



Solar Electric

Installation Requirements

Developed by Energy Trust of Oregon

V 15.1

Acknowledgments

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Revisions

Energy Trust updates these installation requirements annually. Many thanks to the industry members and technical specialists that have invested their time to help keep this document current. Revisions from the previous versions are summarized in Tables 1a & 1b, below.

Table 1a. May, 2011 Revisions

Section	Revision
2.1.6	New requirement for the preparation and submission of physical layout
2.1.7-8	Sections renumbered
2.2.5	Revised to specify stainless steel fasteners for modules and racking
2.3.3	New requirement specifying the proper sealing of building penetrations
2.3.4-19	Sections renumbered
2.3.11	Revised to recommend the testing of high current carrying conductors
2.3.12	New requirement for DC conduit types
2.3.13	Revised requirement and references to correspond to 2011 NEC
2.3.15	Revised to prohibit bell-type boxes in some locations
2.3.18	New requirement for inverter installation locations
2.3.19	Eliminated requirement for certain AC disconnects for micro-inverter installations
2.5.1	Corrected language
2.6.1	Revised to limit inverter input power
2.6.1	Revised reference temperatures for adjusted array voltage calculations
2.6.2	Eliminated requirement to include wire whips in voltage drop calculations
2.6.4	Revised to limit installations at multiple orientations and/or pitches
2.7.1	Revised requirement specifying meter display
2.7.3	Revised labeling requirement to include "Customer Owned" on output meter
3.1	New requirement for the inclusion of physical layout diagram in customer manual

Table 2b. January, 2012 Revisions

Section	Revision
2.3.9	Requirements for inverter disconnects clarified

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1.0 Purpose

This Solar Electric Installation Requirements document details the requirements and minimum criteria for a solar electric (“photovoltaic” or “PV”) system (“System”) installed by a Solar Electric Program trade ally under Energy Trust’s Solar Electric Program (“Program”).

The purpose of these installation requirements is to help promote the performance and longevity of systems that receive Energy Trust incentive funding. Energy Trust reserves the right to require compliance with installation specifications that may exceed manufacturer or code requirements. Any variations from the Program’s installation requirements shall receive prior approval from Energy Trust.

2.0 System Requirements

2.1 General

- 2.1.1 System shall be grid-connected and installed on real property in Oregon that receives electrical service directly from Portland General Electric or Pacific Power.
- 2.1.2 System shall meet local utility interconnection and net metering requirements, if applicable.
- 2.1.3 The installation shall be of industry standard and workmanlike quality.
- 2.1.4 System should be designed for optimal annual performance, without sacrificing good aesthetics. **See Section 2.5.**
- 2.1.5 System design shall be documented with a schematic diagram that accurately describes all electrical components to be installed and the wiring design. Diagram should include:
 - Module series/parallel wiring
 - Conductor and ground wire types and sizing
 - Conduit types and sizing
 - Voltage drop calculations
 - AC breaker sizing
- 2.1.6 System design shall be documented with a physical layout diagram that accurately describes locations of major system components. Diagram should include:
 - Layout of roof or installation location including existing obstructions
 - Locations of installed modules and inverter(s)
 - Locations of pre-existing photovoltaic or wind components
 - Locations of submitted TSPF measurement(s)
- 2.1.7 System shall be properly permitted, inspected, and in compliance with all applicable building and electrical codes.
- 2.1.8 System equipment installers shall be licensed according to the Oregon Building Codes Division and shall be working for a contractor that is licensed according to the Oregon Construction and Contractors Board.

2.2 Materials

- 2.2.1 Materials used outdoors shall be sunlight/UV-resistant and listed for outdoor locations.
- 2.2.2 Materials used shall be designed to withstand the temperatures to which they are exposed.
- 2.2.3 Dissimilar metals that have galvanic action (such as aluminum and steel) shall be isolated from one another using industry standard practices (such as non-conductive shims, washers, or other methods).
- 2.2.4 Aluminum shall not be placed in direct contact with concrete materials.
- 2.2.5 Fasteners used to secure modules and racking equipment shall be stainless steel. For substructure components, only high-quality fasteners shall be used (stainless steel is preferred). Stainless steel bolts shall be coated with an anti-seize lubricant to prevent galling and allow for removal during system maintenance or repair.
- 2.2.6 Structural members shall be either:
 - Corrosion-resistant aluminum.
 - Hot-dip galvanized steel per ASTM standard A123 equivalent or better.
 - Coated or painted steel (not allowed in marine environments).
 - Stainless steel (recommended for marine environments).
 - Outdoor rated pressure treated lumber or laminated beams:
 - Shall be installed using roofing flashing methods to prevent water pooling and UV exposure on top surface.
 - Shall not be installed in direct contact with roofing material, soil, or where exposed to extended periods of pooled water.

2.3 Equipment and Installation

- 2.3.1 All installed system components shall be new.
- 2.3.2 All components shall be mounted securely.
- 2.3.3 All building penetrations shall be sealed and fire resistance maintained. To prevent intrusion by insects or vermin, all penetrations to building shell (walls, etc.) resulting from the installation of the solar system shall be permanently sealed with appropriate water and pest-proof materials. Any penetrations through fire-rated assemblies shall not reduce the fire resistance required by local codes and standards.
- 2.3.4 All electrical equipment shall meet appropriate current electrical standards and shall be listed by a nationally recognized testing laboratory (e.g. UL, ETL).
 - Inverters shall meet IEEE 929, 1374 and 1547 (listed to UL 1741) or their successor standards and shall be certified by the [California Energy Commission](http://www.gosolarcalifornia.ca.gov/equipment/inverter.php)¹.
 - Photovoltaic modules shall meet IEEE 1262 (listed to UL 1703) or their successor standards and shall be certified by the [California Energy Commission](http://www.gosolarcalifornia.ca.gov/equipment/pvmodule.html)².
- 2.3.5 Manufacturer warranties shall cover:
 - Inverter for a minimum of 5 years against manufacturer's defects

¹ <http://www.gosolarcalifornia.ca.gov/equipment/inverter.php>

² <http://www.gosolarcalifornia.ca.gov/equipment/pvmodule.html>

- PV modules for a minimum of 20 years against degradation of performance below 80% of original output under standard test conditions
- 2.3.6 All electrical equipment shall be listed for the voltage and current ratings necessary for the application.
- 2.3.7 Equipment shall not be modified such that it voids the listing or manufacturer warranty.
- 2.3.8 All required over-current protection shall be included in the system and accessible for maintenance. The inspection or maintenance of combiner or feed through junction boxes shall not require the removal or displacement of modules or other obstructions.
- 2.3.9 Listed means of disconnection shall be provided at the inverter(s) such that the inverter(s) can be safely isolated from all sources of power (DC input and AC output circuits) for service or in an emergency and:
- To allow the inverter electronics to be removed for service, disconnect switches shall be physically separable from the inverter chassis containing the main power electronics.
 - To allow safe, quick operation, the means of disconnection shall be at the location of the inverter or—for AC disconnection only—within sight of the inverter with permanent signage providing the location of the disconnect per OESC 690.56(B).
 - Disconnects shall be designed for load-break operation (e.g., blade-type or circuit breaker). Pull-out style disconnects shall not be used.
- 2.3.10 All electrical terminations shall be torqued to specification, secured, and strain-relieved as appropriate. Wire ends shall be coated with anti-corrosive compound prior to termination.
- 2.3.11 All cables, conduit, exposed conductors, and electrical boxes shall be secured and supported according to code requirements and in accordance with their performance ratings (i.e. NEMA). It is recommended that high current carrying conductors 4 AWG and larger be megohm tested to confirm integrity of insulation.
- 2.3.12 Conduit used for DC conductors shall be electrical metallic tubing (EMT). Heavy-weight flexible steel conduit or hospital grade metal clad (MC) cable may be used as an alternative where allowed by the Oregon Electrical Specialty Code (OESC).
- 2.3.13 Array equipment grounding conductors (EGC) and DC grounding electrode conductors (GEC) shall be copper and shall be either minimum 6 AWG or protected from physical damage and sized to conform to the Oregon Electrical Specialty Code (OESC):
- EGC shall be sized and protected according to OESC 690.45(A) and 690.46.
 - GEC shall be sized and protected according to OESC 690.47(C) and 250.64(B).
 - If a single conductor is used for the EGC and GEC, conductor sizing and protection shall conform to all of the OESC sections listed above.
 - Trade ally is responsible for identifying any additional OESC sections that may apply.
- 2.3.14 Twist-on wire connectors shall not be used on DC conductors or ground wires. Instead, these wire connections shall be made using terminal strips in combiner boxes, feed through blocks in junction boxes, or other similar mechanical wire splicing devices. When outdoors or exposed to moisture, twist-on wire connectors used for AC connections shall be listed for usage in a damp/wet location.
- 2.3.15 Junction boxes and combiner boxes shall be listed and suitable for their environment and conditions of use. Bell-type boxes shall not be used in a damp or wet location.

- 2.3.16 Permanent labels shall be applied to system components as required by the Oregon Electrical Specialty Code.
- 2.3.17 Disconnect switch cover plates (not switch handles) shall be secured closed for safety (i.e. padlock, zip tie, etc.).
- 2.3.18 Inverters shall be installed according to manufacturer's specifications and:
- Inverter shall not be installed in an unconditioned attic.
 - Inverter shall not be installed with direct sun exposure unless shaded by a permanent structure.
 - Inverter shall be installed in an easily accessible and readable location.
- 2.3.19 Micro-inverters shall include the installation of manufacturer-provided equipment that allows local monitoring of system performance and identification of inverter errors.

2.4 Array Mounting

- 2.4.1 If roof-mounted, the roofing material shall have at least 10 years of useful life remaining to ensure the roof will not need repair or replacement early in the System's operational life. If in question, evidence of this requirement may be met by providing either a copy of a recent roof inspection or a receipt showing the date of the most recent roof replacement.
- 2.4.2 If roof-mounted, the roof system shall be capable of handling additional load of the System. Augmentation of the structure may be required by building codes.
- 2.4.3 Array racking and mounting systems shall be engineered and installed to meet local wind, snow and seismic load requirements.
- 2.4.4 All roof penetrations shall be made watertight using roofing industry-standard methods of flashing that protect the warranty of the roof. Sealant compounds used shall be appropriate for the roofing material and application and shall not be the sole method of waterproofing.
- 2.4.5 All mounting hardware shall be installed according to manufacturer specifications.

2.5 Solar Access

- 2.5.1 Solar resource shall be measured with an Energy Trust sun chart or approved shading analysis tool from the point on the array where shading is most significant. Details on using sun charts and a list of approved shading analysis tools are available on the Energy Trust [Solar Trade Ally Forms & Resources webpage](http://energytrust.org/trade-ally/programs/solar/resources/)³.
- 2.5.2 Total Solar Resource Fraction ("TSRF") shall be 75% or greater at all points on the array. See **Program Guide for Solar Electric Trade Allies** for TSRF calculation.
- 2.5.3 It is recommended that the System be installed in an aesthetic manner that blends in with the building architecture. Small trade-offs in system performance due to sub-optimal tilt and orientation can greatly enhance the aesthetics of the installation and thereby increase long term public support for solar.

2.6 Performance

- 2.6.1 Array shall be sized to operate within the current, voltage and power limits approved and warranted by the inverter manufacturer and shall not exceed 125% of inverter output

³ <http://energytrust.org/trade-ally/programs/solar/resources/>

power rating. The temperature-adjusted array voltage shall remain within the inverter limits at the extreme high and low temperatures expected at the installation site. Where available and appropriate, ASHRAE dry-bulb design temperatures may be used (use the 0.4% high temperature and extreme mean minimum temperature). In areas where ASHRAE data is not available (e.g. at higher elevations), historical record high and low temperatures should be used.

At mid-day, module temperatures are typically much higher than ambient conditions. When calculating voltage at the extreme high temperature, use the appropriate adder from Table 2. Systems on a roof that are tilted up 10° or more from the roof plane may be considered “Rack” mounted. See [Energy Trust PV system sizing spreadsheet⁴](#) for temperature data.

Table 3. Temperature Adders for High Temperature Voltage Calculation

Array Mounting	Temperature Adder
Roof	35 °C
Rack	30 °C
Pole	25 °C

- 2.6.2 Wires shall be sized to keep voltage drop at or below 2% in the DC conductors from the array to the inverter. Voltage drop will be calculated using temperature-adjusted V_{mp} (max power voltage) of the array for the location’s average high temperature.
- 2.6.3 Wires also shall be sized to keep voltage drop at or below 2% in the AC conductors from the inverter to the service panel to maintain the AC voltage within the inverter’s operating limits.
- 2.6.4 Voltage mismatch caused by partial shading of the array, different orientations of strings within the array and by variations in module voltages shall be minimized, allowing the inverter to operate within its maximum power point window. Modules in a single string shall be installed at the same tilt and orientation or with no more than 10° variation.

2.7 Output Meter

- 2.7.1 A “revenue quality” electric meter which meets the following specifications shall be installed on the AC output of the System, which measures ONLY the AC output of the PV array(s). Refurbished meters may be used with the Program’s pre-approval.
- ANSI C-12 tested and certified revenue meter
 - Electromechanical meters accurate to within 2% of actual system output (ANSI C-12.10)
 - Electronic meters accurate to within 1% of actual system output (ANSI C-12.16)
 - One of the following configurations
 - Single-phase 120 volt – Form 1S – Class 100
 - Single-phase 240 volt – Form 2S – Class 200
 - Three-phase 120-480 volt – Form 14-16S – Class 200
 - Meter warranty of not less than 1 year
 - Digital or cyclometer display for easy reading by system owner

⁴ http://energytrust.org/library/forms/SLE_TL_SystemSizing.xls

- 2.7.2 Multiple-inverter systems may either combine output through a dedicated sub-panel from which the output is metered or use one electric meter for each inverter.
- 2.7.3 Because the meter may be located near the utility meter, the solar system meter shall have a UV-resistant label identifying it as the Customer Owned Solar Generator Output.
- 2.7.4 All meters shall be set at 000000 or 999999 at time of shipment to the installer to ensure accurate and consistent “start” readings for every system.

2.8 Battery-based Systems

- 2.8.1 Batteries shall be located in a secure enclosure that meets seismic requirements and is weatherproof as needed.
- 2.8.2 Access to live battery terminals shall be limited per Oregon Electrical Specialty Code.
- 2.8.3 Flooded lead acid batteries shall be housed in an enclosure with adequate spill containment and vented to the outdoors, with a nearby clearly marked safety kit.
- 2.8.4 Battery interconnect and inverter cables shall be properly sized, with secured crimps and lugs on ends. Lugs and terminals shall be listed for the wire type used.
- 2.8.5 Charge controller and inverter settings shall be appropriate for the installation’s batteries, and set for grid-tied optimum performance.
- 2.8.6 Temperature compensation probes for inverter and/or charge controller shall be installed to control battery charge properly.
- 2.8.7 Array configuration shall operate within current and voltage limits of charge controller, accounting for temperature-adjusted array voltage under record high and low temperatures for that location.
- 2.8.8 For hybrid systems utilizing wind or micro-hydro turbines in addition to PV, battery overcharge protection using turbine regulation and/or diversion controller and diversion load shall be installed.
- 2.8.9 Ground fault protection shall be added to the System if required by code and not included in the inverter.
- 2.8.10 Customer manual shall include instructions for operation, maintenance and safety procedures for batteries, charge controller and inverter.
- 2.8.11 AC output meter shall be of the 5-jaw type, and correctly wired to meter power flows to both utility and AC loads.

3.0 Customer Manual

Upon completion of installation, Program trade ally shall provide the system owner with a manual (the “Customer Manual”) and instruct the owner on proper system operation and maintenance.

The Customer Manual provides accurate system documentation for the current system owner, as well as future owners and potential service personnel. The Customer Manual shall be bound in a durable and professional-looking binder, and shall contain, at minimum, three sections: 1) System Design and Operation, 2) Warranties and Installation Documentation, 3) Manuals and Data Sheets.

3.1 Section 1 — System Design and Operation

- System Overview Page
 - **Form 221: Solar Electric System Overview** or an equivalent overview page summarizes the system’s operating conditions and provides emergency information. **Form 221** is available on the [Solar Trade Ally Forms & Resources webpage](#)⁵.
- Operation & Maintenance Instructions
 - Installer’s written instructions for system start-up and shutdown procedure, troubleshooting guidelines and recommended routine maintenance schedule.
- Electrical As-built Diagram
 - Schematic diagram that accurately depicts:
 - All electrical components installed, plus main service panel and utility connection.
 - Module series/parallel wiring, conductor and ground wire types and sizing, conduit types and sizing, and voltage drop calculations.
 - Inputs from existing wind or solar systems if present.
- Mechanical Design
 - Description of array support structure, including engineering specifications of structural elements and manufacturer installation instructions. Provide drawings describing racking, pole mount or roof attachment methods systems.
- Physical Layout Diagram
 - Diagram indicating the location of the major system components with respect to the structure or property

3.2 Section 2 — Warranties and Installation Documentation

- Contractor Warranty
 - Program trade ally’s 2-year minimum full system warranty covering labor and materials.
- Manufacturers’ Warranties
 - Written warranties and product registration instructions for PV modules and inverters.
- Incentive Application
 - Final version of the signed form showing incentive and configuration approved by Energy Trust.
- Permit(s)

⁵ <http://energytrust.org/trade-ally/programs/solar/resources/>

Copy of approved electrical and, where applicable, building permit for the system installation.

- Utility Interconnection / Net Metering Agreement

Copy of the agreement between the utility customer and the utility.

3.3 Section 3 — Manuals and Data Sheets

- Parts and Source List

Bill of material listing all system components including part numbers. If feasible, inverter and module serial numbers should be recorded to facilitate replacement in the case of product recall or recovery in the case of theft.

- Inverter Owner's Manual

Documentation from inverter manufacturer.

- Manufacturer Data Sheets for Major Components

Including but not limited to: inverters, PV modules, rack/mounting system, charge controller, batteries, disconnect switches, ground fault protection equipment, lightning arrestors, and combiner boxes.