Introduction to Residential Rooftop PV Permitting

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Online Training
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Highlights

1. Introduction
2. Overview of Solar Energy
3. Improving Your Solar Permitting Process
4. Codes and Standards
5. Plan Review (Structural, Electrical and Fire, and Safety Guidelines)
6. SolarAPP+
7. Key Takeaways

1. Introduction

Introduction

What is the National Renewable Energy Laboratory (NREL)?

NREL Transforming ENERGY

What are we covering today?

- This training focuses on permitting guidelines for residential distributed rooftop photovoltaic (PV) systems.
  - *Most PV systems that you interact with are residential.*
  - *Some systems have energy storage systems (ESSs).*
  - *Similar processes are required when conducting permitting for other applications, so this information can be useful to those other use cases as well.*

What is outside the scope of this training?

- Commercial and utility-scale PV systems.

2. Overview of Solar Energy

Overview of Solar Energy

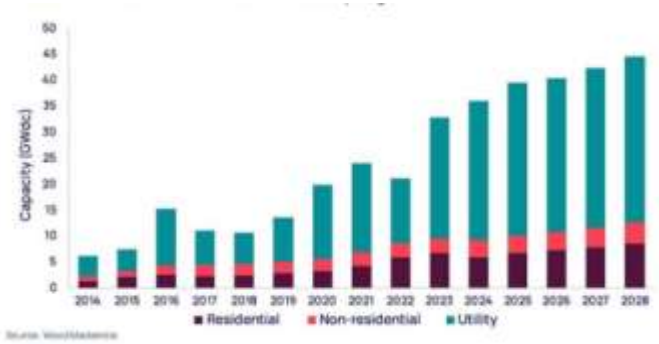
What types of solar energy systems are there?

- Photovoltaic (PV)
- Concentrating solar power (CSP)
- Solar thermal.

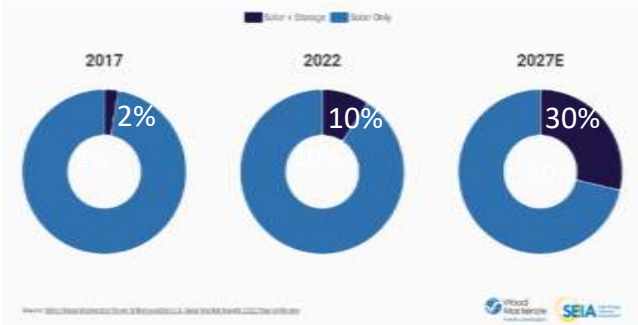
PV is by far the most dominant solar technology.

Many PV systems are now also being paired with storage.

Solar PV installations and Future Projections



Percentage of Solar Systems paired with Energy Storage System



Source: SEIA, 2024

Solar Thermal

Concentrating Solar Power (CSP)

Photovoltaic (PV)

How do local governments interact with these systems?

Local governments typically have oversight of planning, land use, and building safety in their communities.

1. Planning/zoning
2. Permitting
3. Inspection
4. Operation and maintenance/construction
    a. Municipal systems
5. These authorities are over all solar construction:
    a. Residential
    b. Commercial
    c. Utility-scale.

Group Exercise 1: Types of Solar Permits

Q1: What role do you serve in your community?

- Permitting/plan review
- Inspection
- Sustainability/climate
- Zoning/planning
- Combination of roles
- Other

Q2: How many solar PV projects did you permit last year?

- 10 or less
- 25
- 50
- More than 50

Q3: What percentage of solar projects are you seeing that include an energy storage system (ESS)?

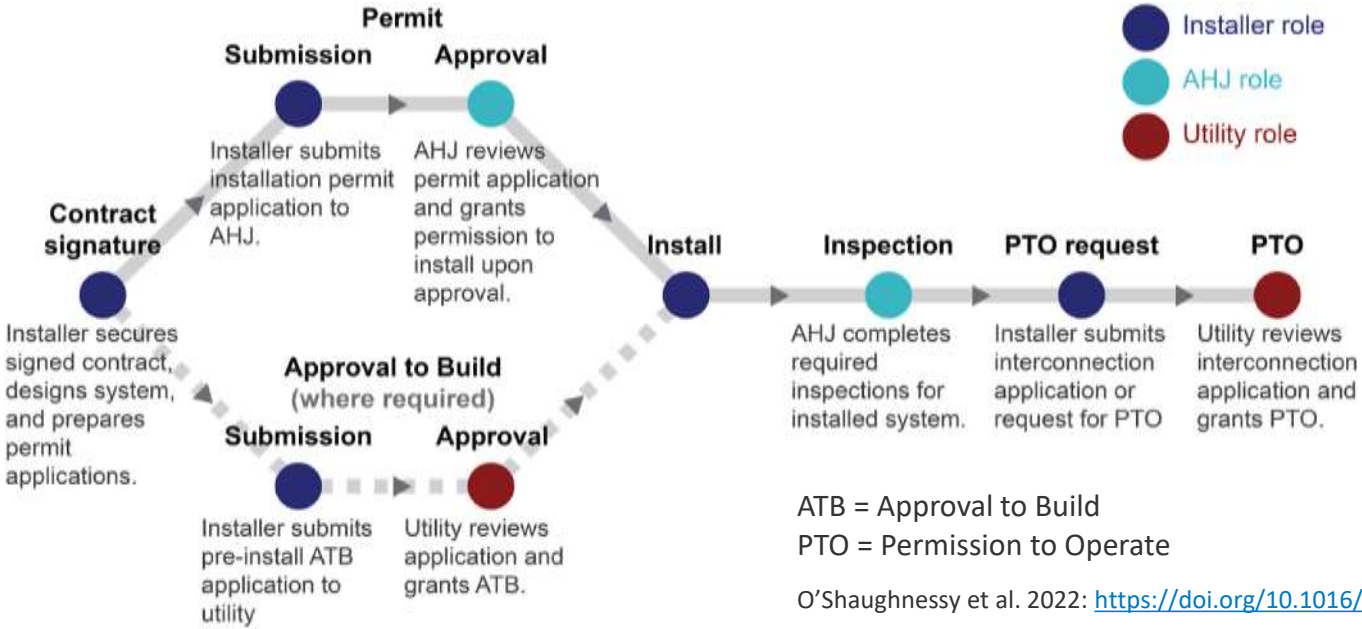
- 5% or less
- 6 - 10%
- 11 - 25%
- 26 - 50%
- 51% or more

3. Improving Your Solar Permitting Process

Improving Your Solar Permitting Process

Local government must protect public health and safety. Permitting ensures that local installations and building development are safe and in line with the plan for the community.

Typical solar adoption process with installers, authorities having jurisdiction (AHJs), and utilities:



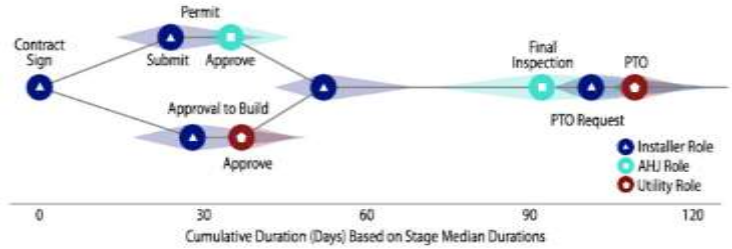
ATB = Approval to Build
PTO = Permission to Operate

O'Shaughnessy et al. 2022: https://doi.org/10.1016/j.enpol.2021.112734

Project Approval Process

1. A permit application must be submitted for review by a local permitting agency, known as the "enforcing agency."
    1. In reviewing a permit, the enforcing agency applies state and local construction code requirements, as well as additional local requirements that apply to solar energy installations (i.e., structural requirements, electrical requirements, and applicable fire safety provisions).
2. Once the permit application is approved, the applicant has permission to build the solar installation.

O'Shaughnessy et al., 2020 http://dx.doi.org/10.1016/j.enpol.2020.111615



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How is permitting done today?

Requirement		Description	% AHJs*
Submission format	Online permitting	AHJ accepts only online permit application submission and issues approved permits online.	7%
	In-person permitting	AHJ accepts only in-person permit application submission and issues approved permits in person.	27%
	Mail permitting	AHJ accepts only mailed permit application submission and issues approved permits by mail.	2%
	Multiple submission formats	AHJ accepts permit submissions in multiple formats (i.e., online, in-person, or mail).	64%
Over-the-counter (OTC) permitting		AHJ provides option for same-day OTC permits; OTC permitting may be restricted to certain days and to systems that meet specified criteria.	15%
Instant online permit		AHJ offers same-day online permit approval for systems that meet specified criteria.	1%

*AHJ requirement descriptions and summary statistics (N = 1605 AHJs).

O'Shaughnessy et al. 2022: https://doi.org/10.1016/j.enpol.2021.112734

Typical Challenges Associated With Permitting

1. Unclear submission processes and/or long turnaround times
    a. Mail permitting and structural reviews are associated with longer project timelines.
2. Inconsistent requirements and/or inconsistent interpretations of the code
    a. Plan review staff may require design changes, and then inspector may require adjustments to those requested changes.
3. Uncertainty and delays in permit review timelines can lead to slower installation timelines and/or higher costs to homeowners.
    a. For instance, if an installer knew that a permit review would take no more than 3 days, the installer could confidently plan an installation date 4 days after permit submission.

Streamlined Permitting

Some communities have developed fast lanes for certain small PV systems (typically residential) via various improvements, such as:

- Adopting solar-specific permits (rather than general building or electrical permits)
- Requiring only a single permit application (rather than separate applications for building, electrical, fire, etc.)
- Removing professional engineering reviews for standard residential rooftop systems that meet the criteria.
- Reducing the number of departments that review a standard residential rooftop permit (i.e., fewer people at the jurisdiction need to review a permit before its approval)
- Streamlining or removing separate fire-specific reviews of standard residential permits
- Adopting an online permitting platform, allowing online submission and permit issuance
- Coordinating permit review improvements between departments and with other local jurisdictions
- Adopting an online instant permitting platform that automatically approves permits that meet predefined criteria (i.e., rooftop residential systems using preapproved equipment).

Group Exercise 2: How do you do permits?

Q1: How do you do permits for solar today?

- In-person
- By mail
- Online
- Multiple submission formats

Q2: Have you changed your permitting process during the COVID-19 pandemic?

- Yes
- No

Q3: Have you recently changed it back?

- Yes
- No

Q4: Have you considered automated permitting?

- Yes
- No

Q5: What might the benefits and drawbacks of this approach be?

- Standardized compliance check, time savings, cost-effectiveness, etc.
- Additional training requirement, software, and internet connection issues, etc.

4. Codes and Standards

Key Permitting Codes and Standards

Authorities having jurisdiction (AHJs) enforce codes, including the following.

a. National Electrical Code (NEC)
b. International Residential Code (IRC)
c. International Building Code (IBC)
d. International Fire Code (IFC)
e. The National Fire Protection Association (NFPA) Standards
f. Local Planning and Zoning
g. American Society of Civil Engineers (ASCE) standards and codes.

Key Permitting Codes and Standards

Key model codes and standards underlying plan review.

i. ***NEC Article 690, 705, and Chapters 1–4***
   - These articles applies to solar PV systems, including the array circuit(s), inverter(s), and controller(s) for such systems.

ii. ***IRC R331, R902, R905, R908***
   - This is a standalone residential code that creates minimum regulations for residential homes.

iii. ***IBC 1505, 1509, 1511***
   - The provision of these chapters shall govern the design, materials, construction, and quality of roof assemblies and roof structures.

iv. ***IFC 605.11***
   - This code applies to Solar PV systems

v. ***ASCE 7-10, 7-16***
   - This code provides requirements for general structural design and includes means for determining snow, rain, atmospheric ice, earthquake, wind loads, etc.

vi. ***NEPA 855***

These codes may be modified to reflect local climate, geographical characteristics, or gaps not in the model codes.

Codes and Standards Adopted Across the United States

https://www.iccsafe.org/content/code-adoption-maps/

https://www.iccsafe.org/content/code-adoption-maps/

https://www.iaei.org/page/nec-code-adoption

Group Exercise 3: Codes and Standards

Q1: Do you know which model codes are enforced in your community?

- Yes
- No
- Unsure

Q2: Does your community have the authority to adopt your own model codes?

- Yes
- No, regulated by the State
- Other
- Unsure

Q3: Do you have local amendments to the model code?

- Yes, city ordinances
- Yes, State modifications
- Other
- Unsure

Q4: Do you use model codes before 2015, for example NEC 2014 or IRC and IBC 2015?

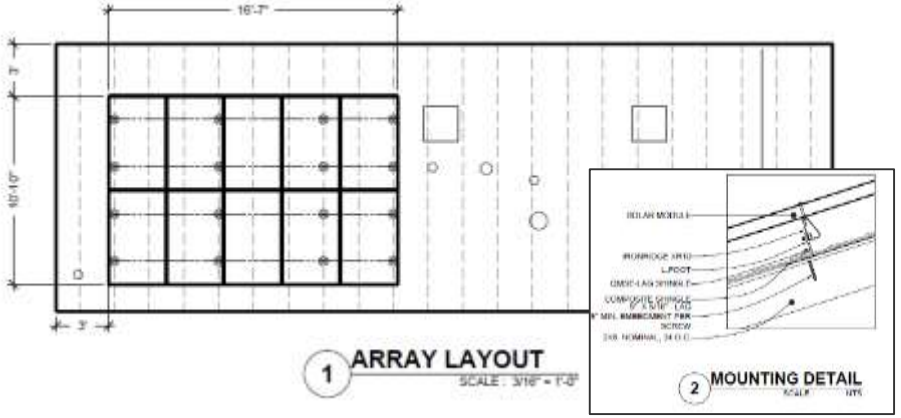
- Yes
- No
- Unsure

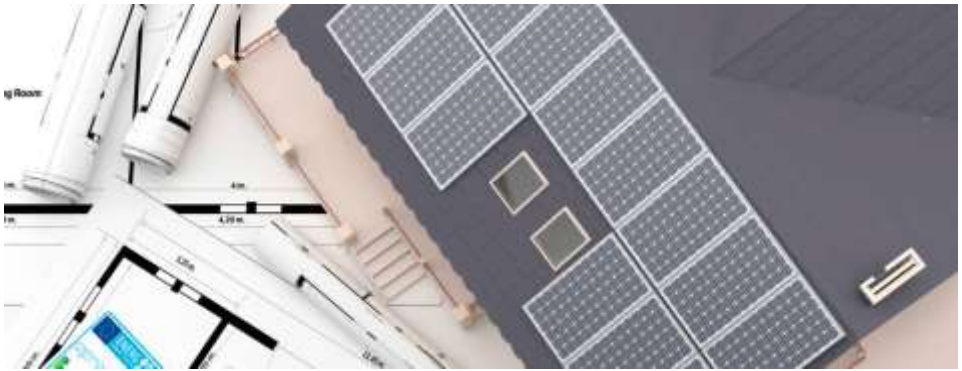
5. Plan Review

(Structural, Electrical, and Fire and Safety Guidelines)

What is included in a plan review?

1. Structural guidelines
   - General site, structure, and array requirements
   - Member-attached provisions
     - High wind requirements
     - Low wind and snow requirements
   - Sheathing-attached provisions
   - Weather sealing
2. Electrical guidelines
   - General electrical requirements
   - Standard electrical diagrams
   - String inverter or DC converter
     - String side connection or
     - Load side connection
   - Microinverter or AC module
     - Supply side connection or
     - Load side connection
3. Fire and safety guidelines





How long does a plan review take?

i. Between 15 and 60 minutes, depending on the expertise level and the quality of the plan.

ii. However, high permit volume can mean long waits.

iii. The plan review process is open for mistakes.

iv. To avoid mistakes, it is recommended to have a plan review checklist.

Plan Review Checklist

- Plan review requires many compliance checks. SolSmart® and other entities have created checklists to help AHJs complete this critical task.
- In this training, we used checklists from SolSmart and Interstate Renewable Energy Council (IREC) as references.

How To Gather Required Information for Permit

- Communities collect different information to complete plan review.
- Some communities require three-line diagram/electrical schematics, a site plan, and equipment installation instructions/cut sheets.
- Some communities just require third-party-reviewed plans, such as SolarAPP+ approved plans.

Step 1: Gather Required Information for Permit

1.	Permit application required by the local jurisdiction: Permit applications normally include information about the project scope, project location, and the installer.	☐
2.	Site plan showing location of major components on the property: This drawing need not be exactly to scale, but it should represent relative location of components at site (see supplied example site plan). PV arrays in compliance with IRC fire setback requirements. Energy storage in acceptable locations.	☐
3.	Electrical worksheets showing PV array configuration, wiring system, overcurrent protection, ESS components, inverters, disconnects, required signs, and AC connection to building (see supplied standard electrical diagram).	☐
4.	Specification sheets and installation manuals (if available) for all major PV system components such as: PV modules, DC-to-DC converters, ESS components, inverters, and mounting systems.	☐

SolSmart 2021: National Simplified Residential PV and Energy Storage Permit Guidelines

Key Structural Requirement Guidelines

i. General site, structure, and array requirements
ii. Member attached provisions and array requirements
    i. *Array gaps*
    ii. *Mounting orientation*
    iii. *Upslope/downslope anchor spacing.*
    iv. *Anchor fastener*
    v. *High wind requirements (180 MPH)*
    vi. *Low wind and snow requirements (120 MPH, 10 PSF)*
iii. Sheathing attached provisions and array requirements
    i. *Array gaps*
    ii. *Roof slope*
    iii. *Roof framing and sheathing nailing options*
    iv. *Anchor location restrictions*

Step 6 (Simplified): Structural PV Array Mounting Requirements

For jurisdictions that require detailed structural PV array mounting information, skip to Step 6 (Detailed)

1.	The weight of the PV system 4 lbs/sq ft. or less.	☐
2.	The attachment points of the mounting system are staggered (no check requires low snow and wind load location).	☐
3.	The maximum spacing in inches between adjacent attachment points of the mounting system 48" or less (no check means that the spacing is no larger than 72" and requires no snow and low wind load location).	☐
4.	The array is on a single roof face (if no check, how many roof surfaces at different slopes and/or orientations will be used for installation? _____(fill in).	☐
5.	The PV array is flush mounted (parallel to roof).	☐
6.	If "5" not checked, is the maximum distance off the roof no greater than 10" (if no check, this process cannot be used).	☐
7.	The solar module and mounting system rated by the manufacturer to withstand the upward force of the local wind speed and evenly distribute load into the supporting structure at the proposed maximum spacing, and confirmed in UL 1703 or 61730, and 2703 listings (validated through the UL 1703 or 61730 module rating for mechanical load rating, and UL 2703 mounting system mechanical load rating).	☐
8.	The individual roof structure appears to be structurally sound, without signs of alterations or significant structural deterioration or sagging.	☐
9.	What is the roof covering material?_____(fill in blank)	☐
10.	What is the slope of the roof surface? _____(fill in blank)	☐

SolSmart 2021: National Simplified Residential PV and Energy Storage Permit Guidelines

MPH = miles per hour
PSF = pounds per square foot

Structural Plan Review Checklist

Structural Plan Review	Related Code
Rooftop systems must be designed in accordance with the IRC or IBC.	IRC Section R324, IBC 1509.7
Roof access points, paths, and clearances are needed to comply with the IFC.	IFC 605.11.3.1–605.11.3.3.3
Rooftop-mounted PV panels and modules must have the proper fire classification rating.	IRC Section R324.4.2
All roofs must have an access point that does not require placing ground ladders over openings, such as windows or doors. These access points must be located at strong points of building construction and must be in locations where the access point does not conflict with overhead obstructions, such as tree limbs, wires, or signs.	IFC 605.11.3.1
The roof must be capable of supporting the weight of the PV system.	N/A

IREC 2018: https://irecusa.org/blog/local-energy-climate-solutions/new-guide-for-solar-plan-review-and-inspection-checklists/

Structural Plan Review Checklist

Roofs with slopes greater than 2:12 must have solar panel layouts that meet the following criteria (some exceptions apply; see diagrams in IFC).

Structural Plan Review	Related Code
Hip Roofs: Panels/modules are located so that there is a 3-foot-wide clear access pathway from the eave to the ridge on each roof slope where panels/modules are located.	IFC 605.11.3.2.1
Hips and Valleys: If panels/modules are placed on both sides of a hip or valley, they are located no closer than 18 inches to a hip or valley. If the panels are located on only one side of a hip or valley that is of equal length, then the panels can be placed directly adjacent to the hip or valley.	IFC 605.11.3.2.3
Single Ridges: Panels/modules are located so that there are two 3-foot-wide access pathways from the eave to the ridge on each roof slope where there are panels/modules installed.	IFC 605.11.3.2.2
Ridges: Panels/modules must be located no higher than 3 feet from the top of the ridge to allow for fire department smoke ventilation operations.	IFC 605.11.3.2.4
Access pathways must be located at a structurally sound location capable of supporting the load of firefighters accessing the roof.	IFC 605.11.3.2.1

IREC 2018: https://irecusa.org/blog/local-energy-climate-solutions/new-guide-for-solar-plan-review-and-inspection-checklists/

Key Electrical Requirement Guidelines

Key electrical requirement guidelines

i. General electrical requirements
ii. String inverter or DC converter
iii. Micro inverter or AC module
iv. Field-installed PV array wiring
v. Total inverter capacity
vi. Equipment maximum DC voltage

Step 2: PV System Electrical Code Installation Requirements

1.	Major electrical components including PV modules, DC-to-DC converters, and inverters, are identified for use in PV systems.	☐
2.	Array mounting system UL2703 certified for bonding and grounding. Alternatively, the array mounting system may incorporate UL2703 grounding devices to bond separate exposed metal parts together or to the equipment grounding conductor.	☐
3.	The PV array consists of no more than 2 series strings per inverter input and no more than 4 series strings in total per inverter.	☐
4.	Field-installed PV array wiring meets the following requirements (all boxes must be checked): ☐ a. All exposed PV source circuit wiring is no smaller than 12 AWG PV Wire or MFG Cable. ☐ b. All PV source circuit wiring in raceway is no smaller than 12 AWG THWN-2, XHHW-2, or RHW-2.	☐
5.	Equipment is rated for the maximum DC voltage applied to the equipment (put N/A in all blanks that do not apply to the specific installation): ☐ a. ASHRAE Extreme Annual Mean Minimum Design Dry Bulb Temperature (one source is https://energyresearch.ucf.edu/solar-certification/solar-reference-map/)=_____; Table 690.7 (NEC) value_____ ☐ b. Max module Voc (adjusted at minimum temperature): Rated Voc _____V x Table 690.7 value_____=_____V ☐ c. DC-to-DC converter(s) or microinverter rated maximum input voltage: _____V (must be greater than Max module Voc in (b.)) ☐ d. Maximum number of DC-to-DC converters allowed in series (up to 600Vdc): _____ ☐ e. Maximum voltage of DC-to-DC converter circuit with maximum number in (c.): _____V ☐ f. Inverter(s) rated maximum input voltage: _____V (must be greater than g. below) ☐ g. Inverter input max V: Max module Voc (b.) _____V x max # in series_____= _____V	☐
6.	PV system circuits on buildings meet requirements for controlled conductors in 690.12.	☐
7.	The PV system disconnecting means meets the requirements of 690.13.	☐
8.	The *standard electrical diagrams can be used to accurately represent the PV System. (See diagrams)	☐

Electrical Plan Review Checklist

Electrical Plan Review	Related Code
PV modules must be listed to Underwriter Laboratories (UL) 1703, and inverters must be listed to UL 1741.	NEC 110.3, 690.4(B); IBC 1509.7.4
Residential one- and two-family dwellings are limited to a maximum PV system voltage of 600 volts DC.	NEC 690.7
A complete grounding electrode system is present. The PV system equipment grounding conductors shall be connected to the grounding electrode system.	NEC 690.47(A)
The calculated maximum source circuit current is the sum of parallel-connected PV-module-rated short-circuit currents multiplied by 125%.	NEC 690.8(A)(1)
The calculated maximum output circuit current is the sum of all combined source circuits.	NEC 690.8(A)(2)
DC source circuit conductors are rated at either 125% of the ampacity calculated above or the ampacity calculated above with conditions of use applied, whichever is greater.	NEC 690.8 (B)(1 & 2)
The inverter output circuit overcurrent protection device (point of connection to AC system breaker) is sized based on the maximum inverter output current multiplied by 125%.	NEC 690.8(A)(3), 690.8(B)(1), and 705.60(B)

IREC 2018: https://irecusa.org/blog/local-energy-climate-solutions/new-guide-for-solar-plan-review-and-inspection-checklists/

Electrical Plan Review Checklist

Electrical Plan Review	Related Code
Overcurrent protection is required for the: a. PV source circuit (modules and parallel connected modules) [exception for strings of modules with no source of overcurrent exceeding the ampacity of the conductors or modules] b. PV output circuit (conductors between source circuits and inverter) c. Inverter output circuit d. Battery circuit conductors and equipment. Overcurrent protective devices are not required for circuits with sufficient ampacity for the highest available current.	NEC 690.9(A)
Where three or more strings are combined, a listed combiner box (UL 1741) must be used, and fuses are required. When DC source circuits (strings) are connected in parallel without fusing, the current through a failed circuit can be the sum of the current connected from the other strings; therefore, special consideration must be taken to ensure that the sum of the total number of strings minus one does not exceed the module manufacturer's series fuse rating or conductor ampacity.	NEC 110.3(B), 690.9(A)
Overcurrent devices, where required, are rated at 125% of the ampacity calculated above or are rated as an assembly for continuous duty.	NEC 690.9(B)

IREC 2018: https://irecusa.org/blog/local-energy-climate-solutions/new-guide-for-solar-plan-review-and-inspection-checklists/

Electrical Plan Review Checklist

Electrical Plan Review	Related Code
For PV source and output circuits, a single overcurrent protection device may be used for each circuit in either the negative or positive conductor. The device must be in the same polarity for all circuits.	NEC 690.9(B)
The PV system disconnect must disconnect the PV system from all other systems.	NEC 690.13
The disconnects or isolating devices are installed for all ungrounded conductors.	NEC 240.15 and 690.15
The rapid shutdown initiation device must be labeled on the plans. The device must be either: service disconnecting means, PV system disconnecting means, or a readily accessible switch that plainly indicates whether it is in the “off” or “on” position.	NEC 690.12(C)

IREC 2018: https://irecusa.org/blog/local-energy-climate-solutions/new-guide-for-solar-plan-review-and-inspection-checklists/

What if the project has storage?

Key electrical requirement guidelines

1. Energy storage system (ESS) electrical code installation requirements
2. PV and ESS electrical code interconnection requirements
   i. Supply side and load side connections must comply with NEC 705.11, 12(A), and 12(B).
   ii. Power control system connection must comply with NEC 705.13.

Electrical Plan Review	Related Code
Batteries other than lead-acid batteries must be listed.	NEC 480.3
A disconnect means is provided for all ungrounded conductors derived from a stationary battery system over 50 volts AC or 60 volts DC.	NEC 480.7 and 706.7
Wiring and connections of inverters, PV source circuits, battery connections, etc. and all interconnections are performed by qualified personnel.	NEC 690.4(C)
High interrupt, listed, DC-rated fuses or circuit breakers must be used in battery circuits, and the Amps Interrupting Capacity (AIC) must be at least 20,000 amps.	NEC 706.21(C) and 110.9

IREC 2018: https://irecusa.org/blog/local-energy-climate-solutions/new-guide-for-solar-plan-review-and-inspection-checklists/

Key Fire Requirement Guidelines

Key fire requirements

i. Fire setbacks
ii. Escape pathways
iii. Battery spacing
iv. Smoke alarms/heat detectors
v. Labeling
vi. Disconnects

Setbacks

Setbacks are considered different from access pathways.

- If the array is 33% of the roof area or less: 18-inch (1.5-foot) distance from the roof ridge.
- If the array is more than 33% of the roof area: 36-inch (3-foot) distance from the roof ridge.

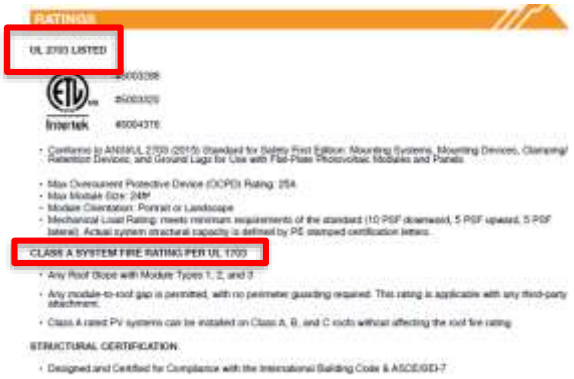
Access Pathways

There should be a minimum of two 36-inch (3-foot) pathways from the eave to the ridge on separate roof planes.

Fire Classification

- Fire Classes
  - Class A – Effective against severe fire exposure
  - Class B - Effective against moderate fire exposure
  - Class C - Effective against light fire exposure

- If the existing roof requires a fire classification, determine the module fire type from the specification sheet, installation instructions, or listing certificate.
  - Modules should be listed and labeled to UL 1703.
  - Racks should be listed to UL 2703.



Group Exercise 4: Plan Review Checklist

Q1: Does your community have a solar permitting checklist?

- Yes
- No
- Unsure

Q2: When was the checklist made/last updated?

- Older than 5 years
- Between 1 and 5 years
- Unsure

Q3: Does the checklist include storage?

- Yes
- No

6. SolarAPP+

What if I don't have expertise in solar?

- But I'm a generalist—how do I know all the things to check?
  1. Automate your process with Solar Automated Permit Processing Plus (SolarAPP+).
     i. Institute 100% of code checks, 100% of the time.
  2. Develop plan review checklist.

SolarAPP+

Shorter project timelines

A typical SolarAPP+ project is permitted, installed, and inspected around 13 business days sooner than traditional projects

Based on differences in median durations

Staff time savings

NREL estimates SolarAPP+ saved around 9,900 hours of jurisdiction staff time through automated permit reviews in 2022

Potential inspection benefits

(further research required)

SolarAPP+ projects have been about 29% less likely to fail inspections than traditional projects

Based on data from 12 jurisdictions

Solar APP+

NREL
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SolarAPP+ is a standardized plan review software *that can run compliance checks and process building permit approvals for eligible rooftop solar systems.*

The tool was developed through a collaborative effort to accelerate rooftop solar adoption by making it easier for local governments to quickly and safely approve rooftop PV projects for installation.

SolarAPP+ Eligibility

SolarAPP+ can cover standardized systems, as defined here.

Current supported parameters:

- Residential PV
- Approved equipment
- NEC 2017 and 2020; 2023
- 2018 and 2021 i-Codes
- Bus <225 Ampere
- Service <400 Ampere
- PV systems <4 PSF
- Single phase utility supply
- No wood shake roofs
- No metal roofs with >15 PSF snow load
- Main panel upgrades
- California's Title 24

Support in progress:

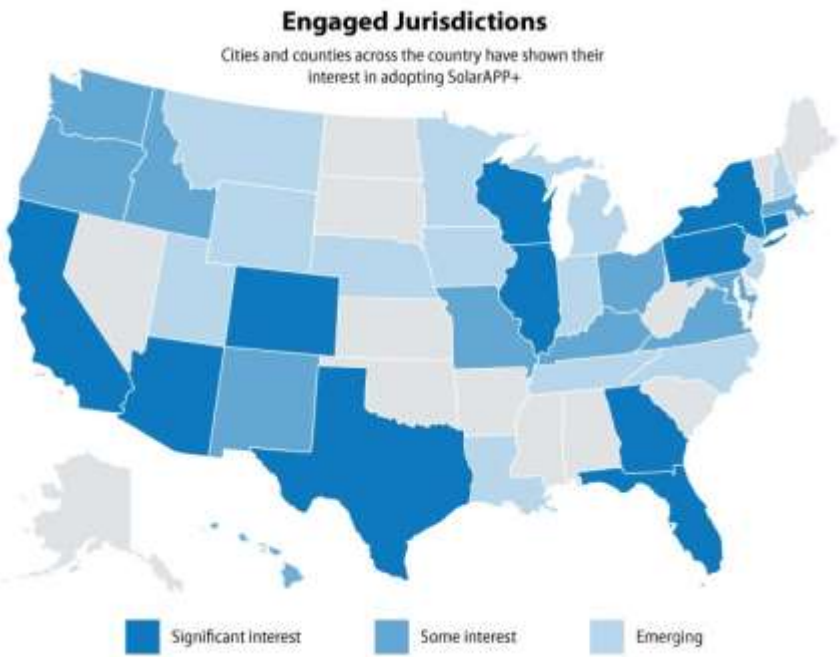
- Residential storage
- Add-ons for existing systems

Planned:

- EV chargers, electric appliances, roof tiles, and more…

Let us know what you'd like to see next!

Interest in SolarAPP+



SolarAPP+ Flow

1

Installer submits an application with design specifications through SolarAPP+.

2

SolarAPP+ checks the application to ensure the system design is code compliant.

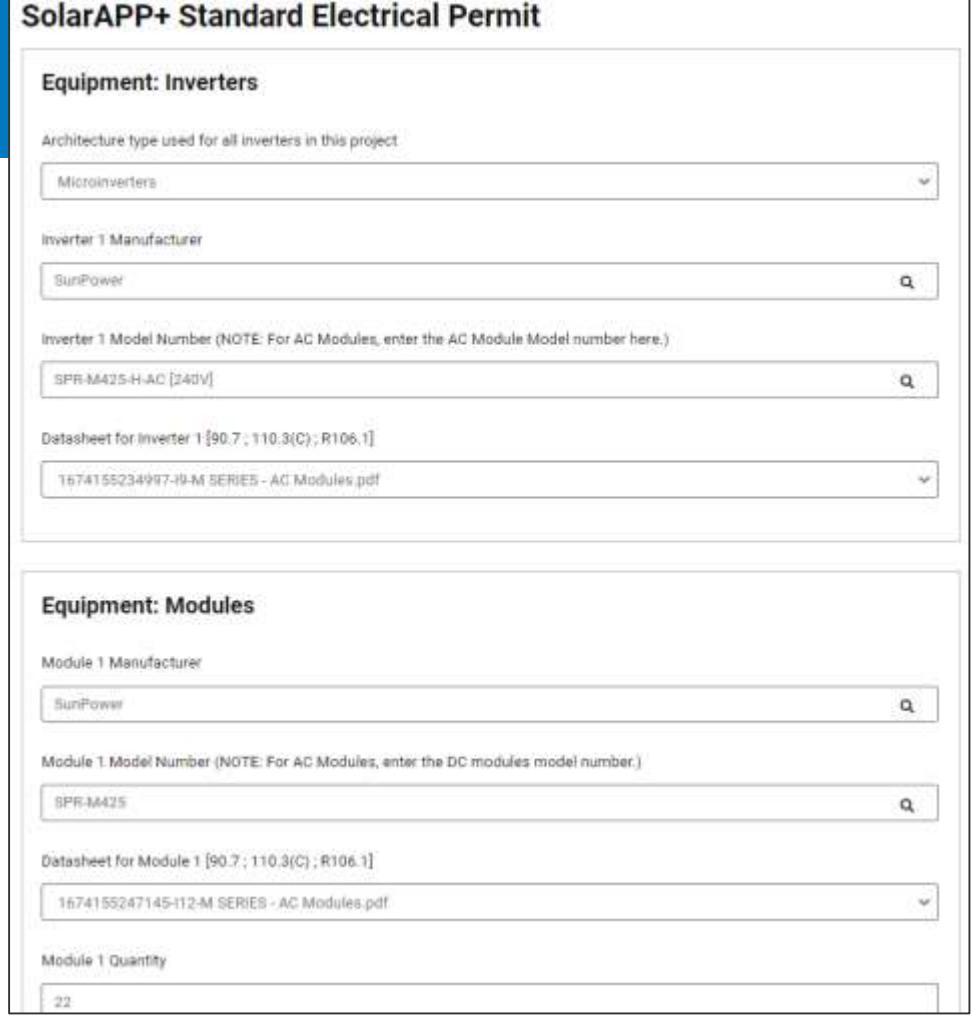
3

Code-compliant applications are issued a permit instantly after fee payment.

(Review sample approval docs here.)

How It Works

- The contractor enters design information into the application.
- No diagrams are uploaded as a part of the submission process.



Real-Time Error Notifications

Four Steps To Adopting SolarAPP+

SolarAPP+ can be set up to:

- **Integrate** with your existing online permitting software
- **Stand alone** as a complete online permitting solution

Local settings include:

- Permitting contacts
- AHJ boundaries
- Local wind and snow variables
- Model code years
- Terms and conditions

Depending on your integration, either:

- Set up an instant permit application in your software
- Set up permit payments in SolarAPP+

This involves:

- Inviting 1–3 installers to use your SolarAPP+ permitting process
- Opening up SolarAPP+ permitting to all installers

7. Key Takeaways

Key Takeaways

In this training, we have:

- Covered best practices for:
  - Permit application review and processes to ensure applications,
  - Streamlining the permitting process,
  - Plan review guidelines, including tips for making review more efficient.
- Provided supporting documents that are compliant with building and electrical codes.
- Increased understanding of the latest codes and standards related to solar installations.
- Learned more about SolarAPP+ opportunities to expedite permit review.

Q&A Session

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