SEIA Solar Energy Industries Association®

Installation Best Practices Guide

Residential Portfolios

Developed by the SEIA Quality Assurance Working Group

December 2023

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Background

The Quality Assurance Working Group (QAWG) seeks to evaluate, develop and encourage adoption of industry best practices in solar asset design, production estimate, installation, commissioning, and contractor qualification. The QAWG represents a wide variety of solar industry stakeholders.

The following document was designed to update installation best practices developed by the Quality Assurance Working Group (QAWG), version 2018, and is intended to be updated as proper protocol dictates.

The primary intention of this document is to provide recommended best practices to facilitate high-quality and consistent residential solar projects. The broader objective in developing and maintaining this document is to build confidence among potential solar customers, regulators, investors, rating agencies, and other stakeholders in the concept that residential solar systems are a valuable home improvement, a consistent and long-term electric generating resource, and credit-worthy investment asset class.

Note: Building Integrated PV Systems (BIPV) are not covered in this document in a technical capacity due to their proprietary design and installation characteristics. Refer to the document UL 7103 Outline of Investigation for Building-Integrated Photovoltaic Roof Coverings for details on BIPV systems.

Contributors

The Solar Energy Industries Association® (SEIA) and the member-based Quality Assurance Working Group convened industry members to review and update the best practices guide developed in 2018. SEIA's Quality Assurance Working Group was formed to bring together industry experts and colleagues to identify opportunities for improved processes and activities in solar finance and associated quality and standards spaces. The working group is Chaired by Rudy Saporite of IBTS and co-chaired by Richard Lawrence of IREC; staff leads from SEIA are Evelyn Butler, VP Technical Services, Jennifer Martin, Director of Standards Development and Cesar Eizaga, Standards Development Manager.

We are grateful and appreciative of the work and effort contributed by members of the working group and additional industry colleagues in the update of this document. A consensus approach was utilized to develop the information and approaches included herein. The working group included the following section leads:

Chair:	Rudy Saporite, IBTS
Co-Chair:	Richard Lawrence, IREC
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Design & Installations Best Practices:	Susan Stark, IronRidge

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Market Actors and Role Definitions

The solar financing marketplace can be complex and involve multiple parties in transactions related to residential solar installations. For the purposes of this document, the following roles are defined:

Investor

The investor originates funds to underwrite portfolios of residential PV installations. They generally have little day to day involvement in managing the portfolio but may have particular due diligence requirements that would apply during transactions, such as purchasing a portfolio of solar loans or leases.

Finance Provider

A Finance Provider will take funds and originate loans, leases, or other financing products that are executed with host customers (i.e., homeowners). While the Finance Provider may have a role in managing PV installations, they more typically will work with contractors who handle day to day customer interaction and installation activities until the PV system is operating.

Contractor

Contractors (also referred to as Installers) will typically have the physical resources (e.g., staff, equipment, licensing) to complete PV installations. These installations may be completed by Contractor staff and/or using subcontractors (including electricians, laborers, roofers, and other tradespeople) and the Contractor will bear responsibility for the PV installations, including holding relevant warranties and agreements with the Finance

Provider to install and maintain the PV systems. The subcontractor individuals will not generally have direct contact with Financing Providers or Investors.

Though this list is not exhaustive, and many variations exist, these groups represent the major general categories that will be addressed in this document.

Authority Having Jurisdiction (AHJ)

As defined in NFPA 70: National Electrical Code, “An organization, office, or individual responsible for enforcing the requirements of a code or standard, or for approving equipment, materials, an installation, or a procedure.” This is typically a local (e.g., town, city or county) authority responsible for the permitting and approval of solar PV installations. Examples of these individuals include electrical and/or building inspectors, fire marshals, and/or local utility representatives.

Contractor Qualifications

Work History

The Contractor shall have a work performance experience that demonstrates its ability to install safe and reliable solar PV systems. The Contractor should provide the number of systems and total kW installed for each year of the past 3 years of experience to demonstrate transparency regarding work experience. The Contractor can demonstrate required experience through one of the following:

- 3 years of company work experience installing residential solar PV systems or
- 5 years of personal work experience installing residential solar PV systems (in a leadership role in both former and current company).

If a Contractor does not have the applicable experience above, it is recommended that they demonstrate additional measures to ensure they are capable to install safe and reliable solar and storage PV systems. Suggestions on additional qualifications include:

- Complete third-party quality assurance inspections for no less than ten percent (10%) of projects completed in the last six (6) months with a minimum of eighty percent (80%) passing score,
- Site Supervisor completed OSHA 10-hour construction safety course and 40 hours of solar PV technical course training.

Financial Transparency

The Contractor shall keep documentation that confirms their financial solvency.

Documents to be kept on file include:

- Two years of financial statements (income statement and balance sheet, audited preferred).
- Last three (3) months of bank statements.

- Supplier references with credit terms provided.
- Bonding Letter with bonding capacity listed.
- Scoring from a well-regarded third-party credit risk assessment entity may be required by some financiers. Others may require specific financial metrics be met regarding cash liquidity and other facets of financial stability. The purpose of these references is to demonstrate that the installation Contractor is/was not in financial distress at the time of installation. Installation Contractor financial distress could have a negative impact on the level of system quality and bankability of warranties and other representations made by the Contractor to the Homeowner (consumer).

Customer Acquisition, Sales, & Contracting

The Contractor should be in compliance with SEIA's Consumer Protection Best Practices and associated Standard.

Health and Safety

The Contractor should create and maintain a health and safety manual which establishes appropriate rules and procedures concerning workplace safety, including rules related to the

reporting of health and safety problems, injuries, and unsafe conditions; risk assessment; and first aid and emergency response.

Some examples of typical rules and procedures follow below:

- Contractor Site Supervisor completed a minimum of Occupational Safety and Health Administration (OSHA) 30-hour Construction Industry training, and all site personnel completed a minimum of OSHA 10-hour Construction Industry training and ladder safety course.
- Additional training should be supplemented to provide sufficient knowledge for installers to identify hazards, provide corrective actions, and prevent recurrence specific to solar PV systems.
- All site personnel shall be equipped with complete Personal Protective Equipment (PPE) and trained on any specific hazards associated with their jobs.
- Contractor Site Supervisor completed a Job Hazard Analysis (JHA).
- Contractor Site Supervisor completed a jobsite orientation with all workers onsite.
- The contractor should maintain an OSHA total case incident rate (TCIR) of 5.00 or less or a similar rate based on a substantially equivalent, accepted measure used to report workplace injuries.

- The contractor shall maintain a company published Injury and Illness Prevention Program (IIPP) manual and conduct regularly scheduled training to all operations impacting employees.

Insurance

The Contractor should maintain current and appropriate business insurances, including liability insurance, workers' compensation insurance, and commercial vehicle insurance. This requirement outlines basic standards for worksite safety to mitigate construction risk and potential liability during the construction phase.

- General liability - $1,000,000 per occurrence, $2,000,000 aggregate.
- Workers' compensation - $1,000,000 for each accident, each employee, policy limit.
- Automobile Liability: bodily injury, death, and property damage combined single limits of at least $1,000,000 per occurrence covering vehicles owned, hired, or non-owned.
- Consider adding an Excess/Umbrella insurance component with limits ranging from $2MM to $5MM for typical Contractors and typical projects.
- If the Contractor is also designing the system, Professional Liability of $1MM and up
- (depending on size of engagement and size of the Contractor).
- If the contractor is storing confidential customer data, it should procure Cyber Liability insurance.
- Insurance policies should name the Finance Provider and any intermediaries as additional insured(s) and certificate holder(s). Additionally: • Subrogation should be waived
- Notice of cancellation to additional insured should be required.
- The contractor's policies should be primary and not require contribution from any other applicable coverages.

Personnel Qualifications

Personnel engaged in "electrical installations" as defined by the local authority having jurisdiction shall meet the definition of "Qualified Person" indicated in NFPA 70 and NFPA 70E and shall hold any credential required by the AHJ for performing such work.

The Contractor Site Supervisor or designated responsible party should have one of the following professional qualifications:

- North American Board of Certified Energy Practitioners (NABCEP) PV Associate (PVA)
- Electrician (associate)

- Carpenter (associate)
- Millwright (associate)
- Professional or Licensed electrician (master or journeyman as applicable by state).

Some Contractors may have proprietary training and education programs that are more specific to the job duties performed by their personnel, which may meet or exceed training and experience requirements for the certifications above.

Additional certifications that installation personnel may hold to ensure a high level of quality workmanship and safety include:

- North American Board of Certified Energy Practitioners (NABCEP) Certified PV Installation Professional (PVIP).
- North American Board of Certified Energy Practitioners (NABCEP) Certified PV Installer Specialist (PVIS).
- Professional or Licensed Engineer.
- Proprietary technology training or certification offered by an original equipment manufacturer.
- Other NABCEP certifications are PV Design Specialist, PV Technical Sales, and PV Commissioning and Maintenance Specialist.

Trade License

The Contractor should have all professional and trade licenses required by the state and local AHJ. Required solar PV licenses can be found through the Interstate Renewable Energy Council's (IREC) Solar Licensing Database. All updated trade licenses should be stored electronically by the Contractor.

Business License

The Contractor should be in good standing with all applicable business licenses required to sell and install residential solar and storage PV systems in each state of current operation. These requirements will vary by state and may be different requirements to either sell or install solar PV.

Program Requirements

In some states, outside of professional license and business license requirements, the Contractor may need to be registered with or pre-approved by a state agency so that consumers can participate in incentive programs or other renewable energy programs. In these cases, the Contractor must maintain and be able to provide proof of good standing and eligibility to secure incentives under such programs if those incentives are included in the sale.

Design and Installation Best Practices

Site Assessment

The Contractor is responsible for gathering relevant site-specific information such that the PV system designer can design a PV system appropriate for the application. The Contractor shall ensure that system design and production estimates are made using reliable data. For this purpose, Contractors can use the NABCEP Resource Guides which are available at no cost and addresses many of the key factors and current industry best practices regarding PV system design. Below are brief summaries of major design topics, with references to existing documentation that provide further detail. Relevant information from the following list should be noted on the construction plans submitted for permit application.

Array Location	Structure	Electric	Equipment Locations
All Sites Obstructions and shading (3) Roof-Mounted Building footprint Building Height Age of roof covering (1) Dimensions, pitch, and azimuth orientation Roof Fire Classification Locally required minimum roof setback dimensions from ridge, hips/valleys (2) Type of roof covering / coursing Underlayment type and lap dimensions Roof condition assessment Roof Zone locations Safety or liability considerations Building Risk Category (occupancy type) Ground-Mounted Soil type and composition Accessibility to unqualified persons Ground slope suitable for safe construction and drainage Distance to property lines Easements/wetlands	Local design wind speed and exposure category (and source of info) Local ground snow load (and source of info) Design roof snow load Framing lumber dimensions Rafter or truss spacing Max. rafter span or longest truss top chord panel length between struts Lumber species and grade (4) Sheathing thickness and type	Type of service (overhead vs. underground) Location of service disconnect and/or main service panel Size (in Amperes) and voltage of service Rating of service equipment (including overcurrent device, enclosure, busbar, etc.). Service panel make and model Availability of breaker spaces Meter location Existing PV equipment, cable, connectors, etc.	Inverter(s) Conduit Array location(s) Service Disconnect Monitoring equipment Revenue Grade Meter (RGM) Energy Storage (ESS) locations Other utility equipment on site Rapid Shutdown initiation device

Notes:

To avoid unnecessary cost to the Contractor or the homeowner, the roof covering should have sufficient life remaining such that re-roofing is unlikely to be needed during the contract term (if a TPO project), or during the payback period (if owned by the customer).

Document any existing roof issues based on customer input.

From IRC, section 324.6 or local AHJ.

Vents, equipment, skylights, satellite dishes, snow guards, roof heaters, etc.

Indicate whether identified in field or assumed.

Solar Resource Measurement

Both on-site (using an industry standard handheld tool) or remote (using software verified by a third-party to deliver results similar to a handheld device) shade analysis tools are acceptable. The pitch and azimuth orientation of each array section should be measured and recorded.

For on-site shade tools, multiple locations per array section shall be measured. The goal is to accurately capture the shading profile of each array section so that modules can be placed to minimize shading and so that shading can be accurately accounted for in energy production simulations. Examples of shade location policies include:

1. The shade measurement locations for each array section shall include at least the approximate corner locations of the proposed array(s) and along long edges of the proposed array(s), as needed, such that there is no more than 20 feet in between measurements along the edge;
2. If the approximate location of the array(s) is not known at the time of the shade survey, then measurement locations shall be at the corners of the roof section setback regions and along long edges of the roof section set back regions, as needed, such that there is no more than 20 feet in between measurements along the edge. Problem areas, such as the north side of tall obstructions (e.g. chimneys), shall also be measured. Problem areas shall be measured at the approximate point on the proposed array that is nearest the obstruction.

When calculating the Total Solar Resource Fraction (TSRF) or equivalent system-level metrics, each individual TSRF reading shall be weighted by the planned array capacity such that the overall TSRF represents a weighted average of all array planes included in the design.

Refer to NABCEP PV Installation Professional Resource Guides for further guidance on performing an accurate shade analysis.

Remote shade analysis tools should be verified by an objective 3rd party (e.g., NREL, State agencies) for accuracy. The resolution of shade measurements from a remote shade tool should be one (1) meter or less between readings. Data should be no more than three (3) years old to accurately account for tree growth and new construction. When the remote shade tool generates shade readings from a 3D CAD model, care shall be taken to accurately measure the height and shape of all obstructions that are less than a distance (D) from the nearest point of the proposed array where (D) equals 2 times the height of the obstruction above the array. The remote shade tool should provide monthly shade readings for each location on the roof.

Regardless of the shading tool used, the site assessor will provide a copy of a shading report to the system designer and ensure that a copy of all shading measurements and reports is securely stored with other project files.

Two primary sources of data are typically utilized, ground based and satellite measurements. The list below includes examples of some of the available solar resources and weather data. The geographic location used in the weather data should be reasonably proximate to, and relevant to, the location of the proposed installation, and generally should be the closest available.

- Ground Based measurements - TMY2 and TMY3
- Satellite Based measurements - NREL NSRDB PSM model

Production and Savings Estimates

The Contractor needs to substantiate and have a reasonable basis for their production estimate. A production estimate must use inputs consistent with the proposed system's characteristics like weather data, shading, tilt and azimuth, and module performance degradation. The production estimate should list each month's production for the first year of operation, total production for the first year of operation, and total production over the system's life or contract term.

Like production estimates, savings estimates need to be substantiated and have a reasonable basis. For example, a Contractor should not use rules of thumb to estimate annual utility rate increases. Instead, they should use official sources, such as past utility rates or government publications, that reflect the customer's utility and rate class. Also important is the need for the Contractor to explain assumptions used in the savings estimate, such as government incentives.

Estimating Tools

Production modeling software is available to generate estimated monthly energy production for a proposed system design. There are several software options of varying complexity and detail that can be utilized to generate monthly production estimates. A detailed production estimate should produce monthly energy production estimates and account for the following factors:

- Accurate local historical or predicted weather data.
- Site-specific shading, including future projections.
- Component hardware selection (inverter and modules).
- Array orientation (azimuth and tilt).
- Adjustable system derate and loss factors (wire loss, mismatch, soiling, etc.).

Best practice is to estimate production based on present and the best estimate of future conditions, rather than ideal conditions. The information below is based on the standard breakdown of system loss sources available on the NREL PV Watts production estimator with typical ranges of each criterion.

Loss Source	Typical Loss Value	Typical Loss Range
Soiling (%)	2%	2% - 7%
Shading (%)	3%	0% - 20%
Snow (%)	0%	0% - 5%
Mismatch (%)	2%	0% - 3%
Wiring (%)	2%	1% - 4%
Connections (%)	0.5%	0.5% - 1%
Light-Induced Degradation (%)	1.5%	0% - 2%
Nameplate Rating (%)	1%	0% - 3%
Availability (%)	3%	0% - 3%

Contractors or third-party designers should document and disclose changes made to the derate factor provided by NREL to the Contractor (installer) or Finance Provider.

System Design

Contractors should ensure that system design and feasibility estimates are made using reliable data. NABCEP's PV Installation Professional Resource Guides address many of the key factors and current industry best practices regarding PV system design and can be used as a resource. Below is a brief description of components of system design. System designs may vary in content, scope, and location depending on customer and local requirements. The Contractor is responsible for the PV system design (outsourcing is acceptable, provided the details of the design are confirmed onsite). Key factors of PV system design include:

- System design in accordance with state and local AHJ building and safety requirements.
- Accuracy of collected site data (e.g., roof dimensions and slope, existing electrical equipment locations, shade analysis).
- Proper application of applicable codes (e.g., National Electrical Code [NEC], International

- Residential Code [IRC], International Fire Code [IFC], and International Building Code [IBC]).
- Consideration of customer priorities (e.g., aesthetics, maximizing power production, offsetting electrical bills, equipment manufacturer preferences, equipment location preferences).
- Maximizing value of system to avoid expensive scopes of work that are proportionally inefficient based on economics of the system owner (unless system owner specifically states preference).
- Necessary information for applicable AHJs for procuring all permits and approvals, which could include:
    - Site plan.
    - System Size.
    - Electrical diagram (1- or 3-line as required).
    - Roofing system elevation drawing (including roof type and flashing/attachment).
    - Structural design inputs (e.g., design wind speed, and design snow load).
    - Foundation and support structure details (ground mount).
    - Electrical system details (e.g., interconnection method, conductor and Overcurrent Protection Devices [OCPD] calculations, conductor and conduit sizes, grounding/bonding topology, and equipment ratings).
    - Installation detail for mounting system stand-off and roof penetration.
    - Roof framing details (type of sheathing and thickness, i.e. OSB 7/16”, 15/32 or 19/32 Ply, etc.)
    - Design checks (e.g., rail span tables and roof attachment span calculations for each roof zone).
    - Equipment data sheets.
- Necessary information for interconnection filing with utility, which could include:
    - Annual electrical consumption.
    - Single line diagram; although three-lines may be preferred.
    - Equipment specifications.
    - Site Plan.

Snow retention devices may be required in specific areas where homeowners are at risk of snow/ice shedding. Examples of sensitive areas for hazards of sliding snow and ice include roofs over building entries, driveways, and decks. System designs shall incorporate the additional loads added by the snow retention devices in the load calculations.

Equipment Requirements

This section is focused on providing various industry standards to develop a minimum requirement for common components of a solar PV system. Code requirements for equipment can be referenced in the International Code Council (ICC) International Solar Energy Provisions (ISEP) publication, which compiles solar energy provisions from the International Codes, National Electrical Code and related ICC and UL Standards. Reasonable expectations of component manufacturers:

- Manufacturers should remain willing to participate in third-party audits and provide third party warranties if required by the Contractor or Capital provider.
- Manufacturers should assist with reasonable Return Merchandise Authorization (RMA) requests resulting from product deficiencies or degradation within the warrantied timeline.
- There are various qualified equipment lists, known as Approved Vendor Lists (AVLs) that are actively maintained as approved equipment for their respective solar installation and finance programs. Federal, State and local organizations may also offer clean energy and clean manufacturing incentives that may influence product selection.

Equipment - Solar Photovoltaic Modules Baseline Requirements:

- UL 1703 Flat-Plate Photovoltaic Modules and Panels;
- UL/IEC 61730-1: - Photovoltaic (PV) module safety qualification - Part 1: Requirements for construction and component requirements.
- UL/IEC 61730-2: - Photovoltaic (PV) module safety qualification - Part 2: safety testing requirements.
- ASTM E2481-12, Standard Test Method for Hot Spot Protection Testing of Photovoltaic Modules.
- Manufactured using an ISO-9001 quality management system.
- Manufactured using an ISO-14001 Environmental Management System.
- Pollution Degree requirements as included in UL/IEC 61730 standards.
- If installed in Hazardous Locations as defined by 29 CFR 1926, complies with OSHA 1926.407.
- Modules are manufactured with materials ethically produced.

- Modules are certified by relevant state authorities / commissions to qualify for consumer incentives as applicable.

Equipment - Inverter Baseline Requirements:

- UL 1741 Standards for Inverters, Converters, Controllers and Interconnection System Equipment for Use with Distributed Energy Resources; including UL 1741 SA (Supplement A) testing requirements, UL 1741 SB (supplements B) interoperability conformance testing.
- IEEE 1547 Standard for Interconnecting Distributed Resources with Electric Power Systems with Associated Electric Power Systems Interfaces.
- IEEE 1547.1 Standard for Conformance Test Procedures for Equipment Interconnecting Distributed Resources with Electric Power Systems and Associated Interfaces.
- IEEE 2030.5 2018 Smart Energy Profile Application Protocol.
- Inverter installation requirements are governed by the National Electrical Code Articles 690 and 705, Part II lists requirements of Utility Interactive inverters, including circuit sizing and overcurrent protection; see relevant state adopted codes for appropriate version in effect.
- UL 3003 Distributed Generation Cable.
- Manufactured using an ISO-9001 quality management system.
- Manufactured using an ISO-14001 Environmental Management System.
- Inverters are manufactured with materials ethically produced.
- Inverters may be subject to certification by relevant state authorities/commissions for consumer incentives.

Various jurisdictions have inverter-specific requirements including, but not limited to:

- For systems connecting under the Customer Self Supply (CSS) tariff in HI, inverters should be compliant. https://www.hawaiianelectric.com/Documents/clean_energy_hawaii/list_of_advanced_legacy_equipment.pdf
- Systems subject to Rule 21 in CA should provide certain smart inverter functions (e.g., voltage/frequency ride-through, volt / VAR control, energy storage dispatch) in accordance with UL 1741 and IEEE 1547 which are being implemented in phases. IEEE 2030.5 defines the communications protocols and IEEE 1815 addresses direct SCADA control and management.

Equipment - Disconnect Baseline Requirements

- A disconnect should be installed to isolate the PV system from the rest of a building's electrical system for the purpose of safety during installation, maintenance, service, and for first responders.
- AC disconnects should be located near the main utility interconnection for accessibility.
- AC disconnects are required to have a visible-break and lockable per NEC 110.25.
- PV disconnects should meet the requirements of NEC 690.17

Equipment - Conductor Type Baseline Requirements

- Conductor type/insulation should be suitable for the environment in which it is installed and compatible with the ratings of the PV system equipment and terminals.
- Wiring methods shall meet the specific requirements of NEC 690.31 and Chapter 3 in the NEC.
- UL 3003 listed Distributed Generation Cables.
- For outdoor PV cable, tinned copper wire should be used.
- IEC 62852 Connectors For DC-Application In Photovoltaic Systems - Safety Requirements And Tests.
- IEC 62852 Amd.1 Ed. 1.0 b:2020 - Amendment 1 - Connectors For DC-Application In Photovoltaic Systems - Safety Requirements and Tests.
- PV connectors from different manufacturers should not be -cross-mated (connecting one brand to another brand). Cross-mating often voids warranties and violates installation instructions.
- Field-made connectors must be assembled in accordance with the connector manufacturer's instruction manual with the crimping and torquing tools specified.
- For connections on the supply (utility) side of the service disconnecting means, wiring methods shall follow NEC 230.43.

Equipment – Conduit & Raceways

- NEMA Ratings for raceways and conduit fittings shall be in accordance with site-specific environmental conditions.
- NEC 314.15(A) Requirements for conduit bodies installed in damp and wet locations.
- NEC Chapter 9: Combinations of conductors of different sizes or insulation types installed in the same conduit or tubing.
- NEC 310.15 Ampacities for Conductors 0-2000v.
- Securement and Support per NEC 358.30 and 310.15(B)(3)(c).
- Grounding and Bonding per NEC Article 250.
- Labeling – AC vs DC labeling on microinverter systems, “Photovoltaic Power Source” vs “AC Photovoltaic Power Source”
- Aesthetics – Avoid conduit runs across open rooftop, utilizing attic or crawl space when possible.

Equipment - Storage Baseline Requirements

The NEC has sound guidance for the installation of energy storage systems. These systems are covered in Article 706 which applies to all energy storage systems having a capacity greater than 1 kWh that may be stand-alone or interactive with other electric power production sources. The informational note in 706.1 suggests utilizing the following standards for Energy Storage Systems, where applicable:

Design Standards

- NFPA 111, Standard on Stored Electrical Energy Emergency and Standby Power Systems, if applicable.
- IEEE 484, IEEE Recommended Practice for Installation Design and Installation of Vented Lead-Acid Batteries for Stationary Applications.
- IEEE 1187, IEEE Recommended Practice for Installation Design and Installation of Valve Regulated Lead-Acid Batteries for Stationary Applications.
- IEEE 1578, IEEE Recommended Practice for Stationary Battery Electrolyte Spill Containment and Management.
- IEEE /ASHRAE 1635, Guide for the Ventilation and Thermal Management of Batteries for Stationary Applications.

Product Safety Standards

- UL 9540, Standard for Energy Storage Systems and Equipment.

- UL 1973, the Standard for Batteries for Use in Stationary Applications.
- UL 1989, Standard for Standby Batteries.
- UL 2436, Outline of Investigation for Spill Containment for Stationary Acid and Alkaline Electrolyte Battery Systems
- Fire Safety Standards: NFPA 855

Equipment - Racking Baseline Requirements

Safety Standards for Grounding, Bonding, and Fire Testing

- UL 2703 - Standard for Mounting Systems, Mounting Devices, Clamping/Retention Devices, and Ground Lugs for Use with Flat-Plate Photovoltaic Modules and Panels. Covers mounting systems, including mounting devices, clamping devices and ground lugs for use with photovoltaic modules and panels and contains requirements for ground-mounted and roof systems as part of a nonstructural building component.
- ANSI/CAN/UL 3741 Photovoltaic Hazard Control. These requirements provide a means for evaluation of PV Hazard Control components, equipment and systems that provide a reduced level of shock hazard from energized PV system equipment and circuits located within the PV array per NEC 690.12.(B)(2). The PV array shall be installed by qualified persons in accordance with the UL 3741 installation instructions and all applicable installation codes and standards.

Structural Considerations

Structural Design Requirements

- ASCE/SEI 7 Minimum Design Loads and Associated Criteria for Buildings and Other Structures. Racking design shall be in accordance with ASCE/SEI 7, which describes the means for determining design loads including dead, live, soil, flood, tsunami, snow, rain, atmospheric ice, seismic, and wind loads and their combinations for general structural design. Additional requirements, such as those prescribed in the IRC, IBC, and SEAOC PV, shall also be considered and utilized as required by the reviewing jurisdiction. Thermal break requirements: Due to thermal contraction and expansion forces, racking and mounting systems provide maximum array lengths that can be installed before installing a thermal break. Roof attachments may have different thermal break requirements than the racking. Ensure the lesser of the two are included in the array design. PV modules should never be installed over a thermal break.

Equipment - Monitoring System Requirements

To support performance verification and O&M services, a monitoring system is highly recommended. This ensures the ability of a provider to proactively identify performance issues in a timely, effective manner. Key features of a residential PV monitoring system include:

- Compliant with IEC 61724-1 Photovoltaic System Performance - Part 1: Monitoring.
- Listed:
  - For field installed equipment, production metering devices shall be listed. Should comply with relevant safety standard (e.g., UL 916, UL 2735 or as appropriate).
  - Reliable communications either over the network or a dedicated cellular connection if required.
- Labeling:
  - Identify and label solar monitoring devices/equipment for customers (ethernet cables, powerline adapters, range extenders) to avoid disconnections and 3rd party (internet service providers, cable company, etc.) interference.
  - Remote data access functionality:
  - Established workflow to provide third-party users (such as installer, TPO firm, bank investor) authorization to access relevant system data.
  - APIs available to access monitoring data.
- Monitoring and Data access:
  - Operational data should be captured in a minimum of 15 min intervals and exported to the PV monitoring portal.
  - Historical data should be made available on-line via a portal or website that allows the relevant stakeholders access to the relevant data.
  - The chosen monitoring platform should support operational monitoring by providing viability of onsite equipment faults and fault codes and allow for custom alerting based on specific performance parameters.
  - Production data should be easily exportable and transferable to other platforms or programs utilized by various stakeholders.

- Data points to be available on monitoring platform:
    - AC voltage, current and frequency at generation meter or Inverter.
    - DC voltage and current.
    - Inverter fault-codes.
    - Inverter internal register values.
    - Network connection health.

Equipment - Metering Hardware

- The system should be equipped with a metering device that allows for recording of system production for the purposes of invoicing and determining gross or net production depending on the terms of the interconnection agreement.
- ANSI C12.1-2022 specifies performance criteria for AC energy meters including installation, testing, and measurement accuracy.
- Meter Access and data should be made available to all relevant stakeholders including Utility and/or Off-taker, Owner, and regulatory or certifications agencies.

Equipment - Electrical Components Baseline Requirements

- National Electrical Code version as currently required in the installation locale.
- IEC 62852 – Connectors For DC-Application in Photovoltaic Systems - Safety Requirements and Tests.
- IEC 62790 – Junction Boxes for Photovoltaic Modules - Safety Requirements and Tests.
- UL 1565 Positioning Devices.
- UL 2703 Standard for Mounting Systems, Mounting Devices, Clamping/Retention Devices, And Ground Lugs for Use with Flat-Plate Photovoltaic Modules and Panels.
- NEMA- and/or IP-rated enclosures appropriate for environmental conditions.
- Documentation (white papers) showing all applicable product “listings” (e.g., UL) should be made available by manufacturer to be provided to AHJ upon request.

Defined Installation Best Practices

The following resources define solar PV installation best practices. Additionally, installations should be compliant with all state, utility, and local AHJ requirements, as well as equipment manufacturers’ installation requirements.

Installation - System Grounding and Bonding

- Proper bonding and grounding is an important safety element of an installed PV system. Grounding and bonding for PV systems is covered in NEC 690(V), along with many sections of Article 250. A grounding system consists of:
  - Equipment-Grounding Conductors.
  - Grounding-Electrode.
  - Grounding-Electrode Conductor.
- The purpose for the Equipment Grounding (EG) system is to ensure that there is no hazardous voltage between non-current carrying metal parts of a system and Earth (NEC 690.43). Non-current carrying metallic equipment (both DC and AC) should be grounded per the requirements of the NEC 250 and equipment manufacturer. This includes metal raceways, enclosures, mounting hardware, module frames, conduit fittings, etc.
- If there is a Lightning Protection System (LPS) existing on the building, the Engineer of record for the PV system should make a determination as to whether, and how, to bond the array EG to the LPS main ground.

Installation - Labeling Best Practices

Strict conformance to system marking (or labeling) requirements of PV systems and their components is crucial for the safety of operators, service personnel, emergency responders, and others. PV system general labeling requirements are covered in NEC 690 Ch. VI, as well as specific accompanying requirements throughout Articles 690 and 705. Required and desired labeling language shall be included in the design drawings. Electrical equipment and components used in PV systems have markings identifying the manufacturer, size, type, ratings, hazard warnings, and other specifications. Equipment markings should never be removed, and equipment markings should be durable for the environment in which the equipment is installed per NEC 110.21. This is also referenced similarly in the International Fire Code (IFC) labeling requirements. It is recommended that the adhesives used in non-riveted labels meet the UL 969 labeling standards. In addition, markings should be visible or easily accessible during and after installation.

Field-applied markings are required for certain components and for the inclusive PV system.

These markings should be designed to withstand the environment in which they are installed (e.g., "UV rated" for outdoor labels [i.e., ANSI Z535 and NEC 110.21]) and permanently affixed to the respective equipment in a manner appropriate for the environment and compatible with the substrate materials, while not obscuring manufacturer-applied labeling.

Field-applied markings are required on many types of equipment and components, and may include (but are not limited to):

- Conductors.
- Circuits.
- Connectors.
- Raceways/cables/conduits.
- Disconnecting means.
- Point of utility connection.
- Bi-polar arrays and ungrounded arrays.
- Battery storage systems.
- Standalone inverters provide a single 120-volt supply.
- Rapid shutdown equipment.
- Other markings as required by codes and local AHJ requirements.

Installation - Mechanical Components

Though a PV system's purpose is electrical in nature, it is very important that the components are mechanically installed in a manner appropriate for the local environment. This holds true for all types of installations but is particularly important for residential rooftop installations due to the load forces to which they may be exposed (e.g., wind, snow, seismic), and the potential damage to life or property that could occur if mechanical connections were to fail.

Applicable codes for the installation of mechanical components include:

- State specific Codes, i.e. CBC & FBC.

Installation – Mounting/Racking Systems

PV modules are typically attached to roofs via purpose-built metal (usually aluminum) mounting systems. Module mounting systems should be certified (Listed) for the application and capable of withstanding the uplift (due to wind) and downward forces (e.g., snow-load) to which they could potentially be exposed based on the specific location of the installation, including an appropriate safety factor.

Consider the following important items when installing the mounting system:

- Appropriate flashing and weather sealing of all penetrations of the building envelope, including conduit, lag bolts, screws for mounting equipment, and other types of penetrations through the roof plane.
- Building code requirements related to array setbacks (requirements vary based on roof design and building occupancy type).
- Dead loads that result from the weight of the array, including any ballast material that may be required by the racking manufacturer and local building codes.
- Environmental loads (e.g., wind, snow, seismic, and sliding snow) and the impact these loads will have on the array components, including uplift, shear (or lateral) loads, and the spacing between rails and attachments to the roof structure or foundation.
- Compliance with local building codes when navigating existing vents or equipment on the roof.
- Best practices for working with a given roof covering as per the Roofing Manufacturer's installation instructions, the National Roofing Contractors Association Roofing Manual for composition shingle roofs, Tile Roofing Industries Alliance Manuals for tile roofing systems, and applicable installation instructions for other roofing systems.
- A balance of customer aesthetics expectations with code requirements and airflow directives from the module or racking manufacturer.
- Assessment of the roof structure (usually via attic or crawl space inspection) for lumber and sheathing type, dimension, condition and proper attic ventilation.
- Assessment of the condition of the roofing system. If the roofing system needs replacement before the end of the expected PV system lifetime (20-25 years), the homeowner should consider roof replacement prior to PV system installation. The contractor should notify the customer of any estimated re-racking costs if removing

and installing new equipment for the PV system if required as part of the roof replacement process.

- Usage of the appropriate size and type of fasteners for the application, which meet the required loading conditions, including applicable safety factors, and achieve the proper embedment in the substrate.
- Use of flashing systems, and/or sealants, with the recognition that these are separate products that serve different functions based upon the PV system design.
- Comprehension of the cause and effect of inter-row shading in tilted arrays. The span and cantilever limitations of the mounting system.
- Fastener torque specifications.
- Impacts of local ordinances on the installation of ground mounted systems, including property setbacks, physical size, and visual impact.

Mixing of Listed system components from different racking systems, unless specifically referenced in the Installation Manual, is not Code-compliant. UL 2703 requires all grounding and bonding components to be tested together as a system. Further information on PV mounting structure installation can be found in resources such as the NABCEP Resource Guide and Solar Energy International's Solar Electric Handbook.

Installation - PV Modules

There are a variety of module construction types (e.g., metal-framed, frameless, and bi-facial), but the majority of PV modules used in residential applications are aluminum-framed, poly- or mono-crystalline, glass-enclosed laminates. Regardless of construction type, care should be taken to comply with all manufacturers' installation instructions concerning the transportation, storage, mounting, grounding, and connecting of the PV modules. Failure to do so could result in voiding of the module warranty, underproduction of the PV system over time, and increased shock- or fire-hazard risk.

Important items to consider when installing the PV modules include:

- Module Manufacturers' Installations Instructions are Series-specific and required in order to maintain Code Compliance and Product Warranties.
- Awareness of specific mounting location stipulations from the module manufacturer, which can be found in the series-specific PV Module Installation Manual.
- Understanding of the different module mounting options, such as bolting the module frame to the mounting structure or clamping the frame with the compatible hardware and compression force.
- Ensure that the module load rating is adequate for the project. The listed permissible design loads for the module must exceed the design loads with key consideration of wind loads and snow loads. The design loads will impact the specific clamping zone

requirements. Module manufacturers may also perform Florida High Wind testing with specific racking systems, and this can be used in lieu of UL 1703/61730 load rating for permitting.

- Appropriate use of fall protection equipment is particularly important during array installation because PV modules tend to be large and unwieldy, presenting elevated risk for installer injury and to workers on the ground if any equipment is dropped. This risk is further exacerbated on steeper roofs.
- Knowledge of electrical safety protocols, such as ensuring that homerun conductors are not connected during installation to ensure the safety of any personnel wiring electrical equipment.
- Understanding the module bonding requirements, including the Listing of the module by the Racking Manufacturer per UL 2703.
- Ensuring wire management is completed in a neat and workmanlike manner using long-lasting materials, such as clips, to prevent conductors from contacting sharp edges or abrasive surfaces.
- Minimize the chance of module short circuits by maintaining clearance between the module back sheet and protrusions such as bolts, screws, lay in lugs, or other hardware that could compress the module back sheet.
- Follow module and racking manufacturer requirements for clamp installation and spacing, including the minimum spacing between modules and module rows. Minimum spacing required between module rows may exceed ¼" minimum required per ASCE 7. Meet or exceed minimum distance between end clamps and rail ends and follow relevant torque specifications for attachment and bonding hardware.

Installation – Inverters

- Inverter Manufacturer Installation Instructions shall be followed per IBC 3111.3.1.
- Installation Certification on the Inverter may be required to commission the system.
- Clearances.
- Sizing OCPD.
- Disconnects.

Installation - Module-Level Power Electronics (MLPE)

- The installation of MLPE shall be in accordance with manufacturer-specific installation instructions.
- MLPE should be approved and Listed by the Racking manufacturer according to the requirements of UL 2703.

- Installation Certification on the MLPE system may be a requirement in order to commission the System.

For monitoring and future O&M purposes, the serial numbers of module-level power electronics (e.g., power optimizers, microinverters) shall be mapped during installation using the MLPE Manufacturer's protocol.

Installation - Waterproofing

Roof penetration baseline requirements:

- Weather Protection: Per IRC Chapter 9, Flashings should be installed in a manner that prevents moisture from entering penetrations through the roofing system.
- Flashings should be in Accordance with UL 2703A – Flashing Devices and Systems for Rooftop-Mounted Photovoltaics: These requirements cover flashing materials, devices and systems intended to provide resistance to water penetration to the interior of the building, in situations where rack mounting systems penetrate roof covering systems. Alternatively an ICC-ESR (Evaluation Services) report indicating a flashing system is in compliance with the IBC and IRC codes is recommended.
- Exposed, Sealant-only solutions for flashing penetrations are cautioned against due to the expected lifespan of PV Systems. When sealant is utilized for un-exposed or ancillary purposes a quality sealant with an appropriate service temperature that is compatible with the substrate (roofing material) is required.
- Thermal contraction and expansion forces can affect the long-term water resistance of a roof penetration. Follow thermal break requirements for both the racking system and roof attachments, utilizing the lesser of the two.
- In regions prone to sliding snow and ice, modules and racking systems should be rated for the design. Snow load and snow guards should be installed in areas where homeowners are at risk of snow/ice shedding. When snow guards are utilized, additional loading may occur due to snow retention, and system designs must accommodate the additional loading. Examples of sensitive areas for hazards of sliding snow and ice include roofs over building entries, driveways, and decks. Fully Waterproof flashings are recommended for ice dam prone areas.

Installation – PV Ground Based Systems

- Ground-Based PV systems shall be designed and installed in accordance with IRC Chapter 3, section R301, and shall be constructed to safely support all loads.
- Systems should be Listed to UL 2703, or bond and ground according to NEC section 250.
- OSHA 2226 Trenching and Excavation Safety.

- IBC 1806.2 Soil Classification and Load Bearing Values.
- Soil testing shall be considered when the soil is known to be corrosive or acidic.
- Foundations shall be installed below the freeze/thaw depth.
- Consideration should be given to the risk of flooding in the area of installation.
- Vegetation control should be conducted per NFPA 1, Fire Code.

System Interconnection

Before a grid interactive PV system is allowed to operate legally, the local utility will need to provide written Permission to Operate (PTO) or Interconnection Agreement. Similar to PV permitting, PV interconnection requirements vary widely, but are generally based on one or a combination of the following three major interconnection standards:

- FERC's Small Generator Interconnection Standards (SGIP).
- California's Rule 21.
- IREC's Model Interconnection Standards.

The interconnection of a distributed generation system, such as a PV system with the local utility, depends upon state regulations and utility policies and practices. Freeing the Grid, a joint effort of Vote Solar and IREC, provides a detailed evaluation of interconnection provisions that have been adopted in each state. In states where interconnection procedures have not been formally adopted, those procedures are typically under the jurisdiction of the utility. (FOOTNOTE: Regulated interconnection procedures for consumer-owned utilities may differ from those of investor-owned utilities).

Interconnection guidelines and state- and utility-specific rules can usually be accessed by installers through the utility regulator, such as a public utilities commission, or utility websites. Contractual aspects of interconnection include fees, metering requirements, billing arrangements, and size restrictions on the system. Understanding the local utility's requirements is a very important process and varies for each local utility. In addition, national and local codes have interconnection and system equipment and labeling requirements so that the system can be easily identified and/or shut off. For example, some states or utilities require a readily accessible external disconnect switch.

The NEC specifies how the output of a PV system can be connected to the utility in Article 705. The two relevant connections would be:

- Supply side (similar to installing another service onsite and is usually found for larger installations) of the service disconnecting means.
- Load side (most commonly used for smaller systems and requires a dedicated circuit breaker or overcurrent device) of the service disconnecting means. Please note that load side connection requirements can vary by AHJ. It is imperative to understand these requirements to prevent complications during the final inspection.

The Contractor should apply for interconnection approval as early in the process as possible. This allows added costs or barriers to be factored into the decision to install at a particular location, as it can impact decisions about system design. The need for transformer or other equipment upgrades on local circuits can change the economics of a project and should be identified as early as possible.

In areas with a high penetration rate of distributed generation facilities, such as solar PV projects, export control methods that limit the maximum output of the facility below the inverter's nameplate rating may be required by the utility in order for a PV system to be safely interconnected to the utility's distribution system.

Changing the true-up anniversary date for a net-metered project from the date interconnected to a date that accommodates any banked hours to be fully utilized can affect the financial payback of the system.

Further details on interconnection requirements can be found on the Database of State Incentives for Renewable Energy and from the local Utility.

System Documentation

Contractors should store basic homeowner and system information for the term of the initial customer agreement.

Outlining the minimum documentation that should be provided for grid-tied residential PV systems will ensure transparency to investors of basic system components (information on design and installation, and O&M requirements). Additional data may be required by financiers, including consumer credit metrics and EPC cost, but are not included on this document for brevity.

The Contractor shall maintain a photo inventory of all active systems. Photos may be captured through the installation Contractor, third-party inspector, or in-house personnel. A photo inventory allows the Contractor to have a strong understanding of onsite conditions and the overall level of quality of the system. It will also reduce O&M costs and may even assist an AHJ during an inspection. Photos shall be stored throughout the life of the service contract and retrievable through customer/address query. Electronic capture and cataloguing of site information is preferred to ensure consistency and accuracy.

See Required Information Matrix located in the References section below.

Site specific warranty documentation is critical for the Operations and Maintenance of a solar PV system. Warranties by the Contractor should specify the home address and clear terms of the warranty and/or O&M services included in the initial purchase transaction. Many manufacturer warranties require registration with the manufacturer for the warranty to be valid. Many manufacturers also have specific transferability clauses that require notice in the event of a change in ownership of the system. It is always encouraged for all warranties to be 1) site specific, listing the address and system owner name and 2) to be kept on files by the Contractor and Finance Provider during either the lifespan of the system or term of the financing.

Nonpublic Personal Information Disclosure

As a best practice, Contractors should not collect, share or retain nonpublic personal information, unless they are prepared to meet federal and state consumer protection requirements. Examples include, but are not limited to, social security number, birthday, income, and any documentation showing this information (driver's license, utility bill, etc.). It is important to understand that complying with consumer protection standards takes enterprise controls and compliance management capabilities, therefore, if the Contractor business is not able to accommodate these requirements, then it should not retain any of this data.

Quality Management & O&M Best Practices

System Documentation

A complete list of required data and documentation for each system financed is listed below in the Required Documentation section.

Finance Providers or Contractors should store basic homeowner and system information for the term of the initial customer agreement. Data naming methodology should follow the Orange Button taxonomy. Outlining the minimum documentation that should be provided for grid-tied residential PV systems will ensure transparency to investors of basic system components, information on design and installation, and O&M requirements. Additional data representing consumer credit worthiness is not included in this list.

When storing these datasets, it is important to remember that certain combinations of customer information-such as utility bill numbers combined with name and address are considered Personally Identifiable Information (PII) and may be subject to regulations and privacy laws. These factors should be considered when designing a data storage/filing system and establishing company policies related to emailing and transferring information.

Third-party Inspection and Verification

Finance Providers or Contractors should measure and verify installed asset quality through a continuous process of third-party Field Inspection Verification (FIV) of the Finance Provider's completed systems. For the purposes of this document, a third-party inspector shall mean any technically qualified party that was not directly involved in the system installation or design. The third-party inspector can be part of the installation company (e.g., part of the O&M division) or an entirely separate entity.

The FIV process includes onsite inspections of completed system installations to verify the systems have been installed in accordance with specifications, codes, and installation best practices. This process is essential to the checks and balances of solar as an asset class. Inspection results should be shared with Contractor Consumers for a continuous improvement process of installation quality.

Third-Party Inspector Qualifications

The third-party inspector should have one of the following professional credentials and have specific knowledge of solar PV design and installation.

- NABCEP PV Installation Professional Certification.
- NABCEP PV Installation Specialist Certification.
- NABCEP System Inspector Certification.
- UL Certified PV System Installer.

- Licensed Professional Engineer.
- Licensed Electrician.
- ICC Certified Electrical Inspector and/or Plans Examiner.
- Equivalent proprietary training programs.

Sampling Protocols

Inspection determination should be performed using a stratified random sampling method of completed systems per quarter. The variables used for the stratified, random selection process should include: 1) installation Contractor and 2) asset geographic region. The stratified sampling method ensures that the random sampling collects a statistically meaningful sample population. The sample population should serve as a statistical representation of the overall population of the Finance Provider's fleet. Quality metrics collected through inspections should be gathered on a regular basis so that the Finance Provider and Contractor can make continuous adjustments to improve the overall results.

The minimum sampling protocol shall be no lower than three percent (3%), per contractor, on a rolling annual basis. Additional percentages may be used by Finance Providers to properly mitigate risks. Field inspections may also be supplemented with independent desktop reviews of onsite photos; however, such desktop inspections should not be used as a substitute for onsite inspections.

Inspection Checklist and Scoring System

The FIV should result in a system quality scoring metric that can be used as a quantifiable quality assessment of the initial installation.

- Pass/Fail – For each inspection, a report shall be issued that summarizes the issues identified and provides the Contractor with a list of deficiencies requiring corrective action. The report shall also include the overall quality score.
- Define System Components – Data and photos collected on the FIV shall include inverter, modules, conduit/junction box, AC disconnects, DC disconnects, PV system labeling, grounding/bonding, wire management, roof conditions, flashing, shading, and system layout.

Fleet Monitoring

O&M plans rely heavily on accurate and timely data and as such, monitoring systems should be designed to meet those needs for the duration of the system lifespan. Hardware, communication, backend meter data management system/support, and data presentation should be well thought out so that all the components work together seamlessly, and transfer of responsibility is painless.

Monitoring systems should be set up in such a manner that the production data for each system is authorized to be accessed via a dedicated login by the Contractor. Finance Providers may also have direct access to systems financed but shall, at minimum, have the contractual rights to access the monitoring at the Finance Providers' request. System production monitoring is primarily a function that involves only the Contractor and System Owner, however, there are many reasons such as asset reliability and disaster response in servicing, that a Finance Provider may need direct access to system monitoring.

Operations & Maintenance

Residential systems should be designed and installed in a manner that will minimize the need to perform on-site service. Through fleet monitoring, systems that have a reduction in expected production or are offline should be remediated and resolved in a timely manner.

Residential O&M Service contracts are available in many States and can be offered to customers during contract negotiation and may be required or supplied by the Finance Provider.

The Contractor should be in compliance with SEIA's Operations & Maintenance Best Practices and associated Standard.

References and Resources

Required Information Matrix

The following matrix guides Contractors and Finance Providers with 1) which data they should record and store for servicing and 2) provide to the System Owner.

Data Type	Contractor	System Owner	Finance Provider
Required System Documentation - Site Information			
Plant identifier	X	X	X
Site owner name	X	X	X
Site owner address	X	X	X
Site owner city	X	X	X
Site owner state	X	X	X
Site owner zip code	X	X	X

Site owner phone number	X	X	X
Site owner email address	X	X	X
Site owner's utility company	X	X	X
System's Commercial Operations Date / PTO Date	X	X	X
Required System Documentation - System Information			
Design and Production Estimation Tool Used (PVWatts, Aurora, etc.)	X	X	X
System Capacity kWDC	X	X	X
System Output kWAC	X	X	X
Derate factor	X	X	X
Total number of arrays	X	X	X
Array tilt (per array)	X	X	X
Array azimuth (per array)	X	X	X
Module manufacturer	X	X	X
Module model	X	X	X
Module capacity (DC-STC)	X	X	X
Module quantity	X	X	X
Inverter manufacturer	X	X	X
Inverter model(s)	X	X	X
Inverter capacity (Max. AC output)	X	X	X
Inverter number of units	X	X	X
Racking manufacturer	X	X	X
Racking model	X	X	X
Solar availability (%)	X	X	X
Number of Strings	X	X	X
String Configuration per Maximum Power Point Tracker (MPPT)	X	X	
Monitoring Hardware Manufacturer	X	X	X
Monitoring Hardware Model	X	X	X
Monitoring System Provider	X	X	X

Required System Documentation - As-Built Photo Inventory			
Overall Array (showing all modules from above)	X	X	X
Array Horizon (shading)	X	X	X
Module Nameplate (one for each unique make/model used)	X	X	
Conduit Runs and Support (with at least 3 examples of mounting/supporting hardware shown with close-up images)	X		
Junction Box Locations	X	X	X
Junction Box Interior	X		
Under Array and Circuit Wire Management	X		
Flashing of Roof Penetrations (with at least 3 examples shown in close-up photos)	X		
Balance of System (taken standing back to provide single image of all new BOS components)	X	X	X
DC Disconnect Location	X	X	X
DC Disconnect Interior	X		
Inverter Location	X	X	X
Inverter Nameplate	X	X	X
AC Disconnect location and interior	X	X	
Main service panel (cover open)	X		
Main service panel (cover closed)	X		
Connection to premises grounding	X	X	
Production Meter	X	X	X
Monitoring system	X	X	
Utility Meter	X		X
Interconnection Point (line/load taps)	X	X	
Required System Documentation - Documents (PDF)			
Design Drawings (One Line Diagram)	X	X	
Permit Approval from AHJ	X	X	X

Contractor Warranty Terms	X	X	X
Solar PV module Warranty Documentation	X	X	X
Inverter Warranty Information	X	X	X
Third-party Warranty or Service Plan Documentation (as applicable)	X	X	X
Operations and Maintenance System Manual	X	X	
Utility Permission to Operate	X	X	X
FIV Report (with documentation of issues resolution)	X	X	X

Additional Resources

Installation - Additional Resources

Note that the resources below were suggested by members of the Quality Assurance Working Group as helpful references.

- NFPA 70: National Electrical Code 2023.
- NFPA 70E: Electrical Safety in the Workplace.
- International Building Code Section 1504.
- NABCEP Photovoltaic (PV) Installer Resource Guide.
- Best Practices for Solar Photovoltaic Installations - Renewable Energy Vermont Partnership Program.
- IEC 62446 Commissioning Standard .
- Green Job Hazards: Solar Energy.
- Structural Seismic Requirements and Commentary for Rooftop Solar Photovoltaic Arrays by the Structural Engineers Association of California (SEAoC).
- Mike Holt's Solar Photovoltaic Systems - NEC Requirements for Solar Photovoltaic Systems.
- Solar Photovoltaic Basics: A Study Guide for the NABCEP Associate Exam by Sean White.

Installation – Labeling Additional Resources

- ANSI.org, ANSI Z535.4-2011, Product Safety Signs and Labels.

- Hellermann Tyton PV System Labeling Guide.
- IBTS Guide to System Labeling.

Interconnection Additional Resources

- IEEE 1547 - Standard for Interconnecting Distributed Resources with Electric Power Systems.
- IEEE 1547.1 - Standard for Conformance Tests Procedures for Equipment Interconnecting Distributed Resources with Electric Power Systems.
- IEEE 1547.2 - Application Guide for IEEE 1547 Standard for Interconnecting Distributed Resources with Electric Power Systems.
- IEEE 1547.3 - Guide for Monitoring, Information Exchange, and Control of Distributed Resources Interconnected with Electric Power Systems.
- IEEE 1547.4 - Guide for Design, Operation, and Integration of Distributed Resource Island Systems with Electric Power Systems.
- IEEE 1547.6 - Recommended Practice for Interconnecting Distributed Resources with Electric Power Systems Distribution Secondary Networks.
- NEC 690, 705.
- Model Interconnection Procedures, Interstate Renewable Energy Council.