Architectural Drawings for Solar Photovoltaic Systems

Last Updated: 08/04/2014

Scope

Provide an architectural drawing and riser diagram for the homeowner showing the planned location for future photovoltaic and solar hot water system components. Space requirements and layout for photovoltaic and solar water heating system components should be taken into account early in the design process.

DOE Zero Energy Ready Home Notes

The U.S. Department of Energy (DOE) Zero Energy Ready Home National Program Requirements includes in Exhibit 1, Mandatory Requirements, Item 7 Renewable Ready, that all homes must meet the requirements in the Consolidated Renewable Energy Ready Home (RERH) Checklist.

The RERH Checklist requires builders to:

Provide architectural drawing and riser diagram of RERH solar PV system components and solar hot water components.

Alternative: Provide home buyer with the following information:

- List of renewable-ready features
- Available free roof area within +/- 45° of true south
- Location of panel or blocking for future mounting of PV and SWH components
- Location of Riser
- Location of Breaker or slot for future breaker in electrical service panel
- Copy of the Consolidated RERH Checklist
- A copy of the RERH Solar PV Specification Guide

See the Compliance Tab for related codes and standards requirements, and criteria to meet national programs such as DOE’s Zero Energy Ready Home program, ENERGY STAR Certified Homes, and Indoor airPLUS.
Description

A renewable energy-ready home (RERH) is one that is built with the wiring and plumbing conduit and other components in place to facilitate the future installation of solar photovoltaic (PV) panels and/or solar water heating panels. Some energy-efficiency programs, like the U.S. Department of Energy’s [DOE Zero Energy Ready Home Program](https://www.energy.gov/energymodeling/zero-energy-ready-home-program), require homes to be renewable-energy ready.

To meet the requirements of the DOE Zero Energy Ready Home program, provide an architectural drawing and riser diagram of RERH solar PV system components and solar hot water.

Develop architectural drawings and diagrams that summarize the installed system equipment (conduit, etc.) as detailed below (see Figure 1). These drawings should accurately represent the installed elements of the system and should be provided to the homeowner (likely to be used by future solar installer for obtaining a building permit). In addition, the homeowner should be provided with a one-line electrical riser diagram of the PV system components. The diagram should have sufficient detail to clearly identify:

- Configuration of the PV array
- Conduit size and type
- Electrical service panel location and dedicated circuit breaker slots
- Length of conduit from the designated array location to the designated inverter location
- Location and number of necessary pull boxes in line with each conduit run
- Length of conduit from the designated inverter location to the electrical service panel
- Location of the Balance-of-System (BOS) components

The drawings should also contain information about the PV array mounting system and identify the specifications for the major equipment including manufacturer, model and installation details.

![Figure 1. PV system drawing example](image)

When designing the system, always follow the recommendations of all local and national codes as well as manufacturer’s recommendations.
Ensure adequate utility room early in the house design process to allow for ample space for solar photovoltaic (PV) and water heating system components. Confirm with local code officials early in the design process what steps are needed to guarantee that installation of PV panels will meet with local codes, homeowner’s association covenants, and historic district regulations.

Protect the electrical and mechanical components of the PV system from bulk moisture, high temperatures, and direct sunlight. The utility room should be properly ventilated and maintain average indoor temperatures. Proper clearances and working spaces should also be maintained.
Climate

Among other things, the Consolidated Renewable Energy Ready Home (RERH) Checklist is required only under the following condition related to climate:

- Location, based on zip code, has at least 5 kWh/m²/day average daily solar radiation based on annual solar insolation using the [PVWatts online tool](https://pvwatts.nrel.gov).
Training

Right and Wrong Images
None Available
None Available
Compliance

The Compliance tab contains both program and code information. Code language is excerpted and summarized below. For exact code language, refer to the applicable code, which may require purchase from the publisher. While we continually update our database, links may have changed since posting. Please contact our webmaster if you find broken links.

DOE Zero Energy Ready Home (ZERH) Program

The DOE ZERH Consolidated Renewable Energy Ready Home (RERH) Checklist states “Provide architectural drawing and riser diagram of RERH solar PV system components and solar hot water components.”

Alternative: Provide home buyer with the following information:

- List of renewable-ready features
- Available free roof area within +/- 45° of true south
- Location of panel or blocking for future mounting of PV and SWH components
- Location of Riser
- Location of Breaker or slot for future breaker in electrical service panel
- Copy of the Consolidated RERH Checklist
- A copy of the RERH Solar PV Specification Guide
- A copy of the RERH Hot Water Specification Guide

Homes that already have a solar photovoltaic (PV) system installed do not need to meet the PV requirements of the Consolidated RERH checklist.

DOE Zero Energy Ready Home National Program Requirements Mandatory Requirement 7 (Renewable Ready) shall be met by any home certified under the DOE Zero Energy Ready Home program, only where all of the following conditions are met:

1. Location, based on zip code has at least 5 kWh/m²/day average daily solar radiation based on annual solar insolation using PVWatts online tool, AND;
2. Location does not have significant natural shading (e.g., trees, tall buildings on the south-facing roof, AND;
3. Home as designed has adequate free roof area within +/-45° of true south as noted in the table below. Note that in some cases a house may have insufficient roof area for the Solar Electric RERH checklist, but it may still have the minimum roof area for the solar thermal RERH Checklist and would therefore have to comply with the Solar Thermal RERH checklist. In other cases, the home may only have adequate south facing roof for the Solar Electric or Solar Thermal RERH Checklist, but not both. In that case the builder can decide which one of those two checklists to apply.

<table>
<thead>
<tr>
<th>Photovoltaic</th>
<th>Solar Water Heating</th>
</tr>
</thead>
<tbody>
<tr>
<td>House Size (sq. ft.)</td>
<td>Free South Roof Area</td>
</tr>
<tr>
<td>&lt; 2000</td>
<td>110</td>
</tr>
<tr>
<td>&lt; 4000</td>
<td>220</td>
</tr>
<tr>
<td>&lt; 6000</td>
<td>330</td>
</tr>
<tr>
<td>≥ 6000</td>
<td>440</td>
</tr>
</tbody>
</table>

**Table 1. ZERH Requirements for south roof area**

2009, 2012, 2015, and 2018 IECC

Section R401.3 A permanent certificate shall be posted on or near the electrical distribution panel that lists types and efficiencies of water heating, heating, and cooling equipment, as well as insulation R values, and window U and SHGC factors.


Section R101.4.3 (Section R501.1.1 in 2015 and 2018 IECC). Additions, alterations, renovations, or repairs shall conform to the provisions of this code, without requiring the unaltered portions of the existing building to comply with this code. (See code for additional requirements and exceptions.)


Section N1101.3 (Section N1107.1.1 in 2015 and 2018 IRC). Additions, alterations, renovations, or repairs shall conform to the
provisions of this code, without requiring the unaltered portions of the existing building to comply with this code. (See code for additional requirements and exceptions.)

Appendix J regulates the repair, renovation, alteration, and reconstruction of existing buildings and is intended to encourage their continued safe use.

2014 National Electric Code (NEC)

Follow the requirements for solar photovoltaic (PV) systems found in the 2014 National Electric Code (NEC), Article 690, PV Power Systems, and Article 110, Requirements for Electrical Installations.

Design and Installation of Electrical Energy Storage Systems - Code Compliance Brief

Overview:

The intent of this brief is to provide information about Electrical Energy Storage Systems (EES) to help ensure that what is proposed regarding the EES 'product' itself as well as its installation will be accepted as being in compliance with safety-related codes and standards for residential construction. Providing consistent information to document compliance with codes and standards to all relevant parties responsible for verifying compliance with those codes and standards (e.g., code officials, builders, contractors, designers, utilities, fire officials, etc.) is expected to result in increased compliance and more timely, less challenging and more uniform plan review and field inspections.

An increased number of electrical energy storage systems (EESS) utilizing stationary storage batteries are appearing on the market to help meet the energy needs of society—most notably storage of power generated from renewable resources or the electric grid for use during power outages or peak electrical demand periods. Currently, these systems are not required by codes covering residential construction, but when used, the EES itself and its installation must be safe and remain safe. Although the 2015 International Fire Code (IFC) does address some of these systems, the 2015 International Residential Code (IRC) does not specifically address the design and installation of these systems for residential construction.

One requirement for homes to qualify as a U.S. Department of Energy Zero Energy Ready Home[1] is it must be constructed, at a minimum, as "solar energy ready" [2] and likely require installation of a system to store excess energy for subsequent use. Some builders and homeowners choose to install an energy storage system—whether they are participating in a program or not—simply to have backup power during power outages. This brief provides further clarification and resources to assist with designing, constructing, installing, and commissioning these energy storage systems and/or system components and verifying that they are safe.

The following sections list the applicable code and standard requirements and details helpful for Plan Review. The Field Inspection section then provides details for inspecting “…electrical energy storage systems utilizing stationary storage batteries.” For resources on technical validation, best practices, and measure guidelines, refer to the Technical Validation/Reference Materials section of this brief.

The lists and provisions provided below in each section are intended to target the main code sections and provisions. There may be other references, code sections, standards, testing methods, etc., that affect the technology or other assemblies or functions of the building.


[2] The intent of solar energy ready requirements is to provide a penetration free and shade free portion of the roof, called the solar zone. This helps ensure future installation of a solar energy system is not precluded by the original design and layout of the building and its associated equipment.

Plan Review:

This section provides details in the 2015 International Residential Code (IRC) and International Energy Conservation Code (IECC), and the language (underscored and struck-through) from code change proposals being considered for the 2018 IRC. The language underscored and struck-through could change during the final code hearings that occur in late October 2016. (Go to http://www.iccsafe.org/codes-tech-support/codes/code-development-process/20152017-code-development-group-b/ for additional information on the code proposals and hearings.) This Code Compliance Brief will be updated accordingly after the hearings and final online Governmental Consensus voting period in November 2016.

2015 IRC, Section R104 Duties and Powers of the Building Official

2015 IECC/IRC, Section R104.1 General. The building official has authority to render interpretations of this code and to adopt policies and procedures in order to clarify the application of its provisions. Such interpretations, policies and procedures shall be in conformance with the intent and purpose of this code.

R102.1/R104.11 Alternative Materials, Design and Method of Construction and Equipment. The provisions of this code are not intended to prevent the installation of any material or prohibit any design or method of construction not specifically prescribed in the 2015 IECC/IRC, provided that any such alternative has been approved. The building official is
permitted to approve an alternative material, design, or method of construction where the building official finds that the proposed design is satisfactory and complies with the intent of the provisions of this code, and the material, method, or work offered is for the purpose intended, not less than the equivalent of that prescribed in the code. Compliance with the specific performance-based provisions of the International is an alternative to the specific requirements of this code.

For some EESSs, there is a lack of specific requirements in the codes and standards, however, some are covered in existing and recently approved codes and standards that are available for adoption and application. This poses a challenge to determining the acceptability and compliance based on specific performance-based provisions as an alternative.

R104.11.1 Tests. Whenever there is insufficient evidence of compliance with the provisions of this code, or evidence that a material or method does not conform to the requirements of this code, or in order to substantiate claims for alternative materials or methods, the building official has authority to require tests as evidence of compliance to be made at no expense to the jurisdiction. Test methods shall be as specified in this code or by other recognized test standards. In the absence of recognized and accepted test methods, the building official shall approve the testing procedures. Tests shall be performed by an approved agency. Reports of such tests shall be retained by the building official for the period required for retention of public records.

Per the 2015 IECC/IRC, Section R103.3/R106.3 Examination of Documents, the code official/building official must examine or cause to be examined construction documents for code compliance.

Construction Documentation. Review the construction documents for details describing energy storage system and/or components construction techniques. (Bullet items underscored are based on the 2018 ICC code proposals.)

2015 IECC/IRC, Section R103.2/N1101.5 Information on construction documents. Construction documents should include:

- Type of energy storage system, design, size and location
- System ratings, testing, and labeling
- Stored energy capacity (kW)
- Conduit, wiring, and electrical layout design
- Inverter location and listing
- Emergency shut-off controls.

Section R201 Definitions

New definition:

Battery System, Stationary Storage. A rechargeable energy storage system consisting of electrochemical storage batteries, battery chargers, controls, and associated electrical equipment designed to provide electrical power to a building. The system is typically used to provide standby or emergency power, an uninterruptable power supply, load shedding, load sharing or similar capabilities.

The definition provides the code user with information on battery storage systems, and is identical to a definition being proposed for the IFC and International Building Code (IBC).

The Underwriters Laboratory (UL 9540), “Outline of Investigation for Energy Storage Systems and Equipment,” provides construction and performance requirements for investigating and listing stationary storage battery systems. This standard evaluates their ability to operate under both normal operating conditions and under certain fault conditions. In addition, UL 1973, “Batteries for Use in LER and Stationary Applications,” provides construction and performance requirements for batteries used as a component of an EESS. It is important to note that an EESS can be considered a unitary pre-packaged systems or assemblies of matched components where the entire system can be tested and listed to UL 9540. Where an EESS is assembled from different “mix/matched” components, each component would have to be listed, and then, the assembly of those components comprising the EESS would be addressed on-site using the IRC as a basis for review and approval.

New text:

CHAPTER PART R327—STATIONARY STORAGE BATTERY SYSTEMS

R327.1 General. Stationary storage battery systems, where provided, shall comply with the provisions of this section.

R327.2 Equipment listings. Stationary storage battery systems shall be listed and labeled for residential use in accordance with UL 9540.

Exceptions:
1. Where approved, repurposed unlisted battery systems from electric vehicles are allowed to be installed outdoors or in detached sheds located a minimum 5 ft (1524 mm) from exterior walls, property lines and public ways.

2. Battery systems that are an integral part of an electric vehicle are allowed provide the installation complies with Section 625.48 of NFPA 70

3. Battery systems less than 1 KWh (3.6 Mega joules)

Because ESS is a new, evolving technology, exceptions to R327.2 are provided to allow for installations of repurposed, nonlisted ESS from electric vehicles. However a 5-foot separation distance from exterior walls, the property line, and public ways to mitigate the performance of the equipment under fault conditions, which was not determined as part of a listing investigation. Installations using ESSs that are integral to electric vehicles also are allowed, provided they comply with the National Fire Protection Association (NFPA). - NFPA 70[3] “National Electrical Code” requirements that specifically cover such installations. A final exception exempts battery systems under 1 KWh, which is slightly greater than two 12-V, 40-AH batteries. This exemption covers common household standby power systems for tools, alarm systems, and other appliances from compliance with this section.

R327.3 Installation. Stationary storage battery systems shall be installed in accordance with the manufacturer's instructions and their listing, if applicable, and shall not be installed within the habitable space of a dwelling unit.

R327.4 Electrical installation. Stationary storage battery systems shall be installed in accordance with NFPA 70. Inverters shall be listed and labeled in accordance with UL 1741 or provided as part of the UL 9540 listing. Systems connected to the utility grid shall use inverters listed for utility interaction.

The R327.4 electrical installation requirements are based on R324.3, but include an option for inverters included as part of an EESS that is tested and listed to UL 9540. It also is important to note that NFPA 70-2017 includes a new article 706, “Energy Storage Systems,” that governs ESS installation, disconnection, shutdown, and safety labeling on energy storage systems. This new article could be used for guidance on EESS safety. The IRC adopts the National Electrical Code by reference. The 2018 IRC (currently under development) should reference the revised NFPA 70-2017.

R327.5 Ventilation. Indoor installations of stationary storage battery systems that include batteries that produce hydrogen or other flammable gases during charging shall be provided with ventilation in accordance with Section M1307.4.

R327.5 includes ventilation requirements that must be provided for indoor installations of EESS technologies, such as those including lead-acid batteries capable of producing hydrogen gas during charging.

R327.6 Protection from impact. Stationary storage battery systems installed in a location subject to vehicle damage shall be protected by approved barriers.

The R327.6 vehicle protection requirements are based on Section M1307.3.1.


Field Inspection:

Per the 2015 IECC, Section R104 Inspections, construction or work for which a permit is required is subject to inspection. Construction or work is to remain accessible and exposed for inspection purposes until approved. Required inspections include footings and the foundation, framing and rough-in work, plumbing rough-in, mechanical rough-in, and final inspection.

Per the 2015 IRC, Section R109 Inspections, for onsite construction, from time to time the building official, upon notification from the permit holder or his agent, can make or cause to be made any necessary inspections. Further details are provided for inspections regarding foundation, plumbing, mechanical, gas and electrical, floodplain, frame and masonry, and final inspection. Any additional inspections are at the discretion of the building official.

This section provides details for inspecting to the specific provisions for design and installation of energy storage systems where one or more specific types of inspection called for by the IECC or IRC may be necessary to confirm compliance. To confirm code compliance, final inspection typical type of inspection performed. (Bullet items underscored are based on the 2018 ICC code proposals.)

- Confirm the type of energy storage system, design, size and location per the approved construction documentation
- Confirm system ratings, testing and labeling
- Confirm inverter location and listing
- Confirm emergency shut off controls location and listing per approved construction documents.
Technical Validation(s):

This section provides additional related information and references to materials that are applicable to the provision.

  Timely deployment of a safe ESS is the way to document and validate compliance with current Codes, Standards, and Regulations (CSR). A task force under the CSR working group was formed to address compliance with current CSR. Through their efforts, the Energy Storage System Guide for Compliance with Safety Codes and Standards 2016 was developed.


- 2015 IRC—International Residential Code for One- and Two-Family Dwellings
  Author(s): ICC
  Organization(s): ICC
  Publication Date: May 2014
  This code for residential buildings creates minimum regulations for one- and two-family dwellings of three stories or less. It brings together all building, plumbing, mechanical, fuel gas, energy, and electrical provisions for one- and two-family residences.

  Author(s): Baechler, Gilbride, Ruiz, Stewart, Love
  Organization(s): PNNL, ORNL
  Publication Date: June, 2007
  The report provides an introduction to current photovoltaic and solar thermal building practices.

- The End of Fossil Fuels Will Involve a Complex Mix of Renewables, Dan Chiras, September 2016, Green Builder

Related BASC Guides:


Access to some references may require purchase from the publisher. While we continually update our database, links may have changed since posting. Please contact our webmaster if you find broken links.

Case Studies

1. **Case Study: Rural Development, Inc., Wisdom Way Solar Village, Greenfield, MA**
   - **Author(s):** PNNL, ORNL
   - **Organization(s):** PNNL, ORNL
   - **Publication Date:** December, 2010
     - Case study about a 20-unit community of energy-efficient duplexes in Massachusetts that incorporated solar water heating and photovoltaics.

References and Resources*

   - **Author(s):** Baechler, Gilbride, Ruiz, Stewart, Love
   - **Organization(s):** Pacific Northwest National Laboratory, Oak Ridge National Laboratory
   - **Publication Date:** June, 2007
     - Report providing an introduction to current photovoltaic and solar thermal building practices.

2. **DOE Zero Energy Ready Home National Program Requirements (Rev. 07)**
   - **Author(s):** Department of Energy
   - **Organization(s):** DOE
   - **Publication Date:** May, 2019
     - Standard requirements for DOE's Zero Energy Ready Home national program certification.

3. **General PV Specification**
   - **Author(s):** Aldrich
   - **Organization(s):** CARB, Steven Winter Associates, SWA
   - **Publication Date:** March, 2013
     - Brochure on specifications for PV systems.

4. **NABCEP Photovoltaic (PV) Installer Resource Guide**
   - **Author(s):** Brooks, Dunlop
   - **Organization(s):** NABCEP
   - **Publication Date:** March, 2012
     - This Photovoltaic (PV) Installer Resource Guide is an informational resource covering basic requirements for PV installations intended for individuals pursuing the Photovoltaic Installer Certification credential offered by the North American Board of Certified Energy Practitioners (NABCEP).

5. **PV Primer**
   - **Author(s):** Building Science Corporation
   - **Organization(s):** Building Science Corporation
   - **Publication Date:** June, 2006
     - Report aiming to "de-mistify" technology and economic considerations of residential PV systems.

   - **Author(s):** U.S. Environmental Protection Agency
   - **Organization(s):** EPA
   - **Publication Date:** January, 2011
     - The RERH specifications and checklists take a builder and a project design team through the steps of assessing a home’s solar resource potential and defining the minimum structural and system components needed to support a solar energy system.

*Publication dates are shown for formal documents. Dates are not shown for non-dated media. Access dates for referenced, non-dated media, such as web sites, are shown in the measure guide text.

Contributors to this Guide
The following authors and organizations contributed to the content in this Guide.
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