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BUILDING ENERGY EFFICIENCY MEASURE PROPOSAL TO THE

CALIFORNIA ENERGY COMMISSION

FOR THE 2019 UPDATE TO THE

TITLE 24 PART 6 BUILDING ENERGY EFFICIENCY STANDARDS

ROOFTOP SOLAR PV SYSTEM

Measure Number: 2019-RES-PV-D

On-Site Generation

Prepared by: Energy and Environmental Economics, Inc. September 2017

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Document Information

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EXECUTIVE SUMMARY

Introduction

This proposal presents recommendations to support the California Energy Commission's (Energy Commission) efforts to update the Title 24 Standards to include or upgrade requirements for various technologies in California's Building Energy Efficiency Standards. Energy and Environmental Economics, Inc. (E3) sponsored this effort. The goal of this proposal is to create a new measure that will result in cost-effective enhancements to energy efficiency in buildings. This report and the code change proposal presented herein is a part of the Energy Commission effort to develop technical and cost-effectiveness information for proposed regulations on building energy efficient design practices and technologies.

Scope of Code Change Proposal

Rooftop PV will affect the following code documents listed in Table 1.

Table 1: Scope of Code Change Proposal

Measure Name	Type of Requirement	Modified Section(s) of Title 24, Part 6	Modified Title 24, Part 6 Appendices	Would Compliance Software Be Modified	Modified Compliance Document(s)
Photo Voltaic Requirements	Prescriptive	150.1(c)14	Create new RA11 and RA12 Appendices	Yes. Currently available CBECC-Res research software has been modified to model PV requirements	New compliance documents would need to be created to document compliance with the PV requirements

Measure Description

This measure adds a prescriptive requirement for the installation of solar PV systems to all new residential buildings.

The adoption of this measure would culminate the long-standing goal of California energy policy that new residential construction would meet a zero net energy (ZNE) standard by 2020 (CPUC 2008, 2011).

Market Analysis and Regulatory Impact Assessment

The market for distributed solar is strong in California thanks to robust growth in residential rooftop solar installations in recent years. This growth has in large part been induced through favorable compensation structures such as net energy metering (NEM) and incentives such as the California Solar Initiative (CSI) and the federal investment tax credit (ITC). These compensation structures and incentives have driven growth that has reduced costs, which in-turn has driven more growth. We expect the adoption of this measure to continue to drive solar installations in this developed market.

This analysis finds solar PV to be cost-effective, suggesting that owners of new homes would benefit from additional disposable income over the lifetime of their PV systems. Some of this increased disposable income would be invested and circulated within the California economy. However, the cost to ratepayers of the state's net energy metering policy may outweigh this increased investment.

Energy Commission Statewide Energy Impacts

Table 2 shows the estimated energy savings over the first twelve months of implementation of the on-site solar measure.

Table 2: Statewide Estimated First Year Energy Savings

	First Year Statewide Savings			First Year Statewide TDV Savings	
	Electricity Savings (GWh)	Power Demand Reduction (MW)	Natural Gas Savings (MMtherms)	TDV Electricity Savings (Million kBTU)	TDV Natural Gas Savings (Million kBTU)
TOTAL	323	5.31	0	416	0

Section 4 and Section 5 discuss these results in more detail.

Cost-effectiveness

Results of the Cost-effectiveness Analyses for the base case home are presented in Table 3. The TDV Energy Costs Savings are the present-value energy cost savings over the 30-year period of analysis using Energy Commission's TDV methodology. The Total Incremental Cost represents the incremental initial construction and maintenance costs of the proposed solar measure relative to existing conditions (current minimally compliant construction practice under existing Title 24 Standards). Costs incurred in the future (such as periodic maintenance costs or replacement costs) are discounted by a 3 percent real discount rate, per Energy Commission's LCC Methodology. The Benefit to Cost (B/C) Ratio is the incremental TDV Energy Costs Savings divided by the Total Incremental Costs. When the B/C ratio is greater than 1.0, the added cost of the measure is more than offset by the discounted energy cost savings and the measure is deemed to be cost effective. For a detailed description of the Cost-effectiveness Methodology see Section 5 of this report.

Based on these results, we find that the proposed solar measure is cost effective in every climate zone under the base case assumptions. This is shown by a B/C ratio that is greater than 1.0. This means that the code change will result in cost savings relative to the existing conditions in every climate zone.

Table 3: Cost-effectiveness Summary

Climate Zone	Benefits TDV Energy Cost Savings + Other PV Savings[1] (2020 PV $)	Costs Total Incremental Present Valued (PV) Costs[2] (2020 PV $)	Benefit to Cost (B/C) Ratio
1	$17,639	$10,269	1.7
2	$17,992	$8,854	2.0
3	$17,168	$8,511	2.0
4	$17,911	$8,553	2.1
5	$17,132	$7,933	2.2
6	$17,186	$8,615	2.0
7	$16,984	$8,125	2.1
8	$18,442	$9,027	2.0
9	$19,280	$9,309	2.1
10	$19,152	$9,621	2.0
11	$24,824	$11,701	2.1
12	$19,954	$9,563	2.1
13	$24,602	$12,390	2.0
14	$23,744	$10,342	2.3
15	$36,528	$17,730	2.1
16	$18,144	$8,667	2.1

Section 5 discusses the Cost Effectiveness Analysis in more detail.

Greenhouse Gas and Water Related Impacts

For more a detailed and extensive analysis of the possible environmental impacts from the implementation of the proposed measure, please refer to Section 6 of this report.

Greenhouse Gas Impacts

Table 4 presents the estimated avoided greenhouse gas (GHG) emissions of the proposed code change for the first year the standards are in effect. Assumptions used in developing the GHG savings are provided in Section 6 of this report.

Table 4: Estimated Statewide Greenhouse Gas Emissions Impacts

Climate Zone	Electricity Savings (GWH/yr)	Reduced GHG Emissions from Electricity Savings (MT CO_2e)	Natural Gas Savings (Million Therm/yr)	Reduced GHG Emissions from Natural Gas Savings (MT CO_2e)	Total Reduced CO2e Emissions[2] (MT CO_2e)
1	1.65	582	0	0	582
2	6.78	2,393	0	0	2,393
3	16.45	5,807	0	0	5,807
4	14.56	5,140	0	0	5,140
5	2.89	1,020	0	0	1,020
6	12.08	4,264	0	0	4,264
7	15.00	5,295	0	0	5,295
8	18.36	6,481	0	0	6,481
9	16.23	5,729	0	0	5,729
10	56.82	20,057	0	0	20,057
11	22.05	7,784	0	0	7,784
12	57.87	20,428	0	0	20,428
13	46.80	16,520	0	0	16,520
14	12.26	4,328	0	0	4,328
15	19.65	6,936	0	0	6,936
16	3.86	1,363	0	0	1,363
TOTAL	**323**	114,019	0	0	114,019

Water Use and Water Quality Impacts

The proposed measure is not expected to have any impacts on water use or water quality, excluding impacts that occur at power plants.

1. INTRODUCTION

Energy and Environmental Economics, Inc. (E3) sponsored this effort. This Report and the code change proposal presented herein is a part of the effort to develop technical and cost-effectiveness information for proposed regulations on building energy efficiency design practices and technologies.

The overall goal of this Report is to propose a code change to provide a prescriptive requirement for the installation of solar PV systems to all new residential buildings. The report contains pertinent information that justifies the code change.

Section 2 of this Report provides a description of the measure, how the measure came about, and how the measure helps achieve the state's zero net energy (ZNE) goals. This section presents how the proposed code change would be enforced and the expected compliance rates.

Section 3 presents the market analysis, including a review of the current market structure, a discussion of product availability, and the useful life and persistence of the proposed measure. This section offers an overview of how the proposed standard will impact various stakeholders including builders, building designers, building occupants, equipment retailers (including manufacturers and distributors), energy consultants, and building inspectors. Finally, this section presents estimates of how the proposed change will impact statewide employment.

Section 4 describes the key assumptions, methodology, and approach used to estimate energy and demand savings, as well as the associated costs and environmental impacts of those savings. The results of the analyses can be also found in Section 4.

Methodologies and results from the lifecycle Cost-effectiveness analyses are presented in Section 5. E3 calculated energy, demand, and environmental impacts using three metrics: (1) per unit (Section 5), (2) statewide impacts during the first year that buildings complying with the 2016 Title 24 Standards are in operation (Section 6), and (3) the cumulative statewide impacts for all buildings built during the 30-year period of analysis (Section 6). Time Dependent Valuation (TDV) energy impacts, which account for the higher value of peak savings, are presented per unit, first year statewide, and cumulative statewide. The incremental costs relative to existing conditions are presented, as are present value of TDV energy cost savings and the overall cost impacts over the year period of analysis.

The report concludes in Section 7 with specific recommendations for language for the Standards, Appendices, Alternate Calculation Manual (ACM) Reference Manual, and Compliance Forms.

2. MEASURE DESCRIPTION

2.1 Measure Overview

E3 proposes the installation of solar PV systems on all new residential buildings. The proposed change will impact the prescriptive requirements. The code change is creating a new section of code: see Section 7 for further details.

2.2 Measure History

As part of California's ambitious greenhouse gas reduction targets, the California Public Utilities Commission (CPUC), the California Energy Commission (CEC), and the major California utilities have collaboratively endorsed the goal that all new residential construction will be zero net energy (ZNE) by 2020 (CPUC 2008, 2011). A ZNE home is generally one that produces as much energy as it consumes. In the 2013 CEC Integrated Energy Policy Report (IEPR) a specific definition of Time Dependent Valuation (TDV) was adopted as the metric to measure energy (Energy Commission 2013).

For individual homes to achieve ZNE, they must include a source of renewable power generation. Solar PV is currently the only broadly economical renewable generation option for individual homes and is therefore proposed here as a prescriptive compliance approach.

This measure has not been included in previous Title 24 rulemakings, and there are no preemption concerns.

2.3 Summary of Proposed Changes to Code Documents

The sections below provide a summary of how each Title 24 documents will be modified by the proposed change. See Section 7 of this report for detailed proposed revisions to code language.

2.3.1 Standards Change Summary

This proposal would modify the following sections of the Building Energy Efficiency standards as shown below. See Section 7.1 Standards of this report for the detailed proposed revisions to the standards language.

Prescriptive PV requirements are new in the 2019 BEES and therefore there are currently no Standards requirements. For the 2019 Standards a new Section 150.1(c)14 will be created that will specify the prescriptive PV requirements. The requirements will be climate zone specific and will include a multiple regression curve fit equation along with the related climate zone and dwelling unit coefficients to calculate the correct prescriptive PV size for each climate zone and conditioned floor area. Prescriptively, a PV system must be sized to net out the annual kWh of the dwelling.

2.3.2 Reference Appendices Change Summary

The proposed code change will not modify the appendices of the Standards.

2.3.3 Alternative Calculation Method (ACM) Reference Manual Change Summary

This proposal would modify the following sections of the Residential Alternative Calculation Method (ACM) Reference Manual as shown below. See Section 7.3 ACM Reference Manual of this report for the detailed proposed revisions to the text of the Alternative Calculation Method (ACM) Reference Manual.

Section 2.2.3 PV System Credit: The proposed standards add a prescriptive requirement for PV. The current language will be deleted and replaced with language describing the prescriptive PV system, as specified in Section 150.1(c)14.

Section 3.3 Energy Design Rating PV System Credit: Delete.

Section 3.4 Net Energy Metering: Update to reflect current NEM requirements and move to Section 2.2.3.

Section 3.5 Battery Storage: Update and move to Section 2.2.3.

2.3.4 Compliance Manual Change Summary

The proposed code change will modify the following section of the Title 24 Compliance Manual:

The existing Chapter 7, the Solar Ready, will be renamed and expanded to describe the new PV prescriptive requirement in the 2019 Standards and how to comply with these requirements in layman language.

2.3.5 Compliance Forms Change Summary

The proposed code change will modify the following compliance forms listed below. Examples of the revised forms are presented in Section 7.5 Compliance Forms.

The inclusion of solar PV system necessitates additions and modifications to the residential compliance forms to capture the new updates and accomplish enforcement and verifications efforts, as described below:

- **CF1R –** The residential CF1R – Certificate of Compliance – will be modified to include the PV prescriptive requirements of the 2019 Standards.
- **CF2R –** A new Residential CF2R – Certificate of Installation – will be created to document installation of the PV system in accordance to the information included in the CF1R.
- **CF3R –** A new Residential CF3R – Certificate of Field Verification – will be created to document third party Home Energy Rating System (HERS) verification of the PV system.

2.4 Regulatory Context

2.4.1 Existing Standards

Residential Solar PV mandates currently exist in four California cities: Lancaster, Sebastopol, Santa Monica, and San Francisco.

The city of Lancaster requires single family residential units built within Lancaster on or after January 1, 2014 to include a solar PV system of a specified capacity (which varies by zone and lot type) (City of Lancaster 2017b). Builders are also allowed to meet this requirement by providing evidence of having purchased solar renewable energy credits from a system located within the city. During a City Council meeting on January 24, 2017, the City further passed a Zero Net Energy Ordinance (City of Lancaster 2017a), which mandates that residential buildings constructed in 2017 or later include a solar system with a capacity of 2 watts per square foot. Homeowners will receive a zero-balance energy bill in return. Alternatively, builders can comply by paying $1.40 per square foot, in which case the homeowner will received a 50% discount on the energy component (but not the transmission and delivery component) of their electric bill for twenty years. A third compliance option is also available: builders can install a 2 kW system for homes that are 1,000 square feet or less. If a house is larger than 1,000 square feet, the builder pays $1.40 per square foot for the remaining square footage. In this case, the homeowner again receives the 50% energy bill discount.

The City of Sebastopol adopted a similar requirement in 2013, which stated that "All new residential and commercial buildings, and residential additions, remodels, and alterations that exceed seventy five percent of the structure will be required to install a solar photovoltaic system at the time of construction. The Council may establish an in lieu fee for projects that cannot achieve full compliance" (DSIRE 2016).

In late May 2016, Santa Monica also began requiring rooftop solar to be installed on all new residential and commercial buildings: 1.5 watts per square foot for single-family homes, and 2 watts per square foot for multi-family dwellings, hotels, and motels (City of Santa Monica 2017).

Finally, a San Francisco law that took effect in January 2017 mandates that all new residential or commercial buildings up to 10 stories tall use either solar panels for electricity or a solar system to heat water (City of San Francisco 2016).

2.4.2 Relationship to Other Title 24 Requirements

Parts 2, 2.5, and 9 of Title 24 include fire code provisions for the installation of rooftop solar photovoltaic systems. These regulations cover required testing, marking, location of components, and access and pathways restrictions. The access and pathway requirements limit the total area available for solar arrays on any roof face. Therefore, care must be taken during design to ensure there is adequate roof space for PV in all proposed orientations.

Part 3 of Title 24 includes provisions for electrical safety of photovoltaic systems. These regulations cover circuit requirements, disconnection means, wiring methods, grounding, marking, and storage batteries.

2.4.3 Relationship to Federal Laws

There are no federal regulatory requirements that address the same topic as this proposed change.

2.4.4 Relationship to Industry Standards

There are no industry standards that address the same topic as this proposed change.

2.5 Compliance and Enforcement

This code change proposal is mandatory and will affect all residential new construction buildings, regardless of the compliance approach applied (prescriptive or performance). The key steps and changes to the compliance process are summarized below:

- **Design Phase**: Architects and designers will need to ensure that roof designs can accommodate the required solar PV system for all proposed plan orientations. This includes incorporating sufficient area after taking into account fire code offsets and minimizing the impacts of shading. They will also need to plan for locating other system components such as the inverter and electrical disconnects. Minimum PV sizing by code will rely on results from the energy consultant's Title 24 compliance calculations. The energy consultant may need to complete their analysis early in the design process to provide PV capacity estimates to the design team. Architects and designers may need to engage PV contractors early in the design process to determine the amount of roof area is required in each orientation based on the minimum PV size required by the compliance calculations.
- **Permit Application Phase**: Generally, the changes to the existing permit application phase process are minimal. During this phase, the plans examiner reviews the permit application document package and verifies that the specifications called out in the Title-24, Part 6 report match the building plans. The plans examiner will now have to verify that the proposed solar PV systems meets the required capacity per the report. The project applicant will need to provide the PV design drawings at the time of permit submittal in order for the plans examiner to verify that the proposed PV systems meet code requirements.
- **Construction Phase**: The solar PV system meeting the minimum PV capacity requirements will be installed during the construction phase by the solar contractor. This will be coordinated by the builder and can be typically completed within the existing construction timeframe.
- **Inspection Phase**: A HERS rater will verify the PV system installation meets the design criteria following a protocol similar to what is currently required for the New Solar Homes Partnership (Energy Commission 2017b) program and the 2016 PV compliance credit. The building inspector will conduct final field inspections and verify that the solar PV installation meets all code requirements before issuing a certificate of occupancy.

While this process will be new for builders who have not incorporated solar PV in the past, it will be familiar for those builders who do already install PV on their buildings. The procedures are well-defined through the NSHP program. Some additional inspection and design time during the design and inspection phases is required, but PV installers in the state are very experienced with the procedures and can provide guidance to first-time PV builders. There are many HERS raters throughout the state who are qualified to conduct PV verifications for the NSHP program. New challenges will be in coordination with the design team to ensure that the buildings have adequate roof area to install PV and early coordination with energy consultants and PV contractors to coordinate the incorporation of PV in the building design and identify required roof area.

3. MARKET ANALYSIS

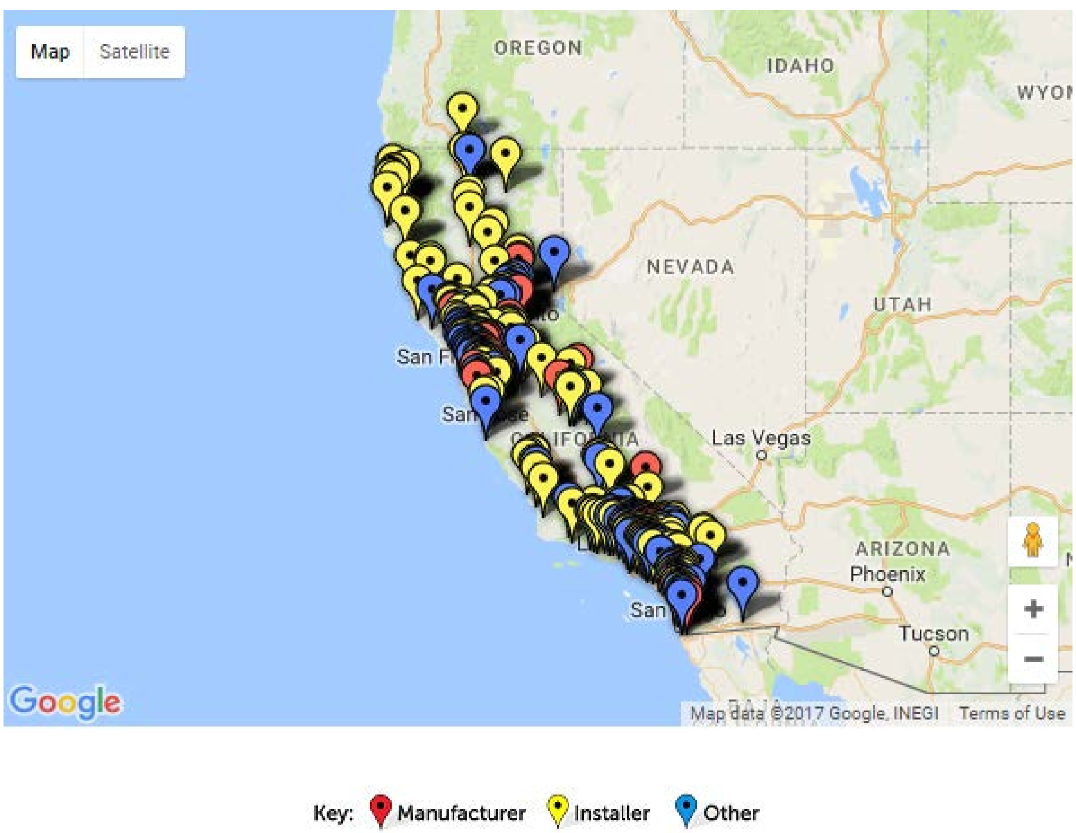
The authors performed a market analysis with the goals of identifying current technology availability, current product availability, and market trends. The authors considered how the proposed standard may impact the market in general and individual market players. The authors gathered information about the incremental cost of complying with the proposed measure.

3.1 Market Structure

The number of suppliers of rooftop PV in California has increased significantly in recent years. According to the Solar Energy Industries Association (SEIA), there are currently more than 2,387 solar companies in California providing goods and services throughout the solar value chain: 392 manufacturers, 85 manufacturing facilities, 1043 contractor/installers, 148 project developers, 149 distributors and 655 working on other solar activities including financing, engineering, and legal support (SEIA 2017). These companies are geographically spread throughout California. See Figure 1.

Figure 1. Companies in the Solar Value Chain Currently Operating in California

Source: SEIA 2017



In addition to California manufacturers, there are a large number of PV wafer, cell, and module manufacturers headquartered and manufacturing in other countries. Table 5 provides the top ten manufacturers in 2015 (the latest year for which this data is available), measured by total shipments of solar PV wafers, cells, and modules.

Table 5: Ranking of Top 10 Solar PV Manufacturers

Source: Power-technology.com 2016

Ranking (highest total 2015 shipments listed first)	Company Name	Solar PV Wafer, Cell, and Module Shipments, 2015
1	Trina Solar	5.74 GW
2	Canadian Solar	4.7 GW
3	JinkoSolar	4.51 GW
4	JA Solar	3.93 GW
5	Hanwha Q CELLS	3.3 GW
6	First Solar	2.8 GW
7	ReneSola	2.69 GW
8	Yingli Solar	2.35 – 2.4 GW
9	SFCE	2.28 GW
10	Risen Energy	1.24 GW

The proposed measure, if adopted, would result in the addition of approximately 200 MW of distributed solar PV per year in California, which would not substantially impact the global supply chain as shown above.

3.2 Technical Feasibility, Market Availability and Current Practices

As described above, California has a robust solar industry. This applies to the larger commercial, industrial, and utility sectors as well as the smaller residential sector on which this proposal focuses. The U.S. Energy Information Administration (EIA) estimates that California had over 5.7 GW (summer capacity) of small scale solar PV installed as of May 2017 (EIA 2017). This accounts for about 40 percent of such capacity for the country. About 1.2 GW of these California small scale PV systems were installed in the previous year, well above the estimated 200 MW annual installations associated with the proposed measure. California's firmly established and growing solar industry in conjunction with the certainty and preparation time inherent to this proposal secure the feasibility of this proposal.

3.3 Market Impacts and Economic Assessments

3.3.1 Impact on Builders

The builder would be responsible for understanding the code requirements for solar PV, ensuring that all subcontractors are aware of the requirements, and ultimately ensuring that all requirements are implemented per the design intent. Additional time may be required during construction, but based on experience from the NSHP program, installation of PV does not have a significant impact on project schedule.

Incorporating PV into buildings will impact builders new to the process. It is also a much more visible feature on the home compared to most efficiency measures. Builders will need to determine how best to market this to their buyers. However, studies have shown that solar homes sell for a higher price (Adomatis & Hoen 2015) and sell more quickly than homes without PV (Dakin, Springer & Kelly 2008). In addition, many of the major solar contractors offer sales and marketing support to builders.

Builders will also have to coordinate with other trades who will make roof penetrations (plumber, HVAC) to ensure there are no penetrations that affect installation or shading of PV. Production home builders, with limited plans built in multiple orientations will also need to coordinate with the installers to ensure that the right amount of PV capacity is installed on the correct roof locations.

3.3.2 Impact on Building Designers and Energy Consultants

Architects and designers are responsible for developing building details and specifications. They will need to ensure that roof designs can accommodate the required solar PV system for all proposed plan orientations. This includes incorporating sufficient area after taking into account fire code offsets and minimizing the impacts of shading. They will also need to plan for locating other system components such as the inverter and electrical disconnects. The design team will need to coordinate with the energy consultant to determine the minimum PV size required for code. Architects and designers may also need to engage PV contractors/ consultants early in the design process to determine the required amount of roof area in each orientation based on the minimum PV size required in compliance calculations. Designers will need to work with PV consultant to provide the PV design drawings at the time of permit submittal in order for the plans examiner to verify that the proposed PV systems meet code requirements. Designs using the multiple orientation analysis for compliance may require additional design drawings for permits to document location of PV with various roof layouts and orientations.

Energy consultants will continue to serve as the primary resource for designers and builders for Title 24, Part 6 compliance information. They will need to work with the design team to provide the PV capacity required for compliance. Sizing will rely on results from the energy compliance analysis. This may require earlier engagement of the energy consultant in the design process to provide input to the building design.

3.3.3 Impact on Occupational Safety and Health

The proposed code change does not alter any existing federal, state, or local regulations pertaining to safety and health, including rules enforced by the California Department of Occupational Safety and Health (Cal/OSHA). All existing health and safety rules will remain in place. Complying with the proposed code change is not anticipated to have any impact on the safety or health of occupants or those involved with the construction, commissioning, and ongoing maintenance of the building.

3.3.4 Impact on Building Owners and Occupants (including homeowners and potential first-time homeowners)

Occupants will benefit from lower cost utility bills. They will receive a net energy metering (NEM) bill from the utility and need to be aware of how this impacts their bill and when they must make payments to the utility. In the case of leased PV systems, the occupant may also be responsible for a lease payment to the solar provider.

Building owners will need to ensure that proper maintenance of the PV solar system is conducted. Maintenance tasks are minimal and primarily involve regular cleaning of the panels. With leased systems, maintenance may be covered by the solar provider in the lease agreement.

With rental units, there may be challenges with split incentives between the building owner and the renter. The building owner invests in the PV solar system, but the renter sees the reduced utility bills. Low-income housing that is applying for tax credits through the California Tax Credit Allocation Committee (CTCAC) can use the California Utility Allowance Calculator (CUAC) to justify higher rents based on investment in efficiency and onsite generation.

3.3.5 Impact on Building Component Retailers (including manufacturers and distributors)

3.3.6 Impact on Building Inspectors

The building inspector will need to verify that the solar PV installation meets all code requirements before issuing a certificate of occupancy on all projects. Inspectors in jurisdictions where builders are constructing homes with solar systems will already be familiar with these inspections.

3.3.7 Impact on Statewide Employment

See Section 3.4.1 Creation or Elimination of Jobs

3.4 Economic Impacts

The estimated impacts that the proposed code change will have on California's economy are discussed below.

3.4.1 Creation or Elimination of Jobs

E3 undertook a literature review of macroeconomic impact studies that quantify the overall employment impacts of increased rooftop solar PV in the United States. Economic impact analysis studies can be classified into two groups: gross economic impact studies and net economic impact studies. Gross economic impact studies only consider the positive (stimulus) effects of a given project or policy on the economy. Results from these studies represent the upper bound of estimated economic impacts. In contrast, net economic impact studies also consider negative (contractionary) effects from a given project or policy. For example, a gross economic impact study assessing the construction of a new rooftop solar PV installation would measure only positive changes in employment during the construction and maintenance phases of the project. A net economic impact study would also include potential contractionary impacts such as: (1) the displacement of fossil fuel or utility-scale renewable energy, which decreases jobs and economic activity in existing energy generation industries; and (2) increases in average retail electricity rates that increase production costs and reduce household income, and, depending on price and substitution elasticities, potentially lead to decreases in total employment and income.

For rooftop PV, only gross economic impact studies were available. The most commonly cited of these is the Jobs and Economic Development (JEDI) Model developed by the National Renewable Energy Laboratory (NREL 2015). JEDI uses outputs from IMPLAN, a national input-output model, to develop economic multipliers for renewable technologies installed across various regions of the United States. Figure 2 shows the assumptions that E3 used to run the JEDI model for this CASE study. Yellow cells are changed from NREL's default assumptions. The system size for each building is just enough to offset each building's load, which is the maximum size that is eligible to receive NEM compensation. Average system size is a weighted average of these individual systems, weighted by a) 2,100 and 2,700 square foot prototype homes (45% 2,100 sf and 55% 2,700 sf homes, which is consistent with CEC CASE protocol from the previous code cycle), and b) projected 2020 housing starts in each climate zone (see Table 21 for this data). Base installed cost is the Current Incremental Construction Cost outlined in Section 5.3, and Annual Direct Operations and Maintenance cost is an annual average of the maintenance costs also outlined in that Section.

Figure 2: JEDI PV Model Inputs

Project Location [?]	California
Year of Construction or Installation [?]	2020
System Application	Residential New Construction
Solar Cell/Module Material	Crystalline Silicon
System Tracking	Fixed Mount
Average System Size - DC Nameplate Capacity (KW) [?]	3.0
Number of Systems Installed	74,153.0
Total Project Size - DC Nameplate Capacity (KW) [?]	218,751.4
Base Installed System Cost ($/KWDC) [?]	3,170.0
Annual Direct Operations and Maintenance Cost ($/kW) [?]	14.86
Money Value - Current or Constant (Dollar Year) [?]	2020

Figure 3 displays the resulting employment estimates. Jobs presented are full-time equivalent (FTE), or 2,080 hours per year, and 'Local' in this instance refers to the state of California.

Figure 3: JEDI PV Model Employment Outputs

Source: NREL 2017

Local Economic Impacts - Summary Results	
During construction and installation period	Jobs
Project Development and Onsite Labor Impacts [?]	
Construction and Installation Labor	1,058.4
Construction and Installation Related Services [?]	1,154.1
Subtotal	2,212.5
Module and Supply Chain Impacts [?]	
Manufacturing Impacts	0.0
Trade (Wholesale and Retail)	477.4
Finance, Insurance and Real Estate	0.0
Professional Services	172.6
Other Services	441.6
Other Sectors	866.7
Subtotal	1,958.2
Induced Impacts [?]	1,253.0
Total Impacts	**5,423.7**
During operating years	Annual Jobs
Onsite Labor Impacts [?]	
PV Project Labor Only [?]	27.4
Local Revenue and Supply Chain Impacts [?]	7.8
Induced Impacts [?]	6.1
Total Impacts	**41.4**

Note:

- Induced impacts refers to “the changes that occur in household spending as household income increases or decreases as a result of the direct and indirect effects from final demand (i.e., purchases of goods and services) changes.”
- PV Project Labor includes “all spending on operations, maintenance, and other required services.”
- Local Revenue and Supply Chain Impacts includes “property and sales tax … as well as any return on investment paid to local investors; Supply chain includes all purchases of materials and components, and all off-site labor for the PV project.”

This JEDI estimate is useful in considering the potential upside employment benefits of mandating rooftop solar PV. However, recall that JEDI is a gross economic impact model; it only models positive, linear relationships between the demand for rooftop PV installations and macroeconomic impacts, and it fails to take into account how rooftop PV may change electricity rates and displace other forms of energy. This inherently leads to model results that show gross positive impacts from spending on renewables.

Unfortunately, no *net* economic impact studies could be found for rooftop solar PV. However, two studies examine the net macroeconomic impacts of technologies under renewable portfolio standards (including utility-scale solar generation plus other generating sources) and one with the impact of solar PV alone (utility-scale and behind-the-meter generation).

Both of the studies that estimated the net macroeconomic impacts of Renewable Portfolio Standards (RPS) found small, negative net employment impacts. Tuerck, Bachman and Head (2013) found a net jobs reduction of 590 to 3,070 jobs due to the Nevada RPS policy. A 2010 California Air Resources Board (CARB 2010b) study found very slight reductions in employment (-0.08%), income (-0.16% to -0.17%), and gross state product (-0.17% to -0.18%) due to California's RPS. CARB found that employment increases in industries that support renewable electricity generation, but retail rate increases cause employment to decrease in other industries, resulting in a net reduction in employment. We note that these impacts are small given the size of the California labor force and economy.

Finally, one net impacts study analyzed the impacts of solar PV (both utility-scale and behind-the-meter). The New York State Energy Research and Development Authority (NYSERDA 2012) studied the net economic impacts of installing 5,000 MW of solar PV by 2025 using Regional Economic Models (REMI). The authors calculated net employment impacts ranging from a loss of 2,500 jobs economy-wide to a gain of 750 jobs over the lifetime of the 5,000 MW of PV installed, depending on the PV cost trajectory and ITC assumption applied.

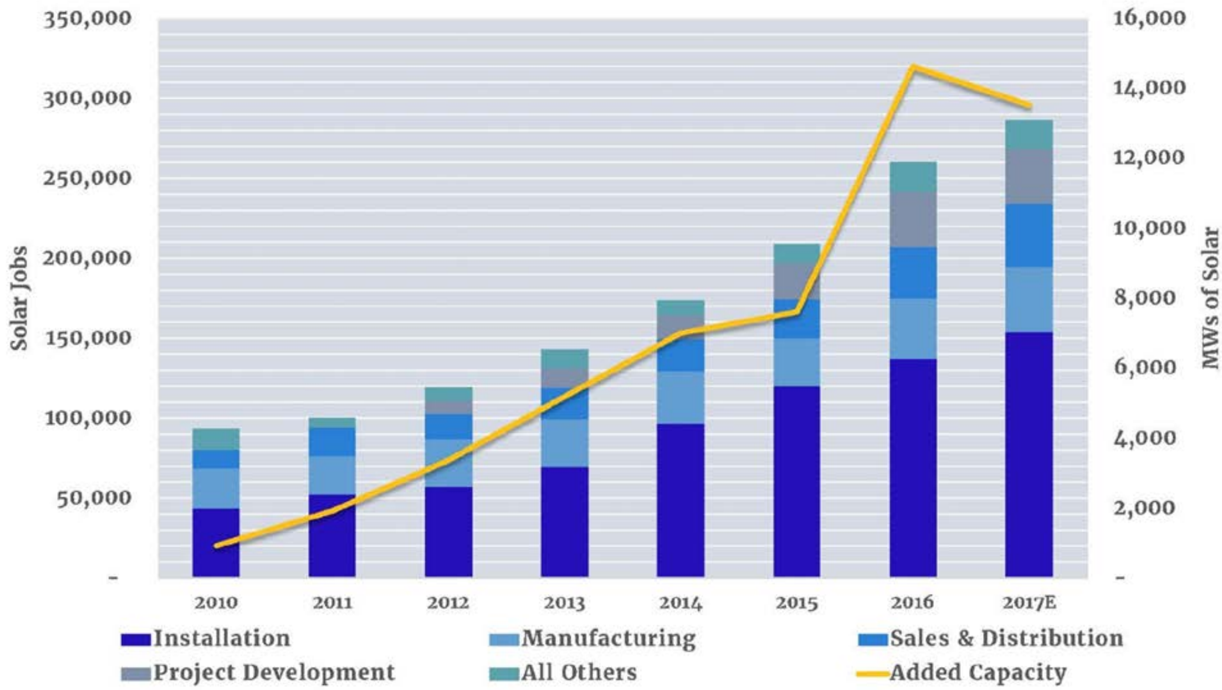
The conclusion to be drawn on the employment benefits of this proposed code change are thus:

1) The addition of rooftop solar to new residences will increase solar industry jobs, by creating direct construction, installation and maintenance jobs, as well as module and supply chain employment and employment in non-solar sectors.
2) Macroeconomic employment impacts, which account for potential rate increases and displacement of jobs in other electricity generation segments, are unclear. They may be positive or negative.

Another way to evaluate how the solar job growth described in 1) above will impact particular business sectors and geographic areas is to observe the employment breakdown in recent years as California's solar capacity has increased. Figure 4 was produced by the Solar Foundation (2017), and shows growth in solar jobs and solar capacity since 2010. A solar job is defined as one in which a worker spends at least 50% of their time on solar-related work.

Figure 4: U.S. Solar Capacity Additions and Solar Jobs, 2010 – 2017

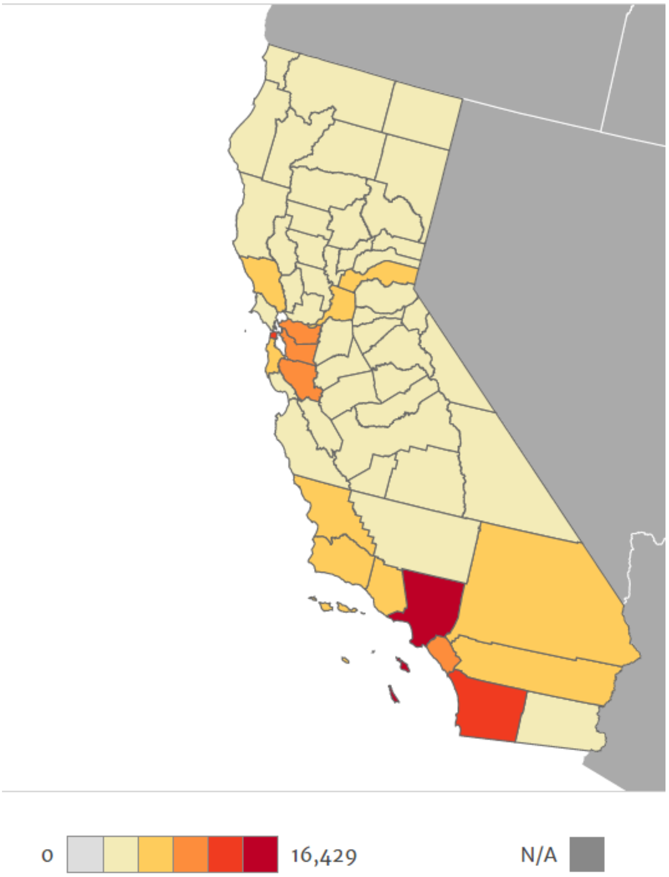
Source: Solar Foundation, 2017



The Solar Foundation estimates that 53% of the 100,050 solar industry jobs that existed in California as of November 2016 were in installation, 15% in manufacturing, 14% in sales and distribution, 11% in project development, and 7% in other solar functions. Significantly, this employment is spread throughout the state. Figure 5 shows California solar jobs by county.

Figure 5: Solar Jobs Added, by County, as of November, 2016

Source: Solar Foundation, 2017



3.4.2 Creation or Elimination of Businesses within California

As described in Sections 3.1 and 3.4.1, recent increases in solar PV installations have been accompanied by the emergence of a significant number of Californian jobs and businesses throughout the solar value chain. Solar businesses can be expected to expand and new businesses open, as solar installations increase under the proposed Standard. Since the majority of solar jobs in California are for on-site installation, which requires labor local to each PV site, at least some of these business additions can be expected to be geographically spread across the state.

Existing businesses that may be eliminated as a result of the proposed Standard are those that currently provide electricity generation for homes that will be *replaced* by new construction with solar PV after the Standard goes into effect. Note that homes built to house new California residents represent new energy demand, and therefore will not displace, to a significant degree, existing electricity generation or cause elimination of any existing businesses. Since the state's investor-owned utilities' revenues are decoupled from volumetric energy sales, the financial impact on these companies is expected to be minimal.

3.4.3 Competitive Advantages or Disadvantages for Businesses within California

The analysis in Section 5 demonstrates that rooftop solar PV sized to the total kWh consumed by each household annually is cost effective over a 30-year horizon. That is, the proposed Standard is not expected to cause financial harm to the owners of new residential homes over the long run. However, the costs and benefits for rooftop PV are such that the costs accrue upfront to the purchaser of the home, while the benefits flow back to the tenant over time. The increase in *upfront* cost caused by PV – an average of $9,365 per household using average system size and Current Incremental Construction Cost[1] per household in our modeling – could have an adverse impact on homebuyers by pushing homes out of their available borrowing range. For example, a potential buyer who is able to purchase a $300,000 home with a $30,000 deposit and a $270,000 loan, would now see that home increase in price by $9,365 due to the addition of solar PV. Though the PV will pay for itself over time through reductions in electricity bills, under the proposed Standard, this homebuyer would be precluded from purchasing this home due to a shortage in upfront capital.

This tradeoff between upfront cost and long-term savings could cause concern for housing developers and real estate agents selling new homes. Those purchasing investment properties (who are paying the upfront cost of the solar PV) may reduce their willingness to pay for new homes slightly if they are unable to fully price the benefit of reduced electric bills from solar PV into the rent they demand. If rental markets are efficient, then this should not be a concern. Investors may therefore increase their preference for homes built prior to the proposed Measure, rather than new homes built with mandatory PV. This would impact the competitiveness of developers and agents selling new homes after the Measure is in place.

The decrease in upfront affordability could have slight impacts on the willingness of investors to purchase new homes in California, versus purchasing them in other states where the upfront costs do not include the price of solar PV. However, we note that the increase in the cost of a home from solar PV is small compared to the cost price differential between California homes and homes in other states,[2] and there are many factors beyond absolute upfront housing price that go into choosing locations for housing investment. This reduction in competitiveness for new California homes is also true for owner-occupied homes, but only to the extent that those buying homes consider multiple states in their housing search.

3.4.4 Increase or Decrease of Investments in the State of California

Without further detailed analysis, it is not possible to form conclusions about the proposed Standard's overall impact on investment in California. To the extent that new homes represent new energy demand, they will create new investment in electricity generation. However, this new electricity generation could come from a number of sources. If the added generation for

[1] Average system size is a weighted average of these individual systems, weighted by a) 2,100 and 2,700 square foot prototype homes (45% 2100 sf and 55% 2700 sf homes, which is consistent with CEC CASE protocol from the previous code cycle), and b) projected 2020 housing starts in each climate zone (see Table 20 for this data). See Section 5.3 for additional detail on cost data.

[2] See, for example, "How Expensive is Your State?", based on data from Zillow.com. https://www.discover.com/home-loans/blog/how-expensive-is-your-state.

new homes is expected (but for the proposed Standard) to originate from out-of-state sources, then the proposed Measure would move this generation onto California roofs, increasing investment in California. If, on the other hand, new generation is expected to be built in-state, then the proposed Standard would offset California investments in generating resources and may not increase overall in-state investment. The cost impacts of rooftop PV must also be accounted for: the analysis presented in this CASE study finds solar PV to be cost-effective, suggesting that owners of new homes would benefit from additional disposable income over the lifetime of their PV systems. Some of this increased disposable income would be invested and circulated within the California economy. However, the cost to other ratepayers of the state's net energy metering policy may outweigh this increased investment.

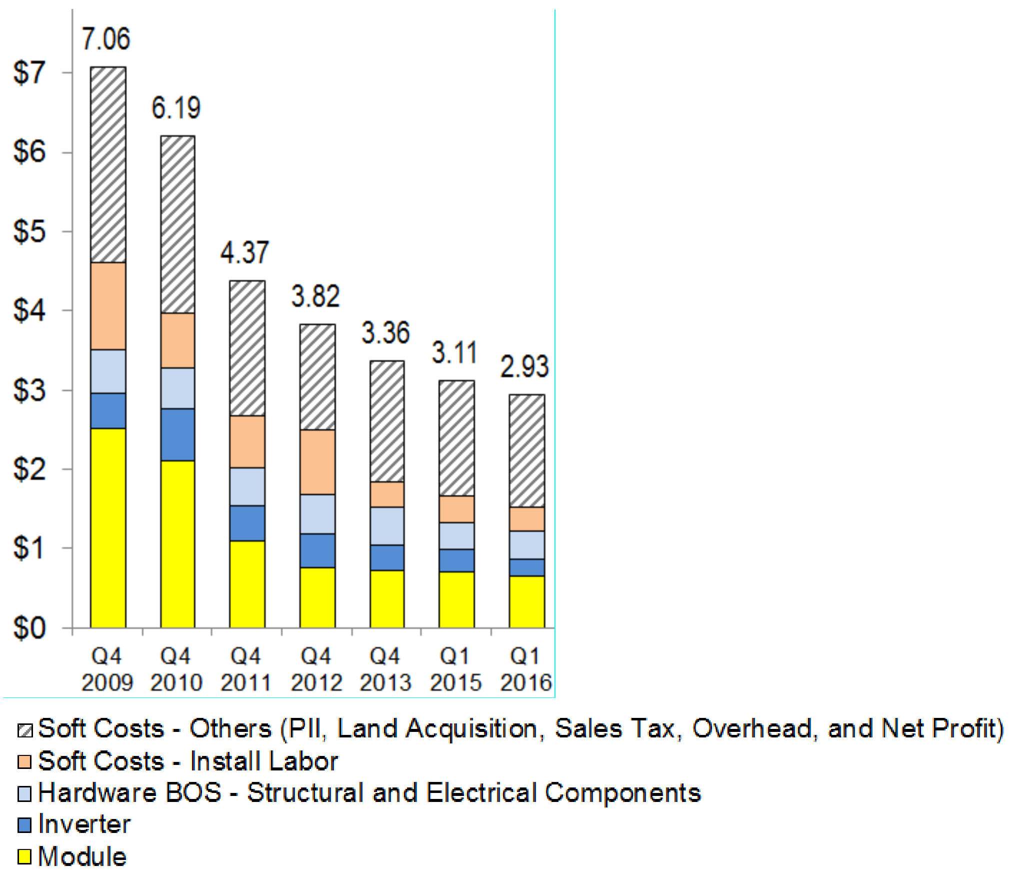
Further study is required to examine the combined impacts of these investments impacts.

3.4.5 Effects on Innovation in Products, Materials, or Processes

The cost of rooftop solar PV systems has declined significantly in recent years, led by reductions in module costs. Figure 6 shows NREL's modeled costs for a 5.6kW residential PV system, for the 2009 – 2016 period.

Figure 6: NREL Residential PV System Cost Benchmark, 5.6kW System. Costs per Watt DC, 2016 USD.

Source: NREL 2016



In thinking about potential innovation and price reductions attributable to the proposed Standard, it is useful to observe differences between 'hard' costs of PV installation (module, inverter, and hardware balance of system) and the ‘soft’ costs (installation labor, permitting, inspection, interconnection, taxes, overhead, and profit). Hard costs involve hardware produced and traded on a global market (recall from Table 5 that the majority of the largest cell, wafer, and module manufacturers are not in the United States). Though increased demand for PV is thought to assist in reducing the costs of these components,[3] the small scale of the PV capacity that would result from the proposed Standard when compared with annual shipments (recall Table 5) means the potential impact on hardware innovation is likely to be small.[4]

Localized learning can, however, be beneficial in stimulating innovation and cost reductions for soft costs. As a result of the sharp falls in hard costs in recent years, soft costs now account for approximately two-thirds of system cost. A recent study by Bollinger and Gillingham (2014) is the first to estimate localized appropriable and non-appropriable learning-by-doing in rooftop solar PV installations. The authors hypothesize the following:

> Learning can be expected to lower non-hardware costs for solar PV installations at a regional or localized level by improving labor productivity. Employees can increase the speed of installation with different types of roof layouts, discover ways to modify the hardware to facilitate installation, refine the site-visit software, and improve the processing of permits. Spillovers may occur through pathways such as hiring employees of other firms, watching competitor strategies, increased efficiency of permitting by building permit offices, and more widespread adoption of best practices as are publicized by industry organizations. Of course, labor markets may adjust in response to some of these pathways based on labor productivity, but if there are sticky wages and sufficiently high unemployment, as was the case in much of our empirical setting, LBD may still bring down labor costs.

The authors test this hypothesis with a dataset of prices and hardware costs for the 138,599 residential PV installations receiving California Solar Initiative incentives through the end of 2012. They find “clear evidence of economically-significant appropriable and non-appropriable learning in the non-hardware costs of solar PV installations,” as demonstrated:

> Learning by contractors within a county can reduce non-hardware costs by $0.036/W with the addition of 100 installations. Outside of the county the same 100 installations can reduce non-hardware costs by $0.021/W. But even more interesting than internal learning, is the evidence of external learning or learning spillovers. We find that 1,000 installations by competitors outside of the county reduces non-hardware costs by $0.005/W.

Since these values are from 2012 and are based on a marginal installation of 100 – 1,000 PV systems, it is not possible to extrapolate with any confidence to the 74,154 new starts projected in California in 2020. Still, the results suggest that the proposed Standard is likely to produce learning-by-doing reductions in soft costs across the state.

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[3] See, for example, International Roadmap for Photovoltaics (2017). This analysis was produced with 31 different solar PV cell and module manufacturers, and finds a learning rate of 22.5% using PV module shipment and sales price data from 1976 to 2016. That is, for every doubling of cumulative module shipments, the average selling price per module falls by 22.5%.

[4] See Hughes and Podolefsky (2015) for further discussion.

3.4.6 Effects on the State General Fund, State Special Funds and Local Governments

3.5.6.1 Cost of Enforcement

Cost to the State

State government already has budget for code development, education, and compliance enforcement. While state government will be allocating resources to update the Title 24, Part 6 Standards, including updating education and compliance materials and responding to questions about the revised requirements, these activities are already covered by existing state budgets. The costs to state government are small when compared to the overall costs savings and policy benefits associated with the code change proposals. The proposed residential changes will not impact state buildings.

Cost to Local Governments

All revisions to Title 24, Part 6 will result in changes to compliance determinations. Local governments will need to train building department staff on the revised Title 24, Part 6 Standards. While this re-training is an expense to local governments, it is not a new cost associated with the 2019 code change cycle. The building code is updated on a triennial basis, and local governments plan and budget for retraining every time the code is updated. There are numerous resources available to local governments to support compliance training that can help mitigate the cost of retraining, including tools, training and resources provided by the Investor Owned Utility codes and standards program.

3.5.6.2 Impacts on Specific Persons

The proposed changes to Title 24, Part 6 are not expected to have a differential impact on any groups relative to the state population as a whole, including migrant workers, commuters or persons by age, race or religion. Given construction costs are not well correlated with home prices, the proposed code changes are not expected to have an impact on financing costs for business or home-buyers. Some financial institutions have progressive policies that recognize the financial implications associated with occupants of energy efficient homes saving on energy bills and therefore have more discretionary income.[5]

Renters will typically benefit from lower energy bills if they pay energy bills directly. These savings should more than offset any capital costs passed-through from landlords. Renters who do not pay directly for energy costs may see some of the net savings depending on if and how landlords account for energy cost when determining rent prices.

On average, low-income families spend less on energy than higher income families, however lower income families spend a much larger portion of their incomes on energy (National Energy Assistance Directors' Association 2011). Thus, low-income families are likely to disproportionately benefit from Title 24, Part 6 Standards that reduce residential energy costs.

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[5] For example, see US EPA's ENERGY STAR website for examples: http://www.energystar.gov/index.cfm?fuseaction=new_homes_partners.showStateResults&s_code=CA.

4. ENERGY SAVINGS

4.1 Key Assumptions for Energy Savings Analysis

This study assumes 2,100 and 2,700 sf homes as modeled in CBECC-Res using 2016 prescriptive requirements that vary by climate zone with the following additions which are intended to represent likely changes that will be included in the 2019 standards:

- High performance attic (certain climates): R19 below deck
- High performance walls (certain climates): 0.043 U-factor wall
- QII (Quality Insulation Inspection)
- High performance windows: U-factor 0.30, SHGC 0.23 for cooling climates and 0.50 for mild climates
- Doors: U-factor 0.20
- 2016 ASHRAE 62.2 ventilation rates
- Improved fan efficacy: 0.40 W/cfm

Using these homes as a starting point, the analysis adds on-site solar as modeled in the CBECC-Res software with the following characteristics:

- 180° south facing orientation
- 5/12 pitch roof
- 96% inverter efficiency
- Standard module type
- No shading

4.2 Energy Savings Methodology

To assess the energy, demand, and energy cost impacts, E3 compared current design practices to design practices that would comply with the proposed requirements. There are no existing Title 24 requirements that cover the proposed on-site solar system in question. E3 used current design practices as the existing conditions. For details on the building home assumptions, see Section 4.1.

The proposed conditions are defined as the design conditions that will comply with the proposed code change. Specifically, the proposed code change will add on-site solar such that the solar panels, over the course of a year, produce the same quantity of electricity (measured in kWh) as the home consumes in electricity (measured in kWh) without solar. To achieve this, a different size solar system (measured in kW) was added to each home in the 16 different climate zones, as shown in Table 6.

Table 6: PV System Capacities Sized to Offset Annual Energy Consumption of Prototypes

Climate Zone	2100 sf Home Installed PV Size (kW-dc)	2700 sf Home Installed PV Size (kW-dc)
1	2.89	3.33
2	2.46	2.87
3	2.38	2.76
4	2.36	2.77
5	2.22	2.57
6	2.38	2.79
7	2.26	2.64
8	2.46	2.93
9	2.51	3.02
10	2.58	3.12
11	3.10	3.80
12	2.58	3.10
13	3.28	4.02
14	2.73	3.35
15	4.83	5.75
16	2.37	2.81

Table 7 presents the details of the prototype residential homes used in the analysis.

Table 7: Prototype Buildings used for Energy, Demand, Cost, and Environmental Impacts Analysis

Prototype ID	Occupancy Type (Residential, Retail, Office, etc.)	Area (Square Feet)	Number of Stories	First Year Statewide Area (million square feet)
2100 sf Prototype	Residential	2,100	1	70.1
2700 sf Prototype	Residential	2,700	2	110.1

The impacts of the proposed solar measure are climate zone specific because 1) the electric loads that the solar system is sized to vary by climate zone and 2) the solar insolation is climate zone specific. As a result, the energy impacts and cost-effectiveness were evaluated by climate zone. Energy savings, energy cost savings, and peak demand savings were calculated using a Time Dependent Valuation (TDV) methodology.

4.3 Per Unit Energy Impacts and Energy Cost Savings Results

Energy savings, peak demand savings, and per unit energy and demand impacts of the proposed measure are presented in Table 8, Table 9, and Table 10 for the 2100 sf, 2700 sf, and weighted average prototypes for each climate zone.

Electricity savings are characterized by the annual kWh generated by the home's PV system. This electricity is equal to the home's electric load for a year. Because the system's generation does not perfectly coincide with the home's consumption, generation is exported to the grid in some hours and consumed from the grid in others. The electricity savings in each hour are multiplied by the TDV for that hour to produce the TDV energy savings.

Peak electricity demand for each climate zone and prototype is calculated by the dot product of the 8,760 hourly PV generation profile and the normalized generation capacity portion of the TDV profiles. Natural gas consumption is not impacted by the installation of solar PV systems.

Table 8: First Year Energy Impacts per Prototype 2100 sf Home

Climate Zone	Electricity Savings (kWh/yr)	Peak Electricity Demand Savings (kW)	Natural Gas Savings (Therms/yr)	TDV Energy Savings (TDVkBTU/yr)[6]
1	3,899	0.13	0	4,512
2	3,870	0.09	0	4,544
3	3,779	0.09	0	4,358
4	3,829	0.09	0	4,499
5	3,758	0.06	0	4,349
6	3,792	0.06	0	4,321
7	3,736	0.04	0	4,293
8	3,926	0.04	0	4,573
9	4,126	0.06	0	4,732
10	4,232	0.04	0	4,671
11	4,946	0.11	0	5,981
12	4,054	0.09	0	4,893
13	5,079	0.09	0	5,925
14	4,925	0.05	0	5,709
15	8,111	0.08	0	9,047
16	4,034	0.09	0	4,506

[6] NEM 2.0 rate structure

Table 9: First Year Energy Impacts per 2700 sf Prototype

Climate Zone	Electricity Savings (kWh/yr)	Peak Electricity Demand Savings (kW)	Natural Gas Savings (Therms/yr)	TDV Energy Savings (TDVkBTU/yr)
1	4,490	0.15	0	5,196
2	4,516	0.11	0	5,300
3	4,386	0.11	0	5,057
4	4,492	0.10	0	5,276
5	4,361	0.08	0	5,047
6	4,445	0.07	0	5,062
7	4,354	0.05	0	5,003
8	4,666	0.05	0	5,432
9	4,955	0.07	0	5,679
10	5,115	0.05	0	5,641
11	6,053	0.13	0	7,312
12	4,874	0.11	0	5,878
13	6,220	0.11	0	7,247
14	6,042	0.07	0	6,994
15	9,652	0.09	0	10,760
16	4,789	0.10	0	5,345

Table 10: First Year Energy Impacts per Weighted Average Prototype

Climate Zone	Electricity Savings (kWh/yr)	Peak Electricity Demand Savings (kW)	Natural Gas Savings (Therms/yr)	TDV Energy Savings (TDVkBTU/yr)
1	4,224	0.14	0	4,888
2	4,225	0.10	0	4,960
3	4,113	0.10	0	4,742
4	4,194	0.10	0	4,926
5	4,090	0.07	0	4,733
6	4,151	0.07	0	4,729
7	4,076	0.05	0	4,684
8	4,333	0.05	0	5,045
9	4,582	0.07	0	5,253
10	4,718	0.05	0	5,205
11	5,555	0.12	0	6,713
12	4,505	0.10	0	5,435
13	5,707	0.10	0	6,652
14	5,539	0.06	0	6,416
15	8,959	0.09	0	9,989
16	4,449	0.10	0	4,967

5. LIFE CYCLE COST AND COST-EFFECTIVENESS

5.1 Energy Cost Savings Methodology

Time Dependent Value (TDV) energy is a normalized format for comparing electricity and natural gas savings that takes into account the cost of electricity and natural gas consumed during each hour of the year. The TDV values are based on long term discounted costs (30 years for all residential measures and nonresidential envelope measures and 15 years for all other nonresidential measures). In this case, the period of analysis used is 30 years. The TDV cost impacts are presented in 2020 present valued dollars. The TDV energy estimates are based on present-valued cost savings but are normalized in terms of "TDVkBTUs". Peak demand savings are presented in peak power reductions (kW). Energy Commission derived the 2019 TDV values that were used in the analyses for this report (Energy Commission 2016).

This study investigated the cost-effectiveness of a 180° south-facing solar PV system for mixed-fuel (natural gas and electricity) home prototypes across California's 16 climate zones. Two sizes of prototypes were analyzed: 2100 and 2700-square feet (sf). For some results, a weighted average of these prototypes was created to reflect the distribution of square footage for making statewide estimates. The proportion used in weighting was 45% 2100 sf and 55% 2700 sf, which is consistent with CEC CASE protocol from the previous code cycle.

The energy consumption of the prototypes were simulated in CBECC, and standard 1 kW-dc PV generation profiles were modeled by NREL's PVWatts for each hour in a year. For each prototype and climate zone, the capacity of the PV system was adjusted such that the annual electricity generated by the system equaled the prototype's simulated electricity consumption over the year. This capacity was calculated by dividing the sum of the prototype's electricity consumption by the sum of the hourly 1 kW PV system's generation profile. The resulting capacity is just enough to offset the building's load over the course of one year, which is the maximum size that is eligible to participate in the net energy metering (NEM) tariff.

Cost savings come from the rooftop PV system's generation output. The NEM Successor Tariff (NEM 2.0) was the assumed compensation structure for the rooftop PV system. TDV was well-suited to proxy PV compensation, since NEM 2.0 requires the customer to be on a time-of-use (TOU) rate. PV generation falls into two buckets: behind-the-meter (BTM) and exports. BTM generation directly serves the building's electric load, thus replacing the electricity that otherwise would have been consumed from the grid. Export generation occurs when a building's load is completely met, so additional generation is exported to the grid. NEM 2.0 ensures that non-bypassable charges (NBCs) are charged for each kWh consumed from the grid. TDV values include these NBCs, and because BTM generation directly offsets grid consumption, BTM is compensated with the full TDV value. Meanwhile, export PV generation does not replace grid consumption, so it is compensated with TDV less the 30-year present value of the NBCs (for consistency with TDV, which is 30-year present value).

Because NEM 2.0 may be further revised to reduce compensation for rooftop solar, two alternative rate structure sensitivities were tested for their impact on cost-effectiveness. TDV values represent the sum of avoided costs of energy, losses, ancillary services, generation capacity, transmission and distribution capacity, emissions, and renewable portfolio standard compliance. As the last step in calculating TDV, a flat retail adjustment is added to the avoided costs, such that the average TDV value averages to the actual utility retail rate. Both rate structure sensitivities use the TDV values without the retail adjustment (i.e. the avoided cost components of TDV) for valuing rooftop PV generation. The *Avoided Cost for Exports* sensitivity compensates BTM generation at the full TDV value but compensates exported generation at avoided cost. The *Avoided Cost for All* sensitivity compensates both BTM and exported generation at avoided cost.

It is worth noting that the addition of an energy storage system to a solar system has the ability to store excess solar PV production that would have otherwise been exported to the grid and use it to offset a customer's own electricity load. Under the *NEM 2.0* and *Avoided Cost for Exports* rate structures, this increases the financial value of solar. However, these additional benefits come at the expense of the storage system itself, resulting in undetermined cost-effectiveness. Because storage is not being considered as a prescriptive requirement for ZNE compliance in the 2019 standards, this report focuses only on the costs and benefits of stand-alone solar PV.

Table 11: Rate Structure Sensitivities Definition and Sample Average Values for CZ12

Rate Structure Sensitivity	Value Stream		Average (2020 30-yr Present Value $/kWh)	
	BTM	Export	BTM	Export
NEM 2.0	TDV	TDV minus NBC	$4.80	$4.21
Avoided Cost for Exports	TDV	Avoided Cost	$4.80	$2.26
Avoided Cost for All	Avoided Cost	Avoided Cost	$2.26	$2.26

5.2 Energy Cost Savings Results

Table 12: TDV Electricity Cost Savings Over 30-Year Period of Analysis – Per 2100 sf, 2700 sf, and Weighted Average Prototypes

	30-Year TDV Electricity Cost Savings (2020 PV $)		
Climate Zone	2100 sf Prototype	2700 sf Prototype	Weighted Average Prototype
1	$15,318	$17,639	$16,595
2	$15,425	$17,992	$16,837
3	$14,796	$17,168	$16,101
4	$15,274	$17,911	$16,724
5	$14,763	$17,132	$16,066
6	$14,667	$17,186	$16,053
7	$14,575	$16,984	$15,900
8	$15,524	$18,442	$17,129
9	$16,065	$19,280	$17,833
10	$15,858	$19,152	$17,669
11	$20,304	$24,824	$22,790
12	$16,612	$19,954	$18,450
13	$20,113	$24,602	$22,582
14	$19,380	$23,744	$21,780
15	$30,713	$36,528	$33,911
16	$15,296	$18,144	$16,862

Table 13: TDV Generation Capacity Cost Savings Over 30-Year Period of Analysis – Per 2100 sf, 2700 sf, and Weighted Average Prototypes

	30-Year TDV Generation Capacity Cost Savings (2020 PV $)		
Climate Zone	2100 sf Prototype	2700 sf Prototype	Weighted Average Prototype
1	$222	$256	$240
2	$155	$181	$169
3	$152	$177	$166
4	$144	$169	$158
5	$109	$126	$118
6	$91	$107	$100
7	$65	$76	$71
8	$71	$84	$78
9	$91	$110	$101
10	$72	$87	$80
11	$183	$224	$206
12	$149	$179	$165
13	$153	$187	$172
14	$90	$110	$101
15	$123	$147	$136
16	$143	$170	$158

5.3 Incremental First Cost

E3 estimated the Current Incremental Construction Costs and Post-adoption Incremental Construction Costs. The Current Incremental Construction Cost represents the incremental cost of the measure if a building meeting the proposed standard were built today. The Post-adoption Incremental Construction Cost represents the anticipated cost assuming full market penetration of the measure as a result of the new Standards, resulting in possible reduction in unit costs as manufacturing practices improve over time and with increased production volume of qualifying products the year the Standard becomes effective.

Per Energy Commission's guidance, design costs are not included in the incremental first cost.

The Current Incremental Construction Cost is assumed to be $2.93 per Watt DC, in 2016 dollars. This represents NREL's estimate of the Q1, 2016 cost of a 5.6-kW residential PV system installed in California if a household uses a PV installer (who does not provide financing).[7] This cost includes: PV module, inverter, structural balance of system, electrical

[7] This is in contrast to a PV integrator, who would also provide financing. NREL (2016) estimates solar costs as approximately 8% higher when using an integrator rather than an installer.

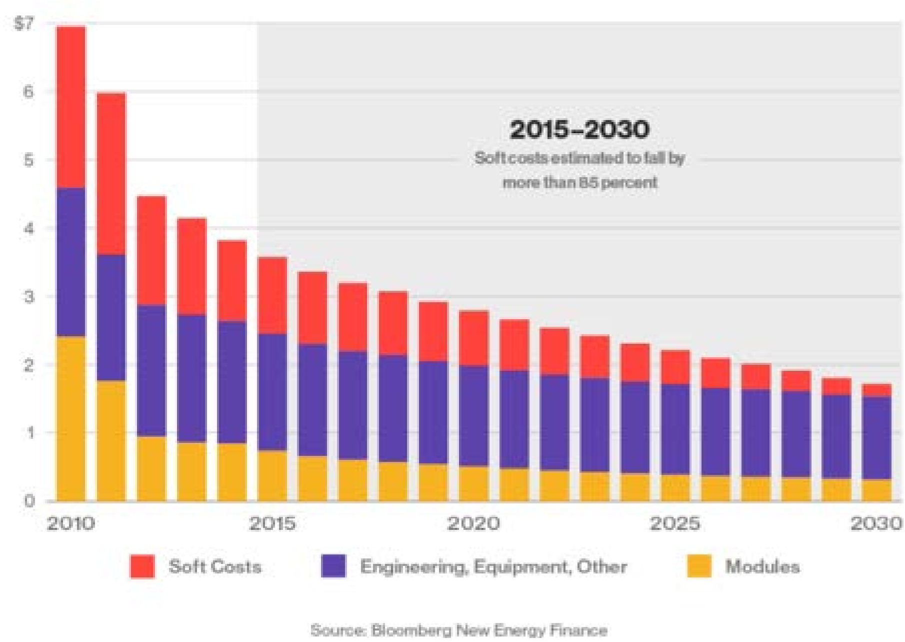
balance of system, supply chain costs, sales tax, install labor, permitting, inspection, interconnection, customer acquisition, general and administrative overhead, and net profit to the installer. E3 took NREL's weighted average system cost for California (where the weights are integrator and installer market shares) of $3.04 per watt DC and used NREL's assumption of 50% integrators and 50% installers in the market to back out an installer cost of $3.15 and an integrator cost of $2.93 per watt DC.

Applying a 2% annual inflation rate, this $2.93 per watt DC in 2016 dollars corresponds to $3.17 per Watt DC in 2020 dollars. The 2% inflation rate assumption is taken from the Energy Commission's 2019 TDV Methodology Report (Energy Commission 2017).

To calculate a Post-adoption Incremental Construction Cost, E3 began with the $2.93 NREL value and applied a cost reduction forecast for 2016 – 2020. The cost reduction applied was 17% over the four-year period, taken from a February 2015 residential PV cost forecast from Bloomberg New Energy Finance Report (Bloomberg 2015). Bloomberg forecasts that 'soft costs' like financing, professional services, and permitting will continue to decline during the 2016 – 2020 period, though at a slower rate than the declines seen in 2010 – 2015. Bloomberg also forecasts slight reductions in module costs over the 2016 – 2020 period. See Figure 7.

Figure 7: Bloomberg New Energy Finance Forecast, Price per Watt for a New Solar System in USD (Average for all 50 States)

Source: Bloomberg, 2015



Applying the 17% cost reduction to the $2.93 per Watt DC value and assuming a 2% inflation rate leads to a Post-adoption Incremental Construction Cost of $2.63 per watt DC in 2020 dollars.

Note that for both the Current and Post-adoption Incremental Construction Costs, E3 assumes no Investment Tax Credit (ITC) benefits flow to households. The residential ITC will step down from 30% to 26% beginning in 2020, and will expire at the beginning of 2022. This conservative assumption is designed to ensure cost-effectiveness results described in Section 5.5 are not reliant on federal ITC policy.

Table 14 summarizes the two cost cases.

Table 14: Current and Post-adoption Incremental Construction Cost Assumptions

Cost Assumption	$2020 per Watt DC
Current Incremental Construction Cost	$3.17
Post-adoption Incremental Construction Cost	$2.63

5.4 Lifetime Incremental Maintenance Costs

Incremental maintenance cost is the incremental cost of replacing the equipment or parts of the equipment, as well as periodic maintenance required to keep the equipment operating relative to current practices over the period of analysis. The present value of equipment and maintenance costs (savings) was calculated using a three percent discount rate (d), which is consistent with the discount rate used when developing the 2019 TDV. The present value of maintenance costs that occurs in the nth year is calculated as follows (where d is the discount rate of 3 percent):

$$\text{Present Value of Maintenance Cost} = \text{Maintenance Cost} \times \left\lfloor \frac{1}{1+\mathrm{d}} \right\rfloor^{\mathrm{n}}$$

The expected useful life of a rooftop PV system was assumed to be thirty years. This was the assumed lifetime in the two sources that E3 used for PV cost: NREL 2016 and SolarCity 2016.

Maintenance costs were taken from SolarCity (2016), and include:

a) operations and maintenance, assumed to be $0.02 / watt / year (nominal)
b) inverter replacement, assumed to occur at year 11 at a cost of $0.15 / watt (nominal), and again at year 21 at a cost of $0.12 / watt (nominal).

These maintenance costs were held constant across each of the two cost cases described in Section 5.3.

Combining the incremental first cost with the lifetime incremental maintenance costs yields a present value of $3.08/W[8] ($2020)

5.5 Lifecycle Cost-Effectiveness

This measure proposes a prescriptive requirement. As such, a lifecycle cost analysis is required to demonstrate that the measure is cost effective over the 30-year period of analysis.

[8] $3.08/W = $2.63/W incremental first cost + $0.32/W present value operations and maintenance [PV(5.06%, 30 yrs, $0.02/W)] + $0.14/W inverter replacement [$0.15/W/(1 + 5.06%)^10 + $0.12/W/(1 + 5.06%)^20]

Energy Commission's procedures for calculating lifecycle cost-effectiveness are documented in LCC Methodology (CEC 2011). E3 followed these guidelines when developing the cost-effectiveness analysis for this measure. Energy Commission's guidance dictated which costs were included in the analysis. Incremental first cost and incremental maintenance costs over the 30-year period of analysis were included. The TDV energy cost savings from electricity savings were also considered.

Design costs were not included nor was the incremental cost of code compliance verification.

According to Energy Commission's definitions, a measure is cost effective if the Benefit-to-Cost (B/C) Ratio is greater than 1.0. The B/C Ratio is calculated by dividing the total present lifecycle cost benefits by the present value of the total incremental costs.

As shown in Table 15, Table 16, and Table 17, rooftop PV saves money over the 30-year period of analysis for the 2100 sf, 2700 sf, and weighted average prototypes. Under the simulated base conditions, i.e., a mixed-fuel home with NEM 2.0 rate structure and a south-facing PV system sized to offset electricity consumption with Post-adoption Incremental Construction Costs, the proposed code change is cost effective in every climate zone. The following tables use these base conditions.

Table 15: Life Cycle Cost-effectiveness Summary Per 2100 sf Prototype – Mixed Fuel Home, NEM 2.0, 180° Orientation, Post-adoption Incremental Construction Cost

Climate Zone	Benefits TDV Energy Cost Savings + Other PV Savings[1] (2020 PV $)	Costs Total Incremental Present Valued (PV) Costs[2] (2020 PV $)	Benefit-to-Cost Ratio
1	$15,318	$8,918	1.7
2	$15,425	$7,588	2.0
3	$14,796	$7,334	2.0
4	$15,274	$7,290	2.1
5	$14,763	$6,836	2.2
6	$14,667	$7,350	2.0
7	$14,575	$6,971	2.1
8	$15,524	$7,596	2.0
9	$16,065	$7,751	2.1
10	$15,858	$7,959	2.0
11	$20,304	$9,561	2.1
12	$16,612	$7,953	2.1
13	$20,113	$10,119	2.0
14	$19,380	$8,429	2.3
15	$30,713	$14,899	2.1
16	$15,296	$7,301	2.1

1. **Other PV Savings:** Includes incremental first cost savings if proposed first cost is less than current first cost. Includes present value maintenance cost savings if PV of proposed maintenance costs is less than the PV of current maintenance costs.
2. **Total Incremental Present Valued Costs:** Includes incremental first cost if proposed first cost is greater than current first cost. Includes present value of maintenance incremental cost if PV of proposed maintenance costs is greater than the PV of current maintenance costs. If there are no Total Incremental Present Valued Costs, the Benefit/Cost Ratio is Infinite.

Table 16: Life Cycle Cost-effectiveness Summary Per 2700 sf Prototype – Mixed Fuel Home, NEM 2.0, 180° Orientation, Post-adoption Incremental Construction Cost

Climate Zone	Benefits TDV Energy Cost Savings + Other PV Savings[1] (2020 PV $)	Costs Total Incremental Present Valued (PV) Costs[2] (2020 PV $)	Benefit-to-Cost Ratio
1	$17,639	$10,269	1.7
2	$17,992	$8,854	2.0
3	$17,168	$8,511	2.0
4	$17,911	$8,553	2.1
5	$17,132	$7,933	2.2
6	$17,186	$8,615	2.0
7	$16,984	$8,125	2.1
8	$18,442	$9,027	2.0
9	$19,280	$9,309	2.1
10	$19,152	$9,621	2.0
11	$24,824	$11,701	2.1
12	$19,954	$9,563	2.1
13	$24,602	$12,390	2.0
14	$23,744	$10,342	2.3
15	$36,528	$17,730	2.1
16	$18,144	$8,667	2.1

3. **Other PV Savings:** Includes incremental first cost savings if proposed first cost is less than current first cost. Includes present value maintenance cost savings if PV of proposed maintenance costs is less than the PV of current maintenance costs.
4. **Total Incremental Present Valued Costs:** Includes incremental first cost if proposed first cost is greater than current first cost. Includes present value of maintenance incremental cost if PV of proposed maintenance costs is greater than the PV of current maintenance costs. If there are no Total Incremental Present Valued Costs, the Benefit/Cost Ratio is Infinite.

Table 17: Life Cycle Cost-effectiveness Summary Per Weighted Average Prototype – Mixed Fuel Home, NEM 2.0, 180° Orientation, Post-adoption Incremental Construction Cost

Climate Zone	Benefits TDV Energy Cost Savings + Other PV Savings[1] (2020 PV $)	Costs Total Incremental Present Valued (PV) Costs[2] (2020 PV $)	Benefit-to-Cost Ratio
1	$16,595	$9,661	1.7
2	$16,837	$8,285	2.0
3	$16,101	$7,981	2.0
4	$16,724	$7,985	2.1
5	$16,066	$7,439	2.2
6	$16,053	$8,046	2.0
7	$15,900	$7,606	2.1
8	$17,129	$8,383	2.0
9	$17,833	$8,608	2.1
10	$17,669	$8,873	2.0
11	$22,790	$10,738	2.1
12	$18,450	$8,838	2.1
13	$22,582	$11,368	2.0
14	$21,780	$9,481	2.3
15	$33,911	$16,456	2.1
16	$16,862	$8,052	2.1

1. **Other PV Savings:** Includes incremental first cost savings if proposed first cost is less than current first cost. Includes present value maintenance cost savings if PV of proposed maintenance costs is less than the PV of current maintenance costs.
2. **Total Incremental Present Valued Costs:** Includes incremental first cost if proposed first cost is greater than current first cost. Includes present value of maintenance incremental cost if PV of proposed maintenance costs is greater than the PV of current maintenance costs. If there are no Total Incremental Present Valued Costs, the Benefit/Cost Ratio is Infinite.

In order to test the dependence of these cost-effectiveness results on the base case assumptions, a number of sensitivities were performed. Sensitivity results are displayed for the 2700 sf prototype, as results for the 2100 sf and weighted average prototypes showed similar trends. While the cost forecasts of rooftop PV considered for this study project a cost decline, the analysis was also performed with the Current Incremental Construction Cost of $3.17 per Watt DC in 2020 dollars. Comparing Table 18 with Table 16 reveals that even though this sensitivity's cost increase reduces the B/C ratio, rooftop PV remains cost-effective in all climate zones.

Table 18: Life Cycle Cost-effectiveness Summary Per 2700 sf Prototype – Mixed Fuel Home, NEM 2.0, 180° Orientation, Current Incremental Construction Cost

Climate Zone	Benefits TDV Energy Cost Savings + Other PV Savings[1] (2020 PV $)	Costs Total Incremental Present Valued (PV) Costs[2] (2020 PV $)	Benefit-to-Cost Ratio
1	$17,639	$12,049	1.5
2	$17,992	$10,389	1.7
3	$17,168	$9,986	1.7
4	$17,911	$10,036	1.8
5	$17,132	$9,308	1.8
6	$17,186	$10,109	1.7
7	$16,984	$9,534	1.8
8	$18,442	$10,592	1.7
9	$19,280	$10,923	1.8
10	$19,152	$11,289	1.7
11	$24,824	$13,729	1.8
12	$19,954	$11,220	1.8
13	$24,602	$14,538	1.7
14	$23,744	$12,135	2.0
15	$36,528	$20,803	1.8
16	$18,144	$10,169	1.8

1. **Other PV Savings:** Includes incremental first cost savings if proposed first cost is less than current first cost. Includes present value maintenance cost savings if PV of proposed maintenance costs is less than the PV of current maintenance costs.
2. **Total Incremental Present Valued Costs:** Includes incremental first cost if proposed first cost is greater than current first cost. Includes present value of maintenance incremental cost if PV of proposed maintenance costs is greater than the PV of current maintenance costs. If there are no Total Incremental Present Valued Costs, the Benefit/Cost Ratio is Infinite.

Table 19 and Table 20 show the impact of potential reforms to NEM rate structure, as described in Section 5.1. These sensitivities represent partial and total reductions in the portion of NEM compensation the exceeds the long-run marginal value of electricity, i.e., avoided cost. The *Avoided Costs for Exports* sensitivity retains NEM 2.0's full retail compensation for BTM generation but reduces compensation for exported generation to avoided cost. Although this decreases the average benefits of rooftop PV by about 31%, the B/C ratio remains above 1.0 for all climate zones. The *Avoided Costs for All* sensitivity reduces rooftop PV compensation further, crediting all electricity with avoided costs. Such a stark reform may not be likely within the timeframe of this code cycle, but this sensitivity serves as a lower bound for potential NEM reforms.

Table 19: Life Cycle Cost-effectiveness Summary Per 2700 sf Prototype – Mixed Fuel Home, Avoided Cost for Exports, 180° Orientation, Post-adoption Incremental Construction Cost

Climate Zone	Benefits TDV Energy Cost Savings + Other PV Savings[1] (2020 PV $)	Costs Total Incremental Present Valued (PV) Costs[2] (2020 PV $)	Benefit-to-Cost Ratio
1	$11,855	$10,269	1.2
2	$12,302	$8,854	1.4
3	$11,548	$8,511	1.4
4	$12,251	$8,553	1.4
5	$11,626	$7,933	1.5
6	$12,122	$8,615	1.4
7	$11,814	$8,125	1.5
8	$13,276	$9,027	1.5
9	$13,789	$9,309	1.5
10	$13,389	$9,621	1.4
11	$16,842	$11,701	1.4
12	$13,786	$9,563	1.4
13	$16,194	$12,390	1.3
14	$16,602	$10,342	1.6
15	$24,371	$17,730	1.4
16	$12,207	$8,667	1.4

1. **Other PV Savings:** Includes incremental first cost savings if proposed first cost is less than current first cost. Includes present value maintenance cost savings if PV of proposed maintenance costs is less than the PV of current maintenance costs.
2. **Total Incremental Present Valued Costs:** Includes incremental first cost if proposed first cost is greater than current first cost. Includes present value of maintenance incremental cost if PV of proposed maintenance costs is greater than the PV of current maintenance costs. If there are no Total Incremental Present Valued Costs, the Benefit/Cost Ratio is Infinite.

Table 20 shows that even with this bookend sensitivity, rooftop PV is cost-effective in five climate zones and narrowly fails the B/C test in several others.

Table 20: Life Cycle Cost-effectiveness Summary Per 2700 sf Prototype – Mixed Fuel Home, Avoided Cost for All, 180° Orientation, Post-adoption Incremental Construction Cost

Climate Zone	Benefits TDV Energy Cost Savings + Other PV Savings[1] (2020 PV $)	Costs Total Incremental Present Valued (PV) Costs[2] (2020 PV $)	Benefit-to-Cost Ratio
1	$7,768	$10,269	0.8
2	$8,245	$8,854	0.9
3	$7,577	$8,511	0.9
4	$8,198	$8,553	1.0
5	$7,588	$7,933	1.0
6	$8,295	$8,615	1.0
7	$7,904	$8,125	1.0
8	$9,365	$9,027	1.0
9	$9,762	$9,309	1.0
10	$9,339	$9,621	1.0
11	$11,930	$11,701	1.0
12	$9,466	$9,563	1.0
13	$11,201	$12,390	0.9
14	$12,077	$10,342	1.2
15	$17,979	$17,730	1.0
16	$7,917	$8,667	0.9

1. **Other PV Savings:** Includes incremental first cost savings if proposed first cost is less than current first cost. Includes present value maintenance cost savings if PV of proposed maintenance costs is less than the PV of current maintenance costs.
2. **Total Incremental Present Valued Costs:** Includes incremental first cost if proposed first cost is greater than current first cost. Includes present value of maintenance incremental cost if PV of proposed maintenance costs is greater than the PV of current maintenance costs. If there are no Total Incremental Present Valued Costs, the Benefit/Cost Ratio is Infinite.

6. FIRST YEAR STATEWIDE IMPACTS

6.1 Statewide Energy Savings and Lifecycle Energy Cost Savings

E3 calculated the first year statewide savings by multiplying the per unit savings, which are presented in Section 4.3 Per Unit Energy Impacts and Energy Cost Savings Results, by the statewide new construction forecast for 2020, which is presented in more detail in Appendix A: Statewide Savings Methodology. The first year energy impacts represent the first year annual savings from all buildings that were completed in 2020. The lifecycle energy cost savings represents the energy cost savings over the entire 30-year period of analysis. Results are presented in Table 21.

Given data regarding the new construction forecast for 2020, E3 estimates that the proposed code change will reduce annual statewide electricity use by 323 GWh in that year, with an associated demand reduction of 5.31 MW. On-site natural gas use is not expected to be reduced. The energy savings for buildings constructed in 2020 are associated with a present valued energy cost savings of approximately $1,411 million in (discounted) energy costs over the 30-year period of analysis. After accounting for the cost of solar PV, *net* cost savings for buildings built in 2020 are $723 million.

Table 21: Statewide Energy and Energy Cost Impacts

Climate Zone	Statewide Construction in 2020 (single-family home starts)	First Year[1] Electricity Savings (GWh)	First Year[1] Peak Electrical Demand Reduction (MW)	First Year[1] Natural Gas Savings (million Therms)	Lifecycle[2] Present Valued Energy Cost Savings (PV$ million)	Lifecycle[3] Present Valued Net Cost Savings (PV$ million)
1	422	1.65	0.05	-	$7.0	$2.9
2	1,751	6.78	0.16	-	$29.5	$15.0
3	4,353	16.45	0.39	-	$70.1	$35.3
4	3,803	14.56	0.34	-	$63.6	$33.2
5	768	2.89	0.05	-	$12.3	$6.6
6	3,185	12.08	0.19	-	$51.1	$25.5
7	4,015	15.00	0.16	-	$63.8	$33.3
8	4,677	18.36	0.19	-	$80.1	$40.9
9	3,934	16.23	0.24	-	$70.2	$36.3
10	13,427	56.82	0.54	-	$237.2	$118.1
11	4,459	22.05	0.49	-	$101.6	$53.7
12	14,276	57.87	1.28	-	$263.4	$137.2
13	9,215	46.80	0.83	-	$208.1	$103.3
14	2,489	12.26	0.12	-	$54.2	$30.6
15	2,423	19.65	0.19	-	$82.2	$42.3
16	957	3.86	0.09	-	$16.1	$8.4
TOTAL	**74,154**	**323**	**5.31**	**-**	**$1,410.6**	**$722.8**

1. First year savings from all buildings completed statewide in 2020.
2. Energy cost savings from all buildings completed statewide in 2020 accrued during 30-year period of analysis.
3. Net Cost Savings are Energy Cost Savings minus Costs.

6.2 Statewide Greenhouse Gas Emissions Reductions

E3 calculated avoided greenhouse gas (GHG) emissions assuming an emission factor of 353 metric tons of carbon dioxide equivalents ($MTCO_2e$) per GWh of electricity savings. The electricity emission factor represents savings from avoided electricity generation and accounts for the GHG impacts if the state meets the Renewable Portfolio Standard (RPS) goal of 33 percent renewable electricity generation by 2020.[9] Avoided GHG emissions from natural gas

9 When evaluating the impact of increasing the Renewable Portfolio Standard (RPS) from 20 percent renewables by 2020 to 33 percent renewables by 2020, California Air Resources Board (CARB) published data on expected air pollution emissions for various future electricity generation scenarios (CARB 2010). The incremental emissions were calculated by dividing the

savings were calculated using an emission factor of 5,303 $MTCO_2e$/million Therms (U.S. EPA 2011).

Table 22 presents the estimated first year avoided GHG emissions of the proposed code change.

Table 22: First Year[1] Statewide Greenhouse Gas Emissions Impacts

Climate Zone	Electricity Savings (GWH/yr)	Reduced GHG Emissions from Electricity Savings (MT CO_2e)	Natural Gas Savings (Million Therm/yr)	Reduced GHG Emissions from Natural Gas Savings (MT CO_2e)	Total Reduced CO2e Emissions[2] (MT CO_2e)
1	1.65	582	0	0	582
2	6.78	2,393	0	0	2,393
3	16.45	5,807	0	0	5,807
4	14.56	5,140	0	0	5,140
5	2.89	1,020	0	0	1,020
6	12.08	4,264	0	0	4,264
7	15.00	5,295	0	0	5,295
8	18.36	6,481	0	0	6,481
9	16.23	5,729	0	0	5,729
10	56.82	20,057	0	0	20,057
11	22.05	7,784	0	0	7,784
12	57.87	20,428	0	0	20,428
13	46.80	16,520	0	0	16,520
14	12.26	4,328	0	0	4,328
15	19.65	6,936	0	0	6,936
16	3.86	1,363	0	0	1,363
TOTAL	**323**	**114,019**	**0**	**0**	**114,019**

1. First year savings from all buildings completed statewide in 2020.
2. Assumes the following emission factors: 353 MTCO2e/GWh and 5,303 MTCO2e/Million Therms.

6.3 Statewide Water Use Impacts

The proposed code change will not result in direct water savings within the scope of this Proposal. Potential water savings may result from the substitution of water-intensive thermal generation with solar PV generation.

difference between California emissions in the CARB high and low generation forecasts by the difference between total electricity generated in those two scenarios.

6.4 Statewide Material Impacts

Impacts on statewide materials are limited. Recent literatures suggests “that while some substances used in manufacturing PV solar cells are considered toxic, they do not pose a risk because they are used in small quantities.” (Environment Canada)

6.5 Other Non-Energy Impacts

Non-energy benefits of the proposed measures for the occupant include increased property valuation and independence from utility rate escalation.

7. Proposed Revisions to Code Language

The proposed changes to the Standards, Reference Appendices, and the ACM Reference Manuals are provided below. Changes to the 2016 documents are marked with underlining (new language) and ~~strikethroughs~~ (deletions).

7.1 Standards

150.1(c)14. PV Requirements. All low-rise residential buildings shall have a PV system meeting the solar access requirements of the solar ready zone specified in Section 110.10, with annual electrical output equal to the dwelling's annual electrical usage, and

A. All single-family and multi-family homes shall have a PV system with annual electrical output equal to the dwelling's annual electrical usage, as determined by Equation 150.1(c)14.1:

Equation 150.1(c)14.1:

$kW_{PV} = (CFA \times A) + B$

Where

kW_{PV} is the kW DC size of the PV system

CFA is the conditioned floor area

A is the are adjustment factor from Table 150.1-2

B is the dwelling adjustment factor from 150.1-2

EXCEPTION 1 to Section 150.1(c)14: Within any available solar ready zone that is restricted to less than 80 contiguous square feet by existing permanent natural or manmade barriers external to the dwelling, including but not limited to trees, hills, and adjacent structures.

EXCEPTION 2 to Section 150.1(c)14: In climate zone 15 the PV size shall be the smaller of a size that can be accommodated by the solar access requirements of the solar ready zone specified in Section 110.10 or a PV size required by Equation 150.1(c)14.1, but no less than 1.5 Watt DC per square foot of conditioned floor area.

EXCEPTION 3 to Section 150.1(c)14: In all climate zones, for single family homes with three or more stories, the PV size shall be the smaller of a size that can be accommodated by the solar access requirements of the solar ready zone specified in Section 110.10 or a PV size required by the Equation 150.1(c)14.1, but no less than 1.0 Watt DC per square foot of conditioned floor area.

EXCEPTION 4 to Section 150.1(c)14: For a dwelling unit plan that is approved by the planning department prior to January 1, 2020 with available solar ready zone between 80 and 200 square feet, the PV size is limited to the lesser of the size that can be accommodated by the solar access requirements of the solar ready zone specified in Section 110.10 or a size that is required by the Standards. If the solar ready zone is less than 80 square feet, no PV system is required

EXCEPTION 5 to Section 150.1(c)14: PV sizes from Section 150.1(c)14 may be reduced by 25% if installed in conjunction with at least an eight kWh battery storage system.

Table 23: CFA and Dwelling adjustment Factors

Climate Zone	CFA	Dwelling Units
1	0.000793063	1.267153141
2	0.000620499	1.217590207
3	0.000628436	1.120351150
4	0.000586081	1.211161300
5	0.000584463	1.057621269
6	0.000594022	1.226256971
7	0.000571663	1.145611739
8	0.000585467	1.365913500
9	0.000612771	1.360441231
10	0.000626954	1.408525846
11	0.000836414	1.439574599
12	0.000612624	1.397880867
13	0.000893548	1.507847895
14	0.000740820	1.259542486
15	0.001559076	1.470769395
16	0.000590309	1.215595108

7.2 Reference Appendices

No Change to Reference Appendices is required.

7.3 ACM Reference Manual

Section 2.2.3 PV System Credit: Modify current language to describe how the proposed and standard design are defined to determine the effects of the proposed PV system. The proposed design language will include the inputs that define the proposed building, PV system, battery storage, and equations that simulate the building and the effects of the proposed PV system. Include any distinctions between single-family and multifamily buildings, and identify how the applicability of any exceptions are determined.

The standard design description will include the prescriptive PV system specified in Section 150.1(c)14 of the Standards, which is the baseline against which the proposed design is measured. The equations used by the software to determine the

Verification and reporting will describe any requirements included in Reference Appendices for verifying the installation of the PV system, and how the system is identified on the CF1R.

Section 3.3 Energy Design Rating PV System Credit: Delete.

Section 3.4 Net Energy Metering: Update as needed to reflect changes to NEM. Identify how NEM limits affect compliance credit, and move to Section 2.2.3.

Section 3.5 Battery Storage: Update and move to Section 2.2.3.

7.4 Compliance Manuals

The existing Chapter 7, the Solar Ready, will be renamed and expanded to describe the new PV prescriptive requirement in the 2019 Standards and how to comply with these requirements in layman language. Detailed language will be developed once the proposed 2019 language is adopted, and its details are known

7.5 Compliance Forms

The inclusion of solar PV system necessitates additions and modifications to the residential compliance forms to capture the new updates and accomplish enforcement and verifications efforts, as described below:

- **CF1R** – The residential CF1R – Certificate of Compliance – will be modified to include the PV prescriptive requirements of the 2019 Standards.
- **CF2R** – A new Residential CF2R – Certificate of Installation – will be created to document installation of the PV system in accordance to the information included in the CF1R.
- **CF3R –** A new Residential CF3R – Certificate of Field Verification – will be created to document third party Home Energy Rating System (HERS) verification of the PV system.

8. REFERENCES

Adomatis, S. & B. Hoen. *Appraising into the Sun: Six-State Solar Home Paired-Sales Analysis*. LBNL-1002778. Berkeley, Calif.: Lawrence Berkeley National Laboratory. https://emp.lbl.gov/sites/default/files/lbnl-1002778.pdf

Bollinger, B. & K. Gillingham. 2014. "Learning-by-Doing in Solar Photovoltaic Installations." http://environment.yale.edu/gillingham/BollingerGillingham_SolarLBD.pdf

[CARB] California Air Resources Board. 2010. "Proposed Regulation for a California Renewable Electricity Standard Staff Report: Initial Statement of Reasons Appendix D." http://www.arb.ca.gov/regact/2010/res2010/res10d.pdf. Accessed November 12, 2013.

[CARB] California Air Resources Board. 2010b. "Updated Economic Analysis of California's Climate Change Scoping Plan: Staff Report to the Air Resources Board." http://www.arb.ca.gov/cc/scopingplan/economics-sp/updated-analysis/updated_sp_analysis.pdf . Accessed April 7, 2017.

[CA DWR] California Department of Water Resources. 2016. "California Counties by Hydrologic Regions". http://www.water.ca.gov/landwateruse/images/maps/California-County.pdf. Accessed April 3, 2016.

[CPUC] California Public Utilities Commissions. 2008. "California Energy Efficiency Strategic Plan." http://www.cpuc.ca.gov/WorkArea/DownloadAsset.aspx?id=5305. Accessed March 25, 2017.

___. 2011. "California Energy Efficiency Strategic Plan January 2011 Update." http://www.energy.ca.gov/ab758/documents/CAEnergyEfficiencyStrategicPlan_Jan2011.pdf

___. 2015a. "Water/Energy Cost-Effectiveness Analysis: Revised Final Report." Prepared by Navigant Consulting, Inc. http://www.cpuc.ca.gov/WorkArea/DownloadAsset.aspx?id=5360.

___. 2015b. "Water/Energy Cost-Effectiveness Analysis: Errata to the Revised Final Report." Prepared by Navigant Consulting, Inc. http://www.cpuc.ca.gov/WorkArea/DownloadAsset.aspx?id=5350

City of Lancaster. 2017a. "City of Lancaster Becomes First City in California to Mandate ZNE Standards for New Builds, Adopts Zero Net Energy Home Ordinance." http://www.cityoflancasterca.org/Home/Components/News/News/7733/20?npage=78. Accessed March 25, 2017.

___. 2017b. "Lancaster Municipal Code Section 17.08.305: Implementation of solar energy systems." https://www.municode.com/library/ca/lancaster/codes/code_of_ordinances?nodeId=TIT17ZO_CH17.08REZO_ARTVSOWIALENUS_17.08.305IMSOENSY. Accessed April 3, 2017.

City of San Francisco. 2016. "Green Building, Environment Codes - Better Roof Requirements for Renewable Energy Facilities."

https://sfgov.legistar.com/View.ashx?M=F&ID=4399794&GUID=FE220DFF-2C3F-4F0B-8C9B-39F1A61039F2. Accessed March 25, 2017.

City of Santa Monica. 2017. "Green Building Overview." https://www.smgov.net/Departments/OSE/Categories/Green_Building/Overview.aspx. Accessed March 25, 2017.

Dakin, W., D. Springer & B. Kelly. 2008. "Case Study: The Effectiveness of Zero Energy Home Strategies in the Marketplace." In *Proceedings from the 2008 ACEEE Summer Study on Energy Efficiency in Buildings*, 6.40-51. Washington, D.C.: American Council for an Energy-Efficient Economy. http://aceee.org/files/proceedings/2008/data/papers/6_616.pdf

[DSIRE] Database of State Incentives for Renewables & Efficiency. 2016. "City of Sebastopol - Mandatory Solar Requirement for Residential and Commercial Buildings." http://programs.dsireusa.org/system/program/detail/5625. Accessed March 25, 2017.

[EIA] U.S. Energy Information Administration. 2017. "Electric Power Monthly with Data for May 2017." https://www.eia.gov/electricity/monthly/current_year/july2017.pdf. Washington, D.C.: U.S. Energy Information Administration.

[Energy Commission] California Energy Commission. 2013. *2013 Integrated Energy Policy Report.* CEC-100-2013-001-CMF. http://www.energy.ca.gov/2013publications/CEC-100-2013-001/CEC-100-2013-001-CMF.pdf . Accessed March 25, 2017.

___. 2017a. "2019 TDV Methodology Report 2-15-17." TN#: 216062. http://docketpublic.energy.ca.gov/PublicDocuments/16-BSTD-06/TN216062_20170216T113300_2019_TDV_Methodology_Report_21517.pdf. Accessed April 5, 2017.

___. 2017b. "Commission Guidebook - Final New Solar Homes Partnership Guidebook, Tenth Edition, Revised Version." TN#: 217634. http://docketpublic.energy.ca.gov/PublicDocuments/16-NSHP-01/TN217634_20170518T080845_Final_NSHP_Guidebook_Tenth_Edition_Revised.pdf . Accessed August 8, 2017.

[Environment Canada] Environment Canada. *Assessment of the Environmental Performance of Solar Photovoltaic Technologies.* 2012

https://www.ec.gc.ca/scitech/B53B14DE-034C-457B-8B2B-39AFCFED04E6/ForContractor_721_Solar_Photovoltaic_Technology_e_09%20FINAL-update%202-s.pdf

Hughes, J.E. & M. Podolefsky. 2015. "Getting Green with Solar Subsidies: Evidence from the California Solar Initiative." http://spot.colorado.edu/~jonathug/Jonathan_E._Hughes/Main_files/PV_Sudsidies.pdf . Accessed April 12, 2017.

"International Roadmap for Photovoltaics." 2017. http://www.itrpv.net/.cm4all/iproc.php/ITRPV%20Eighth%20Edition%202017.pdf?cdp=a

National Energy Assistance Directors' Association. 2011. "2011 National Energy Assistance Survey Summary Report." http://neada.org/wp-content/uploads/2013/05/FINAL_NEADA_2011_Summary_Report1.pdf

[NREL] National Renewable Energy Laboratory. 2015. "JEDI: Jobs and Economic Development Impact Model." http://www.nrel.gov/analysis/jedi/. Accessed April 5, 2017.

[NREL] National Renewable Energy Laboratory. 2016. "U.S. Solar Photovoltaic System Cost Benchmark: Q1 2016." http://www.nrel.gov/docs/fy16osti/67142.pdf. Accessed March 1, 2017.

[NREL] National Renewable Energy Laboratory. 2017. https://jedi.nrel.gov/model.php. Accessed April 14, 2017.

[NYSERDA] New York State Energy Research & Development Authority. 2012. "New York Solar Study: An Analysis of the Benefits and Costs of Increasing Generation from Photovoltaic Devices in New York." https://www.nyserda.ny.gov/-/media/Files/Publications/Energy-Analysis/NY-Solar-Study-Report.pdf . Accessed April 7, 2017.

Power-technology.com. 2016. "The World's Biggest Solar Photovoltaic Cell Manufacturers." http://www.power-technology.com/features/featurethe-worlds-biggest-solar-photovoltaic-cell-manufacturers-4863800/. Accessed April 6, 2017.

[SEIA] Solar Energy Industries Association. 2017. "California Solar." http://www.seia.org/state-solar-policy/california. Washington, D.C.: Solar Energy Industries Association. Accessed February 20, 2017.

SolarCity. 2016. "Investor Presentation." http://files.shareholder.com/downloads/AMDA-14LQRE/2283391043x0x830612/1A32ABBC-4024-44B9-8F81-1B5BD77DD00B/2016.06_SCTY_Investor_Presentation.pdf . Accessed February 20, 2017.

Tuerck, D., P. Bachman & M. Head. 2013. "RPS: A Recipe for Economic Decline." http://www.npri.org/docLib/20130424_RPS-ARecipeforDecline.pdf. Accessed April 7, 2917.

Solar Foundation. 2017. "Solar Jobs Census 2016." http://solarstates.org/#state/california/counties/solar-jobs/2016. Accessed April 7, 2017.

U.S. Census Bureau. 2014. Population Division. "Annual Estimates of the Resident Population: April 1, 2010 to July 1, 2014." http://factfinder2.census.gov/bkmk/table/1.0/en/PEP/2014/PEPANNRES/0400000US06.05000.

[U.S. EPA] United States Environmental Protection Agency. 2011. "Emission Factors for Greenhouse Gas Inventories." http://www.epa.gov/climateleadership/documents/emission-factors.pdf. Accessed December 2, 2013.

[U.S. EPA] United States Environmental Protection Agency. 2011. "Emission Factors for Greenhouse Gas Inventories."

http://www.epa.gov/climateleadership/documents/emission-factors.pdf. Accessed December 2, 2013.

APPENDICES

Appendix A: Statewide Savings Methodology

The Energy Commission Demand Analysis Office provided the projected annual residential dwelling starts for the single family and multifamily sectors. Energy Commission provided a base case projection for 2020 broken out by forecast climate zones (FCZ). E3 translated this data to building climate zones (BCZ) using the weighting table of FCZ to BCZ provided by Energy Commission, as shown in Table 25.

E3 estimated statewide impacts for the first year that new houses comply with the 2019 Title 24 Standards by multiplying per unit savings estimates by statewide construction forecasts. See Section 6 for details and results.

Table 24: Translation from FCZ to BCZ

Table D: To be used for converting Old Forecast Zones to Standards Zone (Using 2010 Census Population Data)

Source:CECCFM/Weather/ClimateZoneOverlap_Population 02-20-15.xls - Table A-4

Building Standards Climate Zones (BCZs)	Old Forecast Climate Zones (FCZs): 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1	21.42%	0.00%	0.00%	0.20%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	14.99%
2	20.47%	0.00%	0.00%	13.53%	4.65%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
3	0.00%	0.00%	0.00%	10.07%	88.48%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
4	0.00%	0.00%	0.00%	43.55%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
5	0.00%	0.00%	0.00%	8.76%	0.00%	0.00%	0.00%	0.05%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
6	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	38.48%	13.68%	0.00%	25.29%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
7	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	68.66%	0.00%	0.00%	0.00%	0.00%
8	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	50.40%	30.13%	0.00%	36.50%	0.46%	0.00%	0.00%	0.00%	0.00%	0.00%
9	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	10.72%	47.98%	0.00%	38.21%	99.09%	0.00%	99.67%	0.00%	99.90%	0.00%
10	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	78.93%	0.00%	0.00%	30.48%	0.00%	0.00%	0.00%	0.00%
11	11.72%	25.93%	19.58%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.35%
12	36.08%	72.97%	22.74%	23.88%	6.87%	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
13	0.00%	0.00%	56.79%	0.00%	0.00%	0.00%	77.06%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
14	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	13.65%	0.00%	7.43%	12.37%	0.00%	0.00%	0.72%	0.00%	0.02%	0.00%	0.00%
15	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	6.75%	0.00%	0.00%	0.14%	0.00%	99.98%	0.00%	0.00%
16	10.31%	1.10%	0.89%	0.00%	0.00%	0.00%	9.30%	0.35%	0.79%	1.95%	0.00%	0.44%	0.00%	0.33%	0.00%	0.10%	84.65%
Total	**100.00%**	**100.00%**	**100.00%**	**100.00%**	**100.00%**	**100.00%**	**100.00%**	**100.00%**	**100.00%**	**100.00%**	**100.00%**	**100.00%**	**100.00%**	**100.00%**	**100.00%**	**100.00%**	**100.00%**

Appendix B: Environmental Impacts Methodology

Greenhouse Gas Emissions Impacts Methodology

The avoided GHG emissions were calculated assuming an emission factor of 353 metric tons of carbon dioxide equivalents ($MTCO_2e$) per GWh of electricity savings. The authors calculated air quality impacts associated with the electricity savings from the proposed measure using emission factors that indicate emissions per GWh of electricity generated.[10] When evaluating the impact of increasing the Renewable Portfolio Standard (RPS) from 20 percent renewables by 2020 to 33 percent renewables by 2020, California Air Resources Board (CARB) published data on expected air pollution emissions for various future electricity generation scenarios (CARB 2010). The authors used data from CARB's analysis to inform the air quality analysis presented in this report.

[10] California power plants are subject to a GHG cap and trade program and linked offset programs until 2020 and potentially beyond.

Appendix C: Additional Graph Outputs

This appendix presents some of the cost-effectiveness results from Section 5 in graphical form.

Figure 8: Net Benefit of Solar PV in 2100 sf home

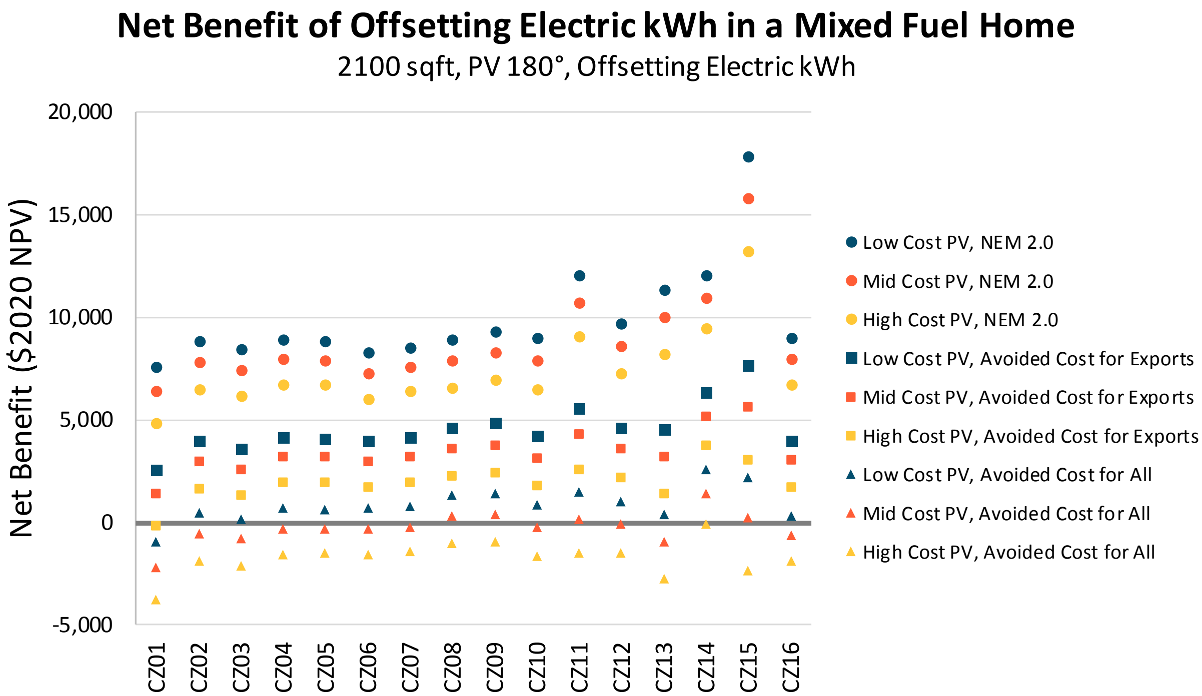
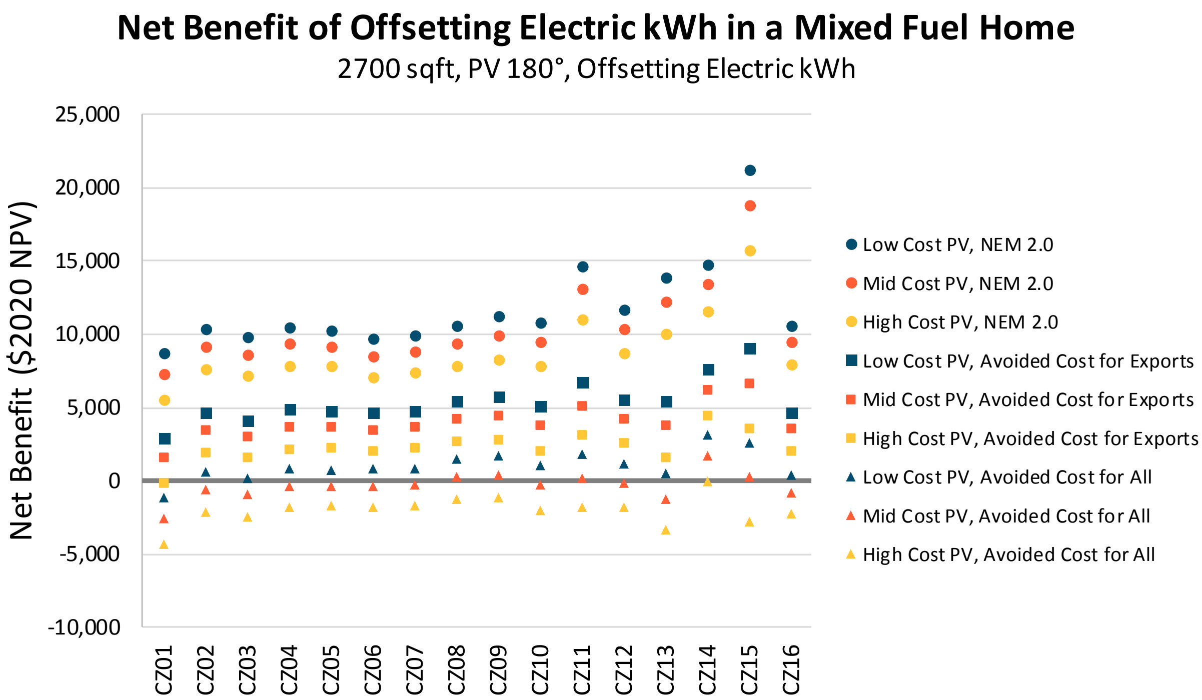
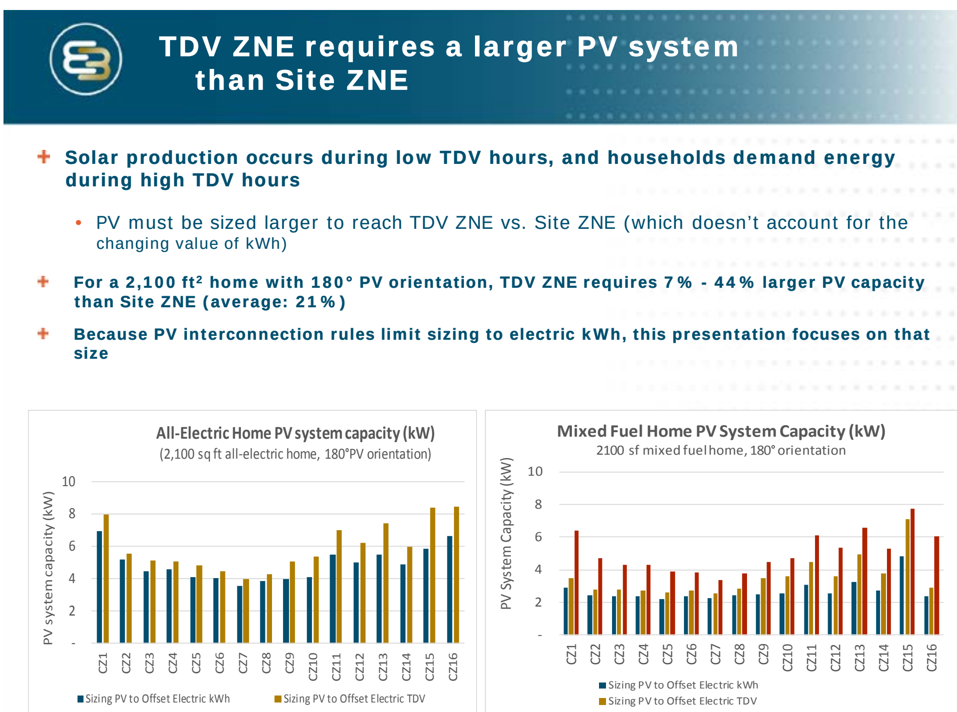


Figure 9: Net Benefit of Solar PV in 2700 sf home



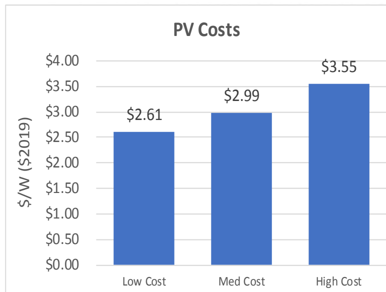


PV Costs

+ **No ITC Assumed - The ITC is scheduled to step down throughout the 2020-2022 building standard cycle (26%, 22%, 20%) and then to 0% for residential systems beginning in 2023**

+ **All costs assume a 30-yr panel life and inverter replacements after 10 and 20 years (comprises ~$0.40/W in the costs)**

+ **Price based on NREL 2016 Installer Price**
  - Low cost case:
    - 30% cost reduction 2016 – 2020 (GreenTech Media)
  - Medium cost case:
    - 18% cost reduction 2016 – 2020 (Bloomberg)
  - High cost case:
    - No cost reduction 2016 - 2020



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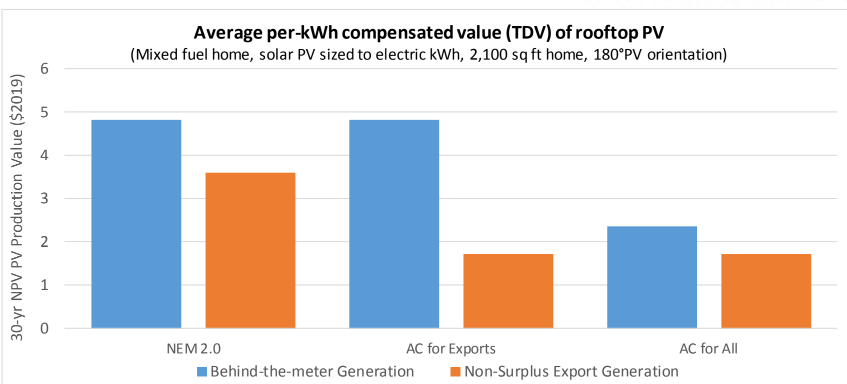
Three solar compensation policies



AC = Avoided Costs

Non-surplus Export Generation are the hourly exports

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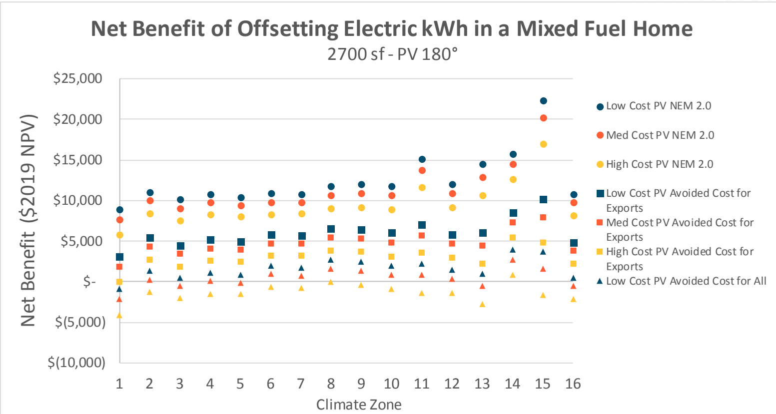
3

Cost-Effectiveness of Offsetting Elec kWh in a Mixed Fuel Home

+ **Offsetting electric kWh with solar PV is cost-effective except under the most aggressive NEM reform scenarios**



CZ	PV kW
1	2.89
2	2.46
3	2.38
4	2.36
5	2.22
6	2.38
7	2.26
8	2.46
9	2.51
10	2.58
11	3.10
12	2.58
13	3.28
14	2.73
15	4.83
16	2.37

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4

PV Sizing Methods

+ **Electric kWh**
  - PV scaled such that annual generation = annual electric load
+ **Maximize Net Benefits**
  - PV scaled to maximize net TDV benefit to customer
    - Practically, this is the same capacity as sizing to kWh, i.e., further generation will only receive Net Surplus Compensation (NSC)
+ **Electric TDV**
  - PV scaled such that annual TDVs generated = annual TDV of electric load
+ **Zero Net Benefits (Breakeven Point)**
  - PV scaled to point at which a larger system will not be cost-effective
  - Cost of PV system = Revenue from PV generation

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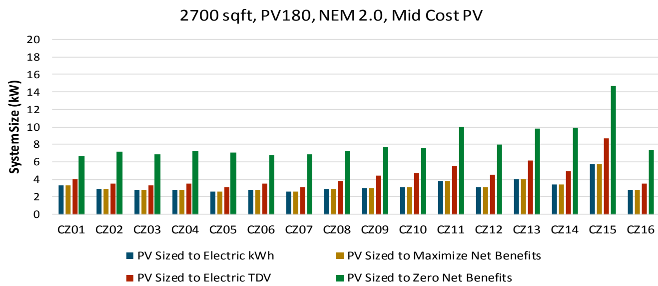
5

Sizing Comparison
NEM 2.0, Mid Cost PV

- **PV sized to max net benefits is smaller than sized to electric TDV**
  - Sizing to TDV does not reflect lower compensation for exports from NEM 2.0
- **At sizes beyond max net benefits, incremental kW only receive NSC**
  - Large net benefit and small marginal net cost (PV cost – NSC) at the point of maximum net benefits require much larger systems to zero out net benefits
  - Retail for self-use and exports, NSC for net surplus – NEM2



Ratio of PV Sized to Zero Net Benefits / PV Sized to Electric kWh

CZ1	1.98
CZ2	2.51
CZ3	2.49
CZ4	2.62
CZ5	2.76
CZ6	2.42
CZ7	2.61
CZ8	2.49
CZ9	2.55
CZ10	2.43
CZ11	2.65
CZ12	2.59
CZ13	2.43
CZ14	2.96
CZ15	2.55
CZ16	2.61

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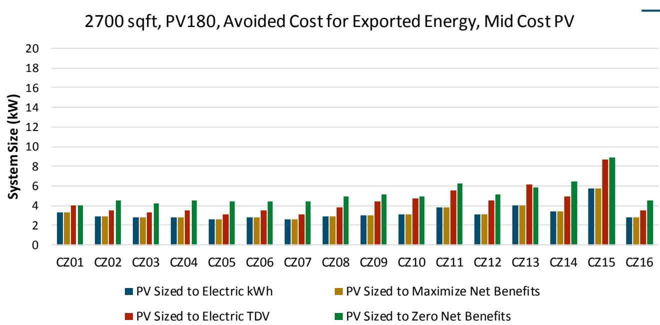
Sizing Comparison
AC for Exports, Mid Cost PV

- **Valuing export PV generation at avoided cost reduces cost-effectiveness of PV sized to offset kWh**
  - Smaller net benefits for systems sized to offset kWh means less kW at marginal net cost are needed to zero out net benefits
  - Retail for self-use, AC for exports, NSC for net surplus, NEM"3"



Ratio of PV Sized to Zero Net Benefits / PV Sized to Electric kWh

CZ01	1.21
CZ02	1.57
CZ03	1.52
CZ04	1.64
CZ05	1.71
CZ06	1.58
CZ07	1.67
CZ08	1.67
CZ09	1.69
CZ10	1.57
CZ11	1.65
CZ12	1.64
CZ13	1.45
CZ14	1.91
CZ15	1.55
CZ16	1.60

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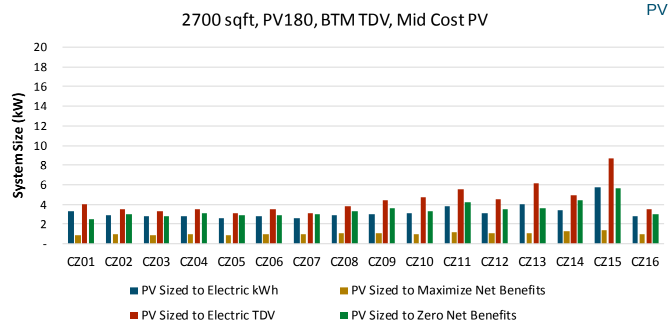
Sizing Comparison
BTM TDV, Mid Cost PV

- **BTM TDV means**
  - All PV production consumed behind-the-meter (BTM) receives full TDV value
  - All PV production exported to the grid as well as all net surplus above a system sized to annual kWh receives net surplus compensation (NSC)
- **PV sized to electric kWh and electric TDV are unchanged from previous rate structures**
- **PV sized to maximize net benefits and PV sized to zero net benefits are substantially reduced**
- Retail for self-use, NSC for exports and annual surplus



Climate Zone	Ratio of PV Sized to Zero Net Benefits / PV Sized to Electric kWh
CZ1	0.74
CZ2	1.05
CZ3	1.01
CZ4	1.11
CZ5	1.14
CZ6	1.04
CZ7	1.12
CZ8	1.11
CZ9	1.18
CZ10	1.05
CZ11	1.11
CZ12	1.14
CZ13	0.89
CZ14	1.30
CZ15	0.98
CZ16	1.07

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8

Storage Overview

- **E3 analyzed the additional value of a battery storage system to an existing PV system of a 2700 sf, mixed fuel home**
- **BTM TDV rate scenario**
  - BTM generation receives full TDV value (~$0.20/kWh); exported generation receives net surplus compensation value (~$0.03/kWh)
- **Battery assumptions**
  - 14 kWh
  - 5 kW
  - 90% round trip efficiency
  - $500/kWh fully installed

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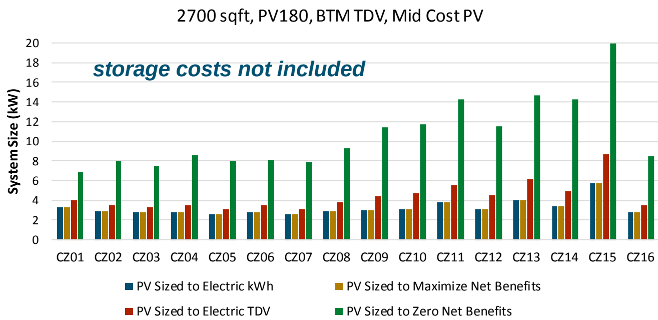
9

Sizing Comparison
BTM TDV With Storage, Mid Cost PV

- **Installing storage (without accounting for the storage costs) increases the benefits to the homeowner, allowing them to install more solar**
- The Generous Santa option: Demonstrates how PV value increases if coupled with storage at no cost
- Retail for self-use, and NSC for exports and annual surplus



Ratio of PV Sized to Zero Net Benefits / PV Sized to Electric kWh	
CZ1	2.05
CZ2	2.78
CZ3	2.70
CZ4	3.09
CZ5	3.09
CZ6	2.89
CZ7	2.97
CZ8	3.17
CZ9	3.77
CZ10	3.75
CZ11	3.76
CZ12	3.71
CZ13	3.66
CZ14	4.26
CZ15	3.47
CZ16	3.02

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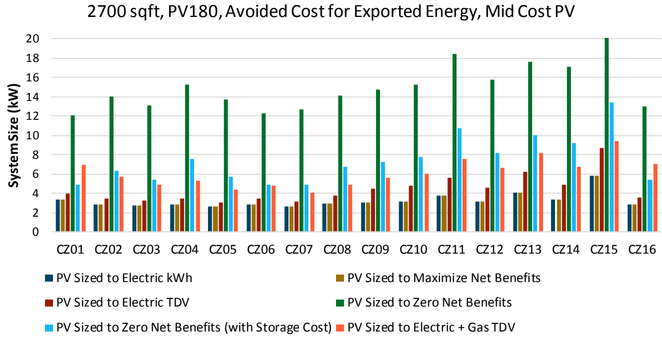
Sizing Comparison
Avoided Cost for Exported Energy With Storage, Mid Cost PV

NEW

- **Changing the rate structure to avoided cost for exported energy increases the net benefits of solar + storage and therefore increases the amount of solar that can be installed before net benefits are reduced to zero; annual surplus at NSC**
- The Stingy Santa option – Demonstrates the impact on the PV if Santa charges you for the storage
- Retail for self-use, AC for exports, and NSC for annual surplus – NEM"3"



Ratio of PV Sized to Zero Net Benefits (with Storage Costs) / PV Sized to Electric kWh	
CZ1	1.48
CZ2	2.21
CZ3	1.96
CZ4	2.71
CZ5	2.23
CZ6	1.73
CZ7	1.87
CZ8	2.29
CZ9	2.39
CZ10	2.47
CZ11	2.82
CZ12	2.63
CZ13	2.49
CZ14	2.73
CZ15	2.33
CZ16	1.90

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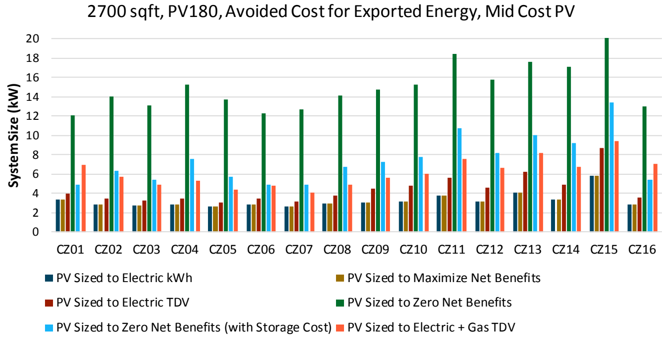
Sizing Comparison
Avoided Cost for Exported Energy With Storage, Mid Cost PV

NEW

- **Changing the rate structure to avoided cost for exported energy increases the net benefits of solar + storage and therefore increases the amount of solar that can be installed before net benefits are reduced to zero; annual surplus at NSC**
- The Stingy Santa option – Demonstrates the impact on the PV if Santa charges you for the storage
- Retail for self-use, AC for exports, and NSC for annual surplus – NEM"3"



Ratio of PV Sized to Zero Net Benefits (with Storage Costs) / PV Sized to Electric kWh	
CZ1	1.48
CZ2	2.21
CZ3	1.96
CZ4	2.71
CZ5	2.23
CZ6	1.73
CZ7	1.87
CZ8	2.29
CZ9	2.39
CZ10	2.47
CZ11	2.82
CZ12	2.63
CZ13	2.49
CZ14	2.73
CZ15	2.33
CZ16	1.90

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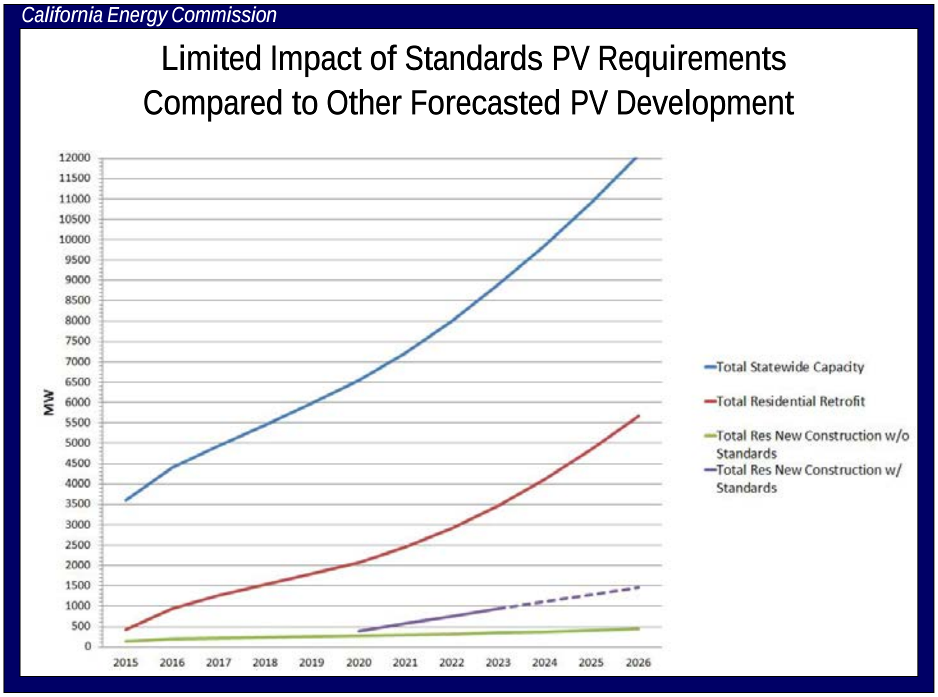
California Energy Commission
Limited Impact of Standards PV Requirements
Compared to Other Forecasted PV Development
MW
Total Statewide Capacity
Total Residential Retrofit
Total Res New Construction w/o Standards
Total Res New Construction w/ Standards

Table 25: Life Cycle Cost-effectiveness Summary Per 2100 sf Prototype – Mixed Fuel Home, NEM 2.0, 180° Orientation, Current Incremental Construction Cost

Climate Zone	Benefits TDV Energy Cost Savings + Other PV Savings[1] (2020 PV $)	Costs Total Incremental Present Valued (PV) Costs[2] (2020 PV $)	Benefit-to-Cost Ratio
1	$15,318	$10,463	1.5
2	$15,425	$8,903	1.7
3	$14,796	$8,605	1.7
4	$15,274	$8,553	1.8
5	$14,763	$8,021	1.8
6	$14,667	$8,624	1.7
7	$14,575	$8,179	1.8
8	$15,524	$8,912	1.7
9	$16,065	$9,095	1.8
10	$15,858	$9,338	1.7
11	$20,304	$11,219	1.8
12	$16,612	$9,332	1.8
13	$20,113	$11,873	1.7
14	$19,380	$9,890	2.0
15	$30,713	$17,481	1.8
16	$15,296	$8,566	1.8

1. **Other PV Savings:** Includes incremental first cost savings if proposed first cost is less than current first cost. Includes present value maintenance cost savings if PV of proposed maintenance costs is less than the PV of current maintenance costs.
2. **Total Incremental Present Valued Costs:** Includes incremental first cost if proposed first cost is greater than current first cost. Includes present value of maintenance incremental cost if PV of proposed maintenance costs is greater than the PV of current maintenance costs. If there are no Total Incremental Present Valued Costs, the Benefit/Cost Ratio is Infinite.

Table 26: Life Cycle Cost-effectiveness Summary Per 2100 sf Prototype – Mixed Fuel Home, Avoided Cost for Exports, 180° Orientation, Post-adoption Incremental Construction Cost

Climate Zone	Benefits TDV Energy Cost Savings + Other PV Savings[1] (2020 PV $)	Costs Total Incremental Present Valued (PV) Costs[2] (2020 PV $)	Benefit-to-Cost Ratio
1	$10,295	$8,918	1.2
2	$10,571	$7,588	1.4
3	$9,958	$7,334	1.4
4	$10,481	$7,290	1.4
5	$10,015	$6,836	1.5
6	$10,365	$7,350	1.4
7	$10,150	$6,971	1.5
8	$11,199	$7,596	1.5
9	$11,530	$7,751	1.5
10	$11,136	$7,959	1.4
11	$13,848	$9,561	1.4
12	$11,536	$7,953	1.5
13	$13,315	$10,119	1.3
14	$13,641	$8,429	1.6
15	$20,549	$14,899	1.4
16	$10,330	$7,301	1.4

1. **Other PV Savings:** Includes incremental first cost savings if proposed first cost is less than current first cost. Includes present value maintenance cost savings if PV of proposed maintenance costs is less than the PV of current maintenance costs.
2. **Total Incremental Present Valued Costs:** Includes incremental first cost if proposed first cost is greater than current first cost. Includes present value of maintenance incremental cost if PV of proposed maintenance costs is greater than the PV of current maintenance costs. If there are no Total Incremental Present Valued Costs, the Benefit/Cost Ratio is Infinite.

Table 27: Life Cycle Cost-effectiveness Summary Per 2100 sf Prototype – Mixed Fuel Home, Avoided Cost for All, 180° Orientation, Post-adoption Incremental Construction Cost

Climate Zone	Benefits TDV Energy Cost Savings + Other PV Savings[1] (2020 PV $)	Costs Total Incremental Present Valued (PV) Costs[2] (2020 PV $)	Benefit-to-Cost Ratio
1	$6,746	$8,918	0.8
2	$7,066	$7,588	0.9
3	$6,529	$7,334	0.9
4	$6,987	$7,290	1.0
5	$6,539	$6,836	1.0
6	$7,076	$7,350	1.0
7	$6,781	$6,971	1.0
8	$7,879	$7,596	1.0
9	$8,128	$7,751	1.0
10	$7,725	$7,959	1.0
11	$9,748	$9,561	1.0
12	$7,872	$7,953	1.0
13	$9,147	$10,119	0.9
14	$9,843	$8,429	1.2
15	$15,108	$14,899	1.0
16	$6,669	$7,301	0.9

1. **Other PV Savings:** Includes incremental first cost savings if proposed first cost is less than current first cost. Includes present value maintenance cost savings if PV of proposed maintenance costs is less than the PV of current maintenance costs.
2. **Total Incremental Present Valued Costs:** Includes incremental first cost if proposed first cost is greater than current first cost. Includes present value of maintenance incremental cost if PV of proposed maintenance costs is greater than the PV of current maintenance costs. If there are no Total Incremental Present Valued Costs, the Benefit/Cost Ratio is Infinite.