California Energy Commission

STAFF REPORT

Appendix C: Photovoltaics

FOR THE 2025 BUILDING ENERGY EFFICIENCY STANDARDS

Energy Conservation Manual

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APPENDIX C: PHOTOVOLTAICS

Photovoltaics

Compliance software shall calculate energy generated by photovoltaic (PV) systems on an hourly basis using the National Renewable Energy Laboratory (NREL) System Advisor Model (SAM) algorithms upon which the PVWatts program is based (see Appendix F), or using a similar calculation method approved by the Energy Commission. PV systems with and without sub-array power electronics (i.e., microinverters and DC power optimizers) are further considered based on user inputs. Appendix C describes calculations and assumptions used in the California Building Energy Code Compliance (CBECC) and CBECC-Res compliance managers.

Power electronics are used to help minimize efficiency losses when the output of sub-array components (e.g., modules or cells) operate under different conditions. The largest driver of variation in conditions across a PV array is partial shading from nearby obstacles. A small fraction of shaded cells could lead to disproportionate reductions in PV power output. PVWatts, does not explicitly handle this effect. Literature describes a shading impact factor (SIF) which is the ratio of relative power output to fraction shaded:

$P_{sh} = P_{sys} \cdot (1\text{-}SIF \cdot f_{sh})$

Where P_{sh} is the power output of the shaded system, P_{sys} is the power output of the unshaded system, and f_{sh} is the fraction shaded.

A value of 1.0 implies that the power output declines proportionally to the fraction shaded. This is a theoretical minimum value of SIF in that it implies there are power electronics that are maintaining output consistent with the level of shading across the module. A value greater than 1.0 implies that shading has a disproportionate effect on system output.

The compliance software shall use an SIF value of 2.0 for central inverters (CEC default) and a value of 1.2 for systems with power electronics (see Table C-2. SIF for Total Inverter Efficiency).

System Loss Assumptions

In PVWatts, a single derating factor is used to cover a variety of system inefficiencies. The compliance software uses slightly different assumptions for this derating factor as described in the table below:

TABLE C-1. DERATING FACTOR

Loss Type	**Value**	**Differences from PVWatts Default Assumptions**
Soiling	0.02	N/A
Shading	0.0	Modeled based on Solar Access input (see below)
Snow	0.0	N/A
Mismatch	0.0	Mismatch from shading is characterized using SIF (see below)
Wiring	0.02	N/A
Connections	0.005	N/A
Light-induced degradation	0.015	N/A
Nameplate rating	0.01	N/A
Age	0.05	Estimated 0.5 percent degradation over 20 years based on these references: [1, 2, 3]
Availability	0.03	N/A
Total	0.14	N/A

Source: California Energy Commission

The total losses assumed shall be based on the Solar Access and SIF value to account for shading and mismatch as follows:

Losses = 1 – ((1 – 0.14)*max(1 – SIF*(1 – Solar Access), 0))

Inverter Efficiency

The software shall characterize the inverter efficiency corresponding to either a central inverter or microinverters depending on the type of power electronics used in the system.

Power Electronics

Options for power electronics are described below:

TABLE C-2. SIF FOR TOTAL INVERTER EFFICIENCY

Option	**SIF**	**Total Inverter Efficiency**
None	2.0	User input
Microinverters	1.2	User input
DC Power Optimizers	1.2	Optimizer efficiency * user input

Source: California Energy Commission

Optimizer efficiencies are assumed to be 0.99 (corresponding to suggestions in this document).

Space Function to PV/Battery Building Type Mapping

The software shall determine the size of the building PV and battery system based on the PV Capacity Factors and Battery Storage Capacity Factors from Energy Code Tables 140.10-A/170.2-U and 140.10-B/170.2-V. The PV Capacity Factors identify the capacity of a PV system based on the climate zone, building type, and conditioned floor area. The Battery Storage Capacity Factors identify the Energy Capacity or Power Capacity based on the building type and PV capacity. The default mapping of space function to PV capacity factor building type is in Appendix 5.4A. Default PV/Battery Building Type is editable so that users may adjust factors to match the proposed building type, or multiple building types when one or more are in the proposed building, according to definitions and requirements in the Energy Code.

Battery Storage

See Status of Modeling Batteries for California Residential Code Compliance, Appendix D.