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Excerpt from Rooftop Solar PV System Report: prepared by E3 for the 2019 Standards update

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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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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.

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

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.

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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.