission. 2006. "California Commercial End-use Survey (CEUS)." March 2006. Publication # CEC-400-2006-005. Available online at: http://www.energy.ca.gov/ceus/

[CPUC] California Public Utilities Commission. 2009. "California Long -Term Energy Efficiency Strategic Plan." Available online at: http://www.californiaenergyefficiency.com.

[CSI] California Solar Imitative Program Data. "California Solar Statistics." Available online at: http://www.californiasolarstatistics.ca.gov/

[CUSCST] California Utilities Statewide Codes and Standards Team. March 2011. "Codes and Standards Enhancement (CASE) Initiative: Draft Measure Information Template – Daylighting". Available online at: http://www.energy.ca.gov/title24/2013standards/prerulemaking/documents/2011-04-04_workshop/review/Nonres_Daylighting.pdf

[EIA] Energy Information Administration, 2006. Office of Energy Markets and End Use, Form EIA-871A of the 2003 Commercial Buildings Energy Consumption Survey. Table B10. Number of Floors, Number of Buildings and Floorspace for Non-Mall Buildings, 2003.

Statewide IOU Codes and Standards Stakeholder Process (IOU C&S Stakeholder Process). *Solar Stakeholder Meeting II Follow-up Webinar*. January 11, 2011. Minutes available online at: http://www.h-m-g.com/T24/Solar/solar.htm.

7. Appendix A: Previous Iteration of Draft Code Language

As discussed in section 3.2.2 of this report, the Team considered three ways to determine the size of the solar zone: a method based on a percentage of the roof space, a design-based method, and a method that used unique multipliers for each building type. When vetting the code language that incorporated all three methods during a public meeting, stakeholders provided feedback that the code language was too complicated and that they preferred a simplified approach. Ultimately, the Team decided to eliminate the third option that uses multipliers to determine the size of the Solar Zone. This appendix describes the multiplier option in more detail and presents the draft code language that incorporated all three options.

7.1 Multiplier Method for Calculating Area of Solar Zone

For the multiplier method, the code would specify the size of the Solar Zone based on the total square footage of the building and the building type. The Solar Zone multipliers are calibrated so the Solar Zone will be capable of generating about 20 percent of the building's total electricity demand. The calculated method would likely be more restrictive than the design method but the design effort would not be as involved.

The objective of the multiplier method is to provide a straightforward calculation that designers can use to determine the size of the Solar Zone. As mentioned above, the multipliers are set so the Solar Zone will be large enough to accommodate a PV system that is capable of generating about 20 percent of the total estimated electricity demand. The multipliers provide a reasonable estimate of the area needed to generate 20 percent of demand, but due to variation in building design and expected electricity demand in each building, the multipliers cannot provide an accurate area requirement for every building in California. The exact area requirement depends on a number of factors including the climate and available solar resource, both of which vary significantly throughout the state. The area the system will occupy also depends on system efficiency, which in turn depends on the type, orientation, and tilt of PV modules, inverter efficiency, length of wiring, and other external factors like temperature and dust factor. If a designer wants a more accurate estimation of the area required to accommodate a PV system, they can use the design method and develop a custom PV system for the building.

To determine the Solar Zone multipliers, the CASE Team relied on California Commercial Energy-use Survey (CEUS) data to determine the statewide average energy intensity per square foot (kWh/SF floorspace). As shown in Table A1, there are different energy intensity values for various building types. CEUS data was collected in 2002 and is based on electricity use in existing buildings. Newly constructed buildings in 2014 or later will likely consume less energy than the existing building stock in 2002. The implication is the Solar Zone may be oversized and the zones might be able to generate more than 20 percent of the building load.

Table A- 1. Statewide Average Electricity Use and Target Electricity Generation from PV System

Building Type	Statewide Average Energy Intensity (kWh/SF floorspace)*	Target Electricity Generation from PV System (kWh/ SF floorspace)
Small Office	13.10	2.62
Large Office	17.70	3.54
Restaurant	40.20	8.04
Retail	14.06	2.81
Grocery	40.99	8.20
Warehouse	4.45	0.89
Refrigerated Warehouse	20.02	4.00
School	7.46	1.49
Colleges	12.26	2.45
Lodging	12.13	2.43
Other	9.84	1.97

* Source: CEC 2006, CEUS Data

After determining the energy intensity of each building the target electricity generation was established by multiplied by annual energy intensity by 20 percent (kWh/SF floorspace). Next Team calculated a statewide average PV system efficiency value. Two representative systems, a high efficiency and a low efficiency system, were selected. For each system, the Team modeled the annual electricity generation per kW (kWh/kW) in all 16 climate zones. Using data from the nonresidential construction forecast, the forecast used in all cost effectiveness calculations for code changes proposed for the 2013 code cycle,[12] the Team weighted the high and low kWh/kW values by the percentage of new nonresidential construction forecasted for each climate zone the year the code would take effect (2014). The result is two statewide values kWh/kW values weighted by the forecasted building SF constructed in each climate zone in 2014. Table A2 presents the findings from modeling representative systems.

To be conservative about the size of the Solar Zone, the Team used the weighted average system efficiency for the lower efficiency system (1,587 kWh/kW) to estimate the capacity (kW) of the systems required to generate the electricity generation goal. Finally, the industry rule-of-thumb sizing factor of 100 kW/SF was used to arrive at the Solar Zone multiplier in units of square feet of Solar Zone per total building floorspace (SF Solar Zone /SF floorspace) (see Table A3). The calculation method is summarized in Equation 1.

The calculated method for determining the size of the Solar Zone depends on the building end use (e.g. office, retail, etc.). If one end-use constitutes at least 80 percent of the floorspace, the Solar Zone multiplier for the predominant end-use should be used in calculations. Otherwise, the mixed use

[12] Nonresidential construction forecast data is provided by the Demand Forecast office at the California Energy Commission. Moshen Abrishami compiled total construction floor space (in ft^2) for 1964 – 2020 in the following nonresidential space types: off-small (offices less than 30,000 ft^2), off-large (offices larger than 30,000 ft^2), restaurants, retail, food service, non-refrigerated warehouse, refrigerated warehouse, schools (K-12), colleges, hospitals, hotel and lodging, and miscellaneous. In addition, the CEC provides estimates in each space type category for additional floor space each year, indicating the total new construction added annually. The data was provided to the CASE Team on August 23, 2010.

multiplier should be used. The mixed use multiplier is the average of the small office, large office, retail, restaurant, and other multipliers weighted by the 2014 forecasted floorspace of each end use. The forecasted floorspace are presented in Table 2 in the main body of this report.

$$\underset{\text{(SF Solar Zone / SF total building)}}{\textbf{Solar Zone Multiplier}} = \underset{\text{(kWh/SF)}}{\textbf{Statewide Avg. Energy Intensity}} \times \underset{\text{20\%}}{\textbf{Target kWh Generation}} \times \underset{\text{(1,587 kW/ kWh)}}{\textbf{Avg. PV System Efficiency}} \times \underset{\text{(SF Solar Zone/ kW)}}{\textbf{Typical PV Area}} \quad \text{[Equ. 1]}$$

Table A- 2. Representative PV System Annual Electricity Generation per kW: 16 Climate Zones

Building Type	Representative Systems: Electricity Generation per kW Capacity (kWh/kW)		Percent of Nonresidential Buildings Forecasted for Construction in 2014
	Low Result	High Result	
Climate Zone 1	1,220	1,475	0.2%
Climate Zone 2	1,420	1,660	2.2%
Climate Zone 3	1,515	1,885	8.7%
Climate Zone 4	1,560	1,920	5.5%
Climate Zone 5	1,570	1,965	1.1%
Climate Zone 6	1,590	1,980	8.2%
Climate Zone 7	1,545	1,940	10.7%
Climate Zone 8	1,565	1,965	9.9%
Climate Zone 9	1,570	1,870	19.7%
Climate Zone 10	1,560	1,880	5.7%
Climate Zone 11	1,595	1,905	2.9%
Climate Zone 12	1,670	1,975	15.0%
Climate Zone 13	1,705	2,000	6.8%
Climate Zone 14	1,790	2,140	1.3%
Climate Zone 15	1,755	2,085	0.5%
Climate Zone 16	1,560	1,860	1.6%
Statewide Weighted Average	**1,587**	**1,926**	---

Table A- 3. Target System Capacity (kW/1000 SF floorspace) and Solar Zone Multipliers

Building Type	Target System Capacity (kW/ 1000 SF floorspace)	Solar Zone Multiplier (SF Solar Zone / SF floorspace)
Small Office	1.65	0.165
Large Office	2.23	0.225
Restaurant	5.07	0.507
Retail	1.77	0.177
Grocery	5.17	0.517
Warehouse	0.56	0.056
Refrigerated Warehouse	2.52	0.252
School	0.94	0.094
Colleges	1.55	0.155
Lodging	1.53	0.153
Other	1.24	0.124
Mixed Use		0.187

7.2 Draft Code Change Language (previous iteration)

SECTION 5.202: DEFINITIONSILDING SITE. ***To come***

SECTION 5.203: SOLAR READINESS

Low-rise nonresidential buildings with three stories or fewer shall provide for the future installation of on-site solar photovoltaic (PV) or solar water heating (SWH). Record drawings shall show allocated Solar Zone and the designs for interconnecting the PV or SWH system with the building electrical or plumbing system. Section 5.203 applies to major retrofits of low-rise nonresidential buildings that would increase the total roof area by more than 20 percent.

> **EXCEPTION: If a PV system that covers 50 percent of the available space on the building site is not capable of generating at least 1 percent of electrical contribution to the estimated annual building energy budget, the building does not need to comply with section 5.203.**

5.203.1 Allocated Solar Zone.

The building must have an allocated Solar Zone located on the roof of the building or elsewhere on the building site. The Solar Zone must be clearly marked on the record mechanical and electrical drawings, and total area of the Solar Zone must be documented and on the EE-1 SOLAR-READY compliance form.[13] The Solar Zone must comply with the following:

7. **Minimum Area. The minimum area of the Solar Zone shall be the larger of (a) or (b)**
    a. **Minimum area of Solar Zone = (total roof area in SF) – (area covered by skylights) x 50%**
    b. **An area determined by one of the following methods:**
        i. **Calculated Method. use equation (1) and the Solar Zone multipliers provided in Table 5.203.1 to calculate the area of the Solar Zone**

Equation 1: area of Solar Zone = (total building SF) x (Solar Zone multiplier) (1)

Table 5.203.1

[13] If code change is added as a mandatory measure in Part 6, the nonresidential Title 24 envelope compliance forms would also need to be modified. A section would be added to form ENV-1C: Certificate of Compliance and Field Inspection Energy Checklist. A new form, ENV-5C, will be used to ensure the area of the Solar Zone has been calculated correctly and to ensure the interconnection plan and the Solar Zone have been designed according to code.

Building Type	Solar Zone Multiplier (SF Solar Zone / Total Building SF)
Small Office	0.165
Large Office	0.223
Restaurant	0.507
Retail	0.177
Grocery	0.517
Warehouse	0.056
Refrigerated Warehouse	0.252
School	0.094
Colleges	0.155
Lodging	0.153
Other	0.124
Mixed Use	0.187

ii. **Design Method. Use a CEC approved calculator tool to determine the area required to generate at least 20 percent of the electrical contribution to the estimated annual building energy budget, as defined by Section 101 of Title 24 Part 6. Calculations must be completed according to CEC guidelines.**

8. **Maximum Area. No Solar Zone is required to be larger than the maximum area defined by:**

   Maximum area of Solar Zone = (total roof area in SF) – (area covered by skylights) x 75%

9. **Obstructions. The Solar Zone must be free of pipes, vents, ducts, HVAC equipment and other similar obstructions.**

10. **Shading. The Solar Zone must be set back a distance of at least two times the height of any objects (including features of the building itself, parapets, rooftop equipment, vegetation, or any other feature) located south, east, or west of the Solar Zone.**

11. **Contiguous Area. The Solar Zone may be comprised of up to five smaller sub-areas. No sub-area can be smaller than 250SF unless the total area of the Solar Zone is less than 250SF. All areas must be at least 5 feet wide in the narrowest dimension.**

12. **Fire Code. The Solar Zone should be designed in accordance with current Fire Code Requirements (see Title 24, Part 11).**[14]

13. **Structural Integrity. The as-designed dead load and live load for the Solar Zone must be clearly marked on the record drawings and on EE-1 SOLAR-READY compliance form.**[15]

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[14] When the 2013 revisions to the fire code have been adopted, the reference to Title 24 Part 9 will be updated with the section of the fire code that addresses solar installations.

[15] If code change is added as a mandatory measure in Part 6, the nonresidential Title 24 envelope compliance forms would also need to be modified. A section would be added to form ENV-1C: Certificate of Compliance and Field Inspection Energy Checklist. A new form, ENV-5C, will be used

EXCEPTION to 5.203.1:

2. **Buildings that have PV or SWH systems installed may count the area the installed system occupies towards the Solar Zone requirement.**

5.203.2 Designed PV or SWH Interconnection.

Buildings must design for the interconnection of a PV system or a solar water heating system, as specified by (1) and (2) below:

3. **PV System Interconnection Design. The building electrical drawings must indicate the plan for connecting the PV system of the specified capacity to building's electrical system. The interconnection must be designed such that the sum of the supply feeders from inverter(s) serving the busbar is no more than 20 percent of the busbar rating and wiring follows the shortest feasible pathway between the Solar Zone to the inverter location and from the inverter location the dedicated electrical interconnection point. D Drawings must clearly label the:**
   a. **Solar Zone**
   b. **location for inverters and metering equipment**
   c. **electrical interconnection**
   d. **pathway for wiring**
4. **SWH System Interconnection Design. The building plumbing drawings must indicate the plan for connecting the SWH system of the specified capacity to building's plumbing system. The interconnection must be designed such that piping follows the shortest feasible pathway between the Solar Zone and the plumbing interconnection point. Drawings must clearly label the:**
   a. **Solar Zone**
   b. **location for hot water storage tanks**
   c. **plumbing interconnection**
   d. **pathway for piping**

to ensure the area of the Solar Zone has been calculated correctly and to ensure the interconnection plan and the Solar Zone have been designed according to code.