



U.S. DEPARTMENT OF ENERGY  
**SOLAR DECATHLON**

# **BUILDING CODE**

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## ***Section 1. Introduction***

Although there is some degree of overlap between the two, it is important to note some crucial distinctions between the Solar Decathlon Rules and the Solar Decathlon Building Code. The Rules exist primarily to promote a fair and interesting competition. The Building Code exists primarily to protect public health and ensure safety. Failure to comply with the Rules may result in official warnings, point penalties, or disqualification from the competition. Failure to comply with the Building Code may prohibit the participation of your house in any aspect of the overall competition. Therefore, compliance with the Building Code is a prerequisite for participation in the competition.

## ***Section 2. Adopted Codes***

The 2012 International Residential Code (IRC) of the International Code Council with amendments and the 2014 National Electric Code (NEC) of the National Fire Protection Agency (NFPA) have been adopted by reference as the Solar Decathlon Building Code and have the same force and effect as though fully set forth in the Solar Decathlon Rules, except as specifically amended by provisions that follow.

## ***Section 3. Building Planning and Construction***

The building is intended to be representative of a single-family dwelling constructed in accordance with the provisions contained in the IRC. Because portions of the building will be open to viewing by the general public, the IRC is amended with specific provisions of the International Building Code (IBC) and the Architectural Barriers Act as appropriate. The following provisions are amended and emphasized as they constitute the highest degree of risk to the building occupants during public exhibition. Compliance with the letter or intent of the referenced codes is mandatory in addition to the items discussed in the paragraphs below.

### **3-1. Fire Protection and Prevention**

#### **a. Fire Protection Plan**

Each team shall provide a fire protection plan. This plan should indicate the location of fire extinguishers, how egress will be made from the unit, and who will be responsible (i.e., the team's health and safety officer) for public tour life safety during the event. Include a written operations plan for team-facilitated orderly and quick evacuation and fire mitigation. Successful demonstration of the plan will be required before any public tour of the building will be permitted.

- #### **b. Each house will be required to have smoke alarms per IRC requirements and a fire extinguisher with a minimum Underwriters Laboratory (UL) rating of 2A-10BC. Smoke alarms shall be connected to the AC voltage side of the inverter and provided with independent, e.g., integral with the alarm, battery backup. All alarms shall be interconnected and all shall sound when one is activated (IRC, Sec. R314).**

### **3-2. Means of Egress**

The following means of egress components accessible to the public shall comply with Chapter 10 of the International Building Code.

- #### **a. Stairs**

**Stairs are prohibited.** All changes in elevation used as part of the public tour, accessible route, or means of egress shall be provided with sloped walking surfaces or ramps. Demonstration or mechanical equipment access stairs located within the interior of the dwelling and excluded from use by the public or any other individual during the public tours may be provided in accordance with IRC Section 311.4. Ladders or stairs that are not IRC compliant may be provided as “demonstrators” but the design team should be aware that United States building codes typically do not permit their use for access to habitable spaces. Stairs to habitable spaces excluded from use by the public or any other individual during public tours may be provided following specific approval by the Building Official.

b. Handrails

Handrails shall be provided on both sides of ramps (sloped walking surfaces in excess of 5% in the direction of travel) used by the public during the display. All handrails shall be designed in accordance with 2010 Standard for Accessible Design Section 505.

### 3-3. Interior Finishes

Interior finishes must comply with IRC Section R302.9. Synthesized building materials, such as those using plastics, must be provided with the manufacturer’s test documentation indicating compliance with ASTM E-84 or UL 723 demonstrating a minimum Class C. Exceptions:

- a. Materials tested to EN 13501 with a minimum Euro-Class C
- b. Materials tested to DIN 4102 with a minimum B1 classification
- c. Other testing methods subject to approval by the Solar Decathlon Building Official

### 3-4. Glazing

The following hazardous locations are subject to human impact and require safety glazing. See IRC Section 308 for specific details and exceptions.

- a. Photovoltaic modules containing glazing materials and placed within any of the locations listed in Items b through g below
- b. Glazing in doors
- c. Glazing in doors, surrounds, and walls enclosing or facing bathtubs or showers where not located more than 60 in. (152 cm) above the finished floor
- d. Glazing in windows within a 24 in. (61.0 cm) arc of either vertical edge of a door and less than 60 in. (152.4 cm) above the floor
- e. Glazing within 36 in. (91.4 cm) of stairways and/or within 60 in. (152.4 cm) of the bottom edge of stair treads when the bottom edge of the glazing is less than 60 in. (152.4 cm) above a walking surface
- f. Glazing in overhead panels (including skylights and glazed solar panels) placed where glazing is not separated from the occupants by a solid surface such as a roof
- g. Glazing in panels located with all the following conditions present:
  - i. Pane of glazing is greater than 9 ft<sup>2</sup> (0.836 m<sup>2</sup>)
  - ii. Bottom edge of glazing is less than 18 in. (45.7 cm) above the floor
  - iii. Top edge of glazing is greater than 36 in. (91.4 cm) above the floor
  - iv. Walking surface is located within 36 in. (91.4 cm) of the glazing (IRC, Sec. 308.4).

### **3-5. Roofing**

All roofing materials shall comply with IRC Chapter 9. Photovoltaic modules and shingles modules must be evaluated in accordance with UL 1703 and be designed for design wind loads.

### **3-6. Foam Plastic Insulation**

Foam plastics used for building construction shall only be permitted if the foam plastic is isolated from the interior of the building with gypsum board 0.5 in. (1.3 cm) thick. This applies to foams typically used in structural insulated panel wall, floor, and roof systems. Provide documentation to demonstrate compliance (IRC, Sec. R316).

- a. Gypsum board containing phase-change materials and other flammable performance enhancements may not qualify as the required thermal barrier unless specifically approved.
- b. The thermal barrier specified in Section R316.4 is not required to be installed on the walking surface of a structural floor system that contains foam plastic insulation where the foam plastic is covered by a minimum nominal 0.5 inch (1.3 cm) thick wood structural panel or equivalent.
- c. Exposed foam plastic located in attics or crawlspaces (interstitial space between the floor assembly and the competition site surface) shall be covered with an ignition barrier consisting of 1.5 in. (3.81 cm) thick mineral fiber insulation, 0.25 in. (0.64 cm) thick wood structural panels, 0.375 in. (0.95 cm) thick particleboard, 0.25 in. (0.64 cm) hardboard, 0.375 in. (0.95 cm) gypsum board, or corrosion-resistant steel having a base metal thickness of 0.016 inch (0.41 mm).

### **3-7. Exterior Envelope**

Drawings submitted for review shall contain section details of proposed wall assembly showing framing, sheathing, water-resistive barrier, flashing, and exterior cladding as applicable (IRC, Sec. R703).

### **3-8. Ceiling Height**

Ceiling height shall provide a minimum of 7 ft (213.4 cm) of headroom in habitable locations and as otherwise specified in IRC, Sec. R305.

### **3-9. Skylights**

IRC Section R308.6 regulates skylight glazing. Glazing is limited to certain types, and screening under the glazing may be required. Indicate which glazing products are to be used and provide sufficient details in the submitted plans to ensure compliance (IRC, Sec. 308.6). Glass PV or hydronic solar collectors used overhead without a solid surface underneath (such as a roof) will be regulated as skylights.

### **3-10. Energy Conservation**

Design and construction for energy conservation shall be in accordance with the 2012 International Residential Code. Buildings shall be designed using the Climate Zone specified at the final location for the structure following the public exhibit in Irvine, California at the Orange County Great Park. For areas outside of the United States, determination of climate zone equivalency shall be provided in accordance with IRC Section N1101.10. Teams will be required to demonstrate compliance by using either the prescriptive method, UA Trade Off approach, or by performance modeling using RESNET or other approved software.

### **3-11. Fire Sprinkler System**

2012 IRC Section R313 requires fire-suppression sprinkler systems in all single-family dwellings. All buildings **shall be provided with fire sprinklers** designed in accordance with IRC Section P2904 or

NFPA 13D. Such systems shall be fully operational during the public exhibit and competition. Each dwelling will be individually required to provide site-stored fire water for sprinkler operations based on the sprinkler system design demand. Each dwelling's sprinkler will be required to be provided with a pump capable of the pressure and volume required for the fire sprinkler design. A test and valve shall be placed in an accessible location at the most remote point of the sprinkler system. This valve will be used to assist in charging the system with water, and will be operated by the team during the inspection period to demonstrate that the sprinkler system is charged and that the pump used for sprinkler pressurization is operating correctly. Pumps used for fire sprinklers may be dedicated to the fire sprinkler system or be used for both domestic and fire system purposes.

## ***Section 4. Accessibility***

### **4-1. Accessible Route – Interior**

An accessible route shall be provided within the unit to all spaces accessible to the public as part of the tour. Components of the accessible route used by the touring public must comply with 2010 Standard for Accessible Design. Other accessible features may be included in rooms such as kitchens and bathrooms at the discretion of the designers. If any of the features are available and intended for use by the public, they shall be accessible in accordance with the 2010 Standard for Accessible Design. Voluntary accessibility provided outside of areas accessible to the touring public should comply with 2012 IBC Chapter 11 and ICC/ANSI A117.1-2009 for the level of accessibility desired.

### **4-2. Accessibility – Habitable Roof Deck and Interior Second Floor/Loft Levels**

Solar Decathlon competition houses are intended to demonstrate single-family dwellings that would not normally be regulated by federal accessibility standards. However, these buildings are open to the public for educational purposes and must be accessible in all primary function areas. Therefore, any portion of the building where the public is permitted must provide an accessible route.

- a. The Americans with Disabilities Act (ADA) requires an elevator to be installed in buildings (funded pursuant to Title II) where an accessible route is required to stories above the first floor (such as the roof deck, second floor, or loft). The 3,000 ft<sup>2</sup> (278.7 m<sup>2</sup>) exception located in IBC Section 1104.4 Exc. 1 is superseded by this Federal regulation.
- b. The ADA Technical Assistance Center has stated that it is acceptable to “demonstrate” a roof deck, loft, or upper level accessed via stairs, or other means of inaccessible access, as long as no member of the public, organizers, or competing teams is allowed to access the space during public exhibit periods. Any provided means of access shall be fully gated or cordoned off to inhibit entry. Adherence to these guidelines should remove any perception that the upper level is being used as a primary function and therefore subject to the accessibility provisions of the ADA.
- c. Please note that the construction of buildings using U.S. Federal Funds requires compliance with the Architectural Barriers Act. Scoping and technical criteria can be found in the [2010 Standard for Accessible Design](http://www.ada.gov/regs2010/2010ADAStandards/2010ADAStandards_prt.pdf): [http://www.ada.gov/regs2010/2010ADAStandards/2010ADAStandards\\_prt.pdf](http://www.ada.gov/regs2010/2010ADAStandards/2010ADAStandards_prt.pdf) Technical provisions in the Guidelines are similar to those contained in ICC A117.1-2009.

### **4-3. Accessibility – Ramps**

The following are the most important regulations and specific Solar Decathlon criteria regarding ramps:

- a. A “ramp” is any sloping surface used as part of the circulation path that has a slope in excess of 1:20. Sloping surfaces less than 1:20 shall comply with 2010 Standard for Accessible Design Section 403.

- b. The slope of a ramp cannot exceed 1:12.
- c. At the top and bottom of any ramp, a landing 60 in. (152.4 cm) long is required.
- d. A 60 in. by 60 in. (152.4 cm by 152.4 cm) landing is required at any point where a ramp changes directions.
- e. Handrails are required if the ramp's rise exceeds 6 in. (15 cm) (2010 Standard for Accessible Design Section 405). Handrails shall be continuous and be provided with 12-in. (305-mm) extensions beyond the top and bottom of the ramp's sloping surface. Handrails with a circular cross section shall have an outside diameter of at least 1.25 in. (32 mm) and not greater than 2 in. (51 mm). If the handrail is not circular, it shall have a perimeter dimension of at least 4 in. (102 mm) and not greater than 6.25 in. (160 mm) with a maximum cross-section dimension of 2.25 in. (57 mm). Handrails shall be uniform in height, not less than 34 in. (864 mm) and not more than 38 in. (965 mm) above the walking surface of the ramp.
- f. Teams must design and provide a metal plate transition component between the access ramp and the walking surface of the competition site. Such plate shall be no greater than 1/2 inch (12.7mm) thick at the edge contacting the walking surface of the competition site. If the edge exceeds 1/4 inch (6.3mm) thickness, it shall be provided with a 1:2 bevel. If the connected ramp exceeds 5% slope, the transition plate and the ramp must be provided with handrails and edge protection. Both shall extend onto the transition plate with the handrails extending 12 in. (305mm) beyond the termination of the transition plate. The design of the transition plate shall accommodate the lateral loads placed on the handrails and extensions without relying on ground embedment for support.

#### **4-4. Changes in Elevation**

All changes in elevation (including even minor changes in areas such as door thresholds) must be considered along an accessible route. Changes not exceeding 0.25 in. (0.64 cm) are acceptable.

- a. Elevation changes between 0.25 in. and 0.5 in. (0.64 cm and 1.3 cm) shall be beveled at a maximum of 1:2 slope.
- b. Any change in elevation exceeding 0.5 in. (1.3 cm) shall be by a ramp with a maximum slope of 1:12 (2010 Standard for Accessible Design Section 405).
- c. Sloped walking surfaces complying with 2010 Standard for Accessible Design Section 403 shall be permitted.

#### **4-5. Doors and Door Approaches**

All doors shall comply with the 2010 Standard for Accessible Design Section 404.

- a. Doors that can be fixed in an open position may be accepted as part of the accessible route if 32 in. (81.3 cm) minimum clearance is provided through the door opening with the door secured in the fully open position.
- b. Doors without required maneuvering clearances that are intended to remain open during the public tour must be clearly identified on the plans and approved by the Solar Decathlon Building Official.

## ***Section 5. Structural***

The structural drawings and calculations shall be stamped by a qualified, licensed professional engineer. Such engineer shall be registered in the State of California or be eligible for California registration reciprocity. Obtaining the stamp is the responsibility of the teams, not the organizers. The organizers will submit stamped structural drawings and calculations to the City of Irvine, California for final approval. It



is strongly recommended that teams involve a qualified, licensed professional throughout the design process because he or she could require structural design changes that could affect other aspects of the house. In addition to meeting applicable IRC requirements, special attention must be given to the structural design challenges unique to the temporary exhibit. These challenges include, but are not limited to, the following:

- a. Increased live loads because of public access to houses.
- b. Necessity for non-earth-embedded foundations employing steel stake anchor embedment tie-down because of the lack of a permanent foundation and unique wind-loading conditions because of roof-mounted solar systems.
- c. Increased dead loads because of unusual or concentrated mechanical and electrical equipment.

## **5-1. Prescriptive Requirements**

- a. Structural systems shall be designed in accordance with the appropriate prescriptive provisions of the IRC where practical. Engineered design may be employed using accepted engineering practice in accordance with the International Building Code. Alternate materials and methods shall comply with IRC Section 104.11 and Sec. CC2.6.
- b. Structural framing: A detailed one-line structural plan view drawing is required at a minimum. Successive plan sheets shall be provided and shall include foundation footings, anchorage details, floor framing, wall locations, and roof framing. All structural components shall be listed including sizes, species and grade, orientation of the structural components, and repetitive spacing (on-center distances). Include details on connections between joists and beams, floor systems and foundations, walls and floors, rafters and beams, etc. Specify proprietary hangers or other mechanical connections (IRC, Sec. R301.1).

## **5-2. Design Loads**

The following minimum loads must be used in the structural design:

- a. Wind: 85 mph (38.0 m/s) (3-second gust), exposure category C (if anchorage design is not employed, the design must show that there is no overturning, uplifting, or sliding with a safety factor of 2).
- b. Seismic: IRC Seismic Design Category (SDC) D<sub>2</sub> See IRC Section R301.2.2.
- c. Railings: 200 lb (890 N) concentrated load applied in any direction at any point at the top of the rail.
- d. Interior floor, decks, ramps: 50 psf (2.39 kPa) live load.
- e. Exterior floor, decks, ramps used for tour staging and egress purposes: 100psf (4.79 kPa) live load.
- f. Roof: 20 psf (0.958 kPa) live load.
- g. Temporary Paved Surface: 6,000 psf (287 kPa) maximum load-bearing pressure. Additional structural design requirements at the post-event house location (to be determined by the licensed professional of record).

Structural plans shall indicate the design live loads [e.g., 40 psf (1.92 kPa) floors, 100 psf (4.79 kPa) means of egress components (ramps), 20 psf (0.958 kPa) snow roof live load] and the location, size, and weight of special loads such as liquid storage tanks and mass or trombe walls. These loads are considered minimums for the temporary event competition. Higher design loads may be mandated by the local authority having jurisdiction in the location where the house will be permanently sited. The design should accommodate the higher of the design values required by the Solar Decathlon Building Code or the local Authority Having Jurisdiction (AHJ).

### 5-3. Exterior Construction

Structural plans shall include design details for any exterior appurtenances such as decks, stairs, ramps, awnings, canopies, and roof projections (IRC, Sec. R301.1). Deck structural framing shall include full details for house ledger connections, joist-to-beam connections, and beam-to-column/footing connections. Special design attention shall be paid to load path for deck foundation systems for concealed footing systems.

### 5-4. Specific Point Loads

Provide wind-analysis calculations for point-load connections demonstrating the components' abilities to withstand 85 mph (38.0 m/s) (3 second gust), exposure category C wind conditions. Provide point-load connection details for all solar panel connections to demonstrate that the connections will resist uplift (IRC, Sec. R301.1 and R905.16).

### 5-5. Foundation

Provide a foundation plan for temporary setup on the competition site. The design must accommodate all design loads, including gravity and lateral derived from wind and seismic. Plans shall include location and size of all temporary footings and required tie-down anchors (e.g., type, number, and installation configuration) to prevent wind uplift or overturning (IRC, Sec. R401.1 and R401.2) and to provide adequate lateral load transference for SDC D<sub>2</sub> design seismic forces. Please provide consideration for sloping or variable site conditions.

General Requirements:

- a. All houses, decks, and other structures shall be provided with foundations sufficient to safely transmit gravity, lateral, and uplift loads. For purposes of design, the presumptive paved surface bearing capacity shall be 6,000 psf (287 kPa). Design wind speed shall be 85 mph (38.0 m/s) (3-second gust) with a C exposure.
- b. Uplift design may employ uplift anchorage, dead-load analysis, or a combination of both. Anchorage embedment into the temporary site will be limited to the method and design values indicated in Section 5.5(c). Teams are encouraged to configure their structures to take advantage of dead loads to resist wind uplift, and seismic- and wind-generated overturning and sliding. All designs shall be supported by calculations demonstrating the efficacy of the designed system. Foundation designs and calculations shall be approved prior to placement of the structure on the Orange County Great Park competition site in Irvine, California.
- c. Ground anchorage may be affected by use of minimum 1-inch (25.4-mm) diameter, A36 mild solid steel stakes driven a minimum of 36 in. into the existing pavement surface. Such stakes shall be driven vertically. Design stake capacity shall be assumed as:
  - 1,250 pounds vertical withdrawal (pull out)
  - 1,500 pounds horizontal shear
  - Or as determined by Calculation 5.5c, where both forces are applied.

$$\text{Calculation 5.5c:} \quad \frac{\text{Actual Withdrawal Load (lbs)}}{1,250 \text{ Pounds}} + \frac{\text{Actual Shear Load (lbs)}}{1,500 \text{ Pounds}} \leq 1$$

Teams will be responsible for the design and structural qualification for the load transference mechanism between the stake and the building structure being anchored. Threaded rods may be used. Driven rods used in multiples must be spaced a minimum of 24 in. on center.

Teams are responsible for removal of the stakes at the conclusion of the event. Teams are not permitted to drive the stake below the surface of the existing pavement. All stakes must be removed from the site at the conclusion of the event.

Alternative ground anchorage methods may be permitted upon approval of the Solar Decathlon Building Official and by special permission of the Orange County Great Park.

## **5-6. Alternate Materials**

Alternate materials are permitted as follows:

- a. Engineered lumber (e.g., TJIs, LPs, and BCIs) pursuant to specific manufacturer's design data: The product selected must carry a current ICC Evaluation Services report. See <http://www.icc-es.org/>.
- b. Structurally insulated panel systems pursuant to specific manufacturer's design data: The product selected must carry a current ICC Evaluation Services report. Also be advised that foam plastics must be thermally isolated from the interior of the dwelling (see Section 3-6 for more details).
- c. Engineered trusses (floor or roof) must be designed in accordance with IRC Sections R502.11 or R802.10 as appropriate: Individual truss reports shall be provided for review and shall bear the seal of a registered design professional.
- d. Alternate materials may be permitted if approved pursuant to approval by written request under IRC Section 104.11: It is the responsibility of the applicant to provide adequate proof to document the alternate as meeting the intent of the prescriptive code requirements. The organizers reserve the right to deny any alternate for failure to clearly demonstrate code equivalence.
- e. Phase-change materials included within building components must be identified on the plans. Specifications for the material composition must be provided with fire-performance testing data. Be advised that phase-change embedment in gypsum board or interior wall or ceiling finishes may affect the ability of these materials to pass IRC required fire tests.
- f. Unlisted electrical components intended to be used must be fully disclosed no later than 12 months prior to the start of the competition. Such unlisted components will be limited to 60 volts. Such components shall be fully described in a written proposal format with competent technical substantiation provided. The proposal is subject to approval by the event organizers subject to stipulated minimum testing to ensure safe operation during the public event.

## **5-7. Structural Steel**

Provide structural details for load-carrying structural steel assemblies. Include welded or bolted connections within the assembly and where attached to other structures (IRC, Sec. R301.1.3).

# **Section 6. Electrical**

## **6-1. Governing Code**

The provisions of the 2014 NEC supersede the limited prescriptive electrical requirements contained in Chapters 33-42 of the IRC.

Exception: Electrical system design methods required by non-US entrants for compliance in the jurisdiction of final placement may be permitted following review and approval by the Solar Decathlon Building Code Official. Such approval will require compliance with an approved national or international electrical code or standard. Teams seeking approval must submit two copies of the referenced code for evaluation prior to approval. If approved, such teams will be required to provide special inspection of the

electrical system prior to placement of the structure in Irvine, California. Solar Decathlon temporary site final inspections of the visible electrical system will be performed by Solar Decathlon electrical inspectors using team supplied electrical test equipment suitable for the approved NEC-alternate electrical system.

## 6-2. Drawing Requirements

- a. Electrical plan(s) must include layouts of proposed receptacles, switches, light fixtures, smoke alarms, ceiling fans, etc.
- b. Provide details on the proposed PV system along with a key for symbols used in the drawings. Such details shall include information on the photovoltaic panels, distribution (e.g., wiring, inverters, switch gear, and over-current protection), and storage equipment (IRC, Sec. R106.1.1).
- c. Provide a key for electrical symbols used in the electrical plans (IRC, Sec. R106.1.1).

## 6-3. Tamper-Resistant Receptacles

### 406.11 Tamper-Resistant Receptacles in Dwelling Units.

In all areas specified in NEC Article 210.52, all 125-volt, 15- and 20-ampere receptacles shall be listed tamper-resistant receptacles.

Figure 1: NEC excerpt regarding tamper-resistant receptacles

## 6-4. Outdoor Receptacles

Any receptacles used on the exterior of the building must be protected with ground fault circuit interrupters (GFCI). Enclosures provided must be suitable for damp locations.

### 406.8 Receptacles in Damp or Wet Locations.

(A) Damp Locations. A receptacle installed outdoors in a location protected from the weather or in other damp locations shall have an enclosure for the receptacle that is weatherproof when the receptacle is covered (attachment plug cap not inserted and receptacle covers closed).

An installation suitable for wet locations shall also be considered suitable for damp locations.

A receptacle shall be considered to be in a location protected from the weather where located under roofed open porches, canopies, marquees, and the like, and will not be subjected to a beating rain or water runoff. All 15- and 20-ampere, 125- and 250-volt nonlocking receptacles shall be a listed weather-resistant type.

FPN: The types of receptacles covered by this requirement are identified as 5-15, 5-20, 6-15, and 6-20 in ANSI/NEMA WD 6-2002, National Electrical Manufacturers Association Standard for Dimensions of Attachment Plugs and Receptacles.

(B) Wet Locations.

(1) 15- and 20-Ampere Receptacles in a Wet Location. 15- and 20-ampere, 125- and 250-volt receptacles installed in a wet location shall have an enclosure that is weatherproof whether or not the attachment plug cap is inserted. All 15- and 20-ampere, 125- and 250-volt nonlocking receptacles shall be listed weather-resistant type.

FPN: The types of receptacles covered by this requirement are identified as 5-15, 5-20, 6-15, and 6-20 in ANSI/NEMA WD 6-2002, National Electrical Manufacturers Association Standard for Dimensions of Attachment Plugs and Receptacles.]

Exception: 15- and 20-ampere, 125- through 250-volt receptacles installed in a wet location and subject to routine high-pressure spray washing shall be permitted to have an enclosure that is weatherproof when the attachment plug is removed.

Figure 2: NEC excerpt regarding receptacles in damp or wet locations

## 6-5. Arc-Fault Circuit Protection

### 210.12 Arc-Fault Circuit-Interrupter Protection.

(A) Definition: Arc-Fault Circuit Interrupter (AFCI). A device intended to provide protection from the effects of arc faults by recognizing characteristics unique to arcing and by functioning to de-energize the circuit when an arc fault is detected.

(B) Dwelling Units. All 120-volt, single phase, 15- and 20-ampere branch circuits supplying outlets installed in dwelling unit family rooms, dining rooms, living rooms, parlors, libraries, dens, bedrooms, sunrooms, recreation rooms, closets, hallways, or similar rooms or areas shall be protected by a listed arc-fault circuit interrupter, combination-type, installed to provide protection of the branch circuit.

Exception No. 1: Where RMC, IMC, EMT or steel armored cable, Type AC, meeting the requirements of 250.118 using metal outlet and junction boxes is installed for the portion of the branch circuit between the branch-circuit overcurrent device and the first outlet, it shall be permitted to install a combination AFCI at the first outlet to provide protection for the remaining portion of the branch circuit.

Exception No. 2: Where a branch circuit to a fire alarm system installed in accordance with 760.41(B) and 760.121(B) is installed in RMC, IMC, EMT, or steel armored cable, Type AC, meeting the requirements of 250.118, with metal outlet and junction boxes, AFCI protection shall be permitted to be omitted.

Figure 3: NEC excerpt regarding arc-fault circuit protection

## 6-6. Ground-Fault Circuit Protection

Any AC receptacles located in kitchens or bathrooms shall be GFCI protected.

### 210.8 Ground-Fault Circuit-Interrupter Protection for Personnel.

(A) Dwelling Units. All 125-volt, single-phase, 15- and 20-ampere receptacles installed in the locations specified in (1) through (8) shall have ground-fault circuit-interrupter protection for personnel.

(1) Bathrooms

(2) Garages, and also accessory buildings that have a floor located at or below grade level not intended as habitable rooms and limited to storage areas, work areas, and areas of similar use

(3) Outdoors

Exception to (3): Receptacles that are not readily accessible and are supplied by a dedicated branch circuit for electric snow-melting or deicing equipment shall be permitted to be installed in accordance with 426.28.

(4) Crawl spaces — at or below grade level

(5) Unfinished basements — for purposes of this section, unfinished basements are defined as portions or areas of the basement not intended as habitable rooms and limited to storage areas, work areas, and the like

Exception to (5): A receptacle supplying only a permanently installed fire alarm or burglar alarm system shall not be required to have ground-fault circuit-interrupter protection.

FPN: See 760.41(B) and 760.121(B) for power supply requirements for fire alarm systems.

Receptacles installed under the exception to 210.8(A)(5) shall not be considered as meeting the requirements of 210.52(G).

(6) Kitchens — where the receptacles are installed to serve the countertop surfaces

(7) Laundry, utility, and wet bar sinks — where the receptacles are installed within 1.8 m (6 ft) of the outside edge of the sink.

Figure 4: NEC excerpt regarding ground-fault circuit protection

## 6-7. Equipment Listings

All electrical equipment shall carry an approved testing agency's listing or shall have been approved by the Solar Decathlon Building Official and Solar Decathlon electrical inspectors for temporary use during the event in accordance with Section 104.11 of the IRC and Section 110.2 of the NEC.

- a. Unlisted PV modules may be used in a system with a DC bus voltage of no greater than 60 volts (open-circuit) at 32°F (0°C) if, and only if, such equipment has been evaluated and approved by the Solar Decathlon Building Official and Solar Decathlon electrical inspectors. PV cell and module mounting means are subject to increased scrutiny in custom, unlisted, building-integrated PV applications.
- b. The use of unlisted PV modules and the installation of listed PV modules in an unapproved manner in a system with a DC bus voltage of greater than 60 volts (open-circuit) at 32°F (0°C) are prohibited. Listings shall be to United States UL Standards and shall be granted by an OSHA approved, accredited testing laboratory.
- c. The attachment of PV modules to any material where the PV module is not listed for such an application is prohibited, regardless of the bus voltage.
- d. All DC to AC utility-interactive inverters must be fully listed to UL Standard 1741.

## 6-8. Photovoltaics

Particular attention should be paid to Articles 690, 480, 445, 250, 310, 400, and 240 of the NEC, which refer to photovoltaic system design, storage batteries, generators, grounding, conductors for general wiring, flexible cords and cables, and over-current protection devices, respectively.

Teams are also encouraged to follow the guidelines in the following publication: Wiles, John C. *Photovoltaic Power Systems and the 2005 National Electric Code: Suggested Practices*, Southwest Technology Development Institute, New Mexico State University, 2008. This publication can be downloaded for free at <http://www.nmsu.edu/~tdi/Photovoltaics/Codes-Stds/PVnecSugPract.html>.

## 6-9. Grounding

Each team shall provide a grounding electrode conductor from the dwelling's main service equipment to the organizer utility panel. The grounding electrode conductor shall be a minimum size of 4 AWG copper, either bare or insulated. The organizers will bond the dwelling grounding electrode conductor to the organizer grounding electrode.

Each dwelling shall *not* have or install a grounding electrode (commonly referred to as a ground rod).

## 6-10. Inverter Disconnect

Each team shall provide a disconnecting means located between the inverter and the solar array where panel-integrated microinverters are not employed. The disconnecting means should be capable of ready lockout/tagout to facilitate safe service of the inverter(s).

# *Section 7. Mechanical*

## 7-1. Drawing Requirements

Provide a key for symbols used in the drawings (IRC, Sec. R106.1.1).

## **7-2. Return Air**

Return air shall not be taken from a bathroom, kitchen, mechanical, or furnace room. (IRC, Sec. M1602.2).

## **7-3. Outside and Exhaust Air**

### a. Outside Air

Outside air shall not be taken closer than 10 ft (304.8 cm) from an appliance or plumbing vent, or discharge outlet of an exhaust fan [unless the intake is located at least 3 ft (91.4 cm) below the vent or fan discharge] (IRC, Sec. M1602.2, Item 1).

### b. Screens

Outside air inlets shall be equipped with a screen with openings 0.25 in. to 0.5 in. (0.64 cm to 1.3 cm) (IRC, Sec. M1602.3).

### c. Exhaust hood systems capable of exhausting in excess of 400 cubic feet per minute (0.19 m<sup>3</sup>/s) shall be provided with makeup air at a rate approximately equal to the exhaust air rate. Such makeup air systems shall be equipped with a means of closure and shall be automatically controlled to start and operate simultaneously with the exhaust system. (IRC Sec. M1503.4)

## **7-4. Bathroom Ventilation**

Bathrooms shall be provided with mechanical ventilation systems capable of providing 50 cfm (23.6 L/s) for intermittent ventilation or 20 cfm (9.4 L/s) for continuous ventilation, or with windows allowing a 1.5 ft<sup>2</sup> (0.14 m<sup>2</sup>) opening for natural ventilation (IRC, Sec. R303.3).

# ***Section 8. Solar Mechanical***

## **8-1. Drawing Requirements**

Provide plan details for any proposed solar mechanical systems. Provide details on collectors, fluid distribution, heat exchangers, etc., along with a key for symbols used in the drawings (IRC, Sec. 106.1.1). Plans should emphasize compliance with IRC M2301.

## **8-2. Cross Connection**

Provide details for the solar hot-water system. Provide details indicating if potable water or other heat transfer liquids will be employed. If other than potable water is used, an approved heat exchanger shall be employed to isolate potable water from transfer fluids (IRC Section R106.1.1).

## **8-3. Access**

Solar collectors, controls, dampers, fans, and pumps shall be accessible for inspection, maintenance, repair, and replacement (IRC, Sec. M2301.2.1).

## **8-4. Roof-Mounted Collectors**

The roof shall be constructed to support all loads imposed by the collectors. If collectors are intended to serve as the roof covering, documentation shall be provided to determine compliance with the roofing provisions in IRC, Chapter 9. If the collectors will be placed over the roof covering, the collectors and supporting structure shall be constructed of noncombustible material or fire-retardant-treated wood equivalent to that required for the roof covering (IRC, Sec. M2301.2.2).

### **8-5. Pressure and Temperature Relief**

Pressure- and temperature-relief valves shall be provided for components under pressure. Relief devices shall be installed in sections of the system so that a section cannot be valved off or isolated from a relief device (IRC, Sec. M2301.2.3). Pressure and temperature relief devices shall have the capacity to be removed and capped prior to inspection to accommodate the required 100 psi (690 kPa) system pressure test required by Section 8-13.

### **8-6. Vacuum Relief**

A vacuum relief valve shall protect system components that might be subjected to pressure drops below atmospheric pressure during operation or shutdown. Plans shall indicate if this system is subject to vacuum conditions (IRC, Sec. M2301.2.4).

### **8-7. Expansion Tanks**

Expansion tanks in solar systems shall be installed in accordance with IRC, Section M2301 in closed-fluid loops that contain heat-transfer fluid (IRC, Sec. M2301.2.6).

### **8-8. Solar Loop Isolation**

Valves shall be installed to allow isolation of the solar collectors from the remainder of the system (IRC, Sec. M2301.2.8).

### **8-9. Maximum Temperature Limitation**

Systems shall be equipped with means to limit the maximum water temperature of the system fluid entering or exchanging heat with any pressurized vessel inside the dwelling to 180°F (82°C). This protection is required in addition to required temperature and pressure relief valves stated in IRC, Section M2301.2.3 (IRC, Sec. M2301.2.9).

### **8-10. Collector and Thermal Storage Unit Labeling**

- a. Collectors and storage units shall be listed and labeled to show the manufacturer's name, model number, serial number, collector weight, collector maximum allowable temperatures and pressures, and the type of heat transfer fluids that are compatible with the collector and storage units (IRC, Sec. 2301.3).
- b. Identification of system components. All components of the solar hydronic system shall be identified with permanent identification labels. Such labels shall indicate the function of the component (i.e. panel loop supply or return, heat exchanger, domestic loop, etc.) and flow direction.

Exception: Domestic plumbing fixture supply and in-floor radiant heat loops.

### **8-11. Prohibited Heat-Transfer Media**

Flammable gasses and liquids shall not be used as heat-transfer fluids (IRC, Sec. M2301.4).

### **8-12. Backflow Prevention**

All connections from the potable water supply to solar systems shall comply with IRC, Section P2902.4.5 (IRC, Sec. M2301.5).



### **8-13. Pressure Test**

All solar hydronic piping shall be tested hydrostatically at a pressure of not less than 100 psi (690 kPa) for no fewer than 15 minutes. Temperature and pressure relief devices that operate at or less than 100 psi (690 kPa) shall be isolated during the test by removal and capping.

Exception: Systems designed for pressures under 100psi (690kPa) may be tested at lower pressures when approved by the Solar Decathlon Building Official. Such testing must be approved prior to transportation of the structure to the competition site.

## ***Section 9. Plumbing***

### **9-1. Drawing Requirements**

- a. Provide a labeled isometric diagram of the proposed plumbing system for review. Clearly indicate waste lines, vent lines, potable water supply, heat exchange equipment, and the type of any heat transferring fluid used other than potable water.
- b. Provide a key for symbols used in the drawings (IRC, Sec. 106.1.1).

### **9-2. Water Closet Demonstration**

Water closets are installed for demonstration only and shall not be connected to any portion of the sewage disposal system. The water closet may be attached to a PVC or ABS 4 in. to 3 in. (10.2 cm to 7.7 cm) water-closet flange provided with a capped end or with the test plug knock-out in place. No structural member shall be cut or otherwise damaged to accommodate the water-closet flange assembly. No water supply shall be extended to the water closet unless otherwise approved by the Solar Decathlon Building Official. Bowl openings should be provided with a concealed opaque cover to discourage use of the toilet during the temporary exhibit.

### **9-3. Plumbing Wall – Structural**

Recommendation: Create a dedicated plumbing wall with thickness sufficient to allow pipe penetrations within the studs not exceeding 60% of the stud width in nonbearing walls (IRC, Sec. 602.6).

### **9-4. Shower Mixing Valves**

Shower mixing valves shall be pressure balanced, thermostatic mixing, or a combination of the two, with the high limit set at 120°F (48.9°C) to prevent scalding (IRC, Sec. P2708.3).

### **9-5. Backflow Prevention**

Backflow prevention is required to isolate the potable water supply from the solar systems. See IRC Section P2902.2 for permissible devices. Because this project uses supply tanks for potable water, the use of a separate and isolated fill system for the solar component may be deemed acceptable backflow prevention (IRC, Sec. P2902.2).

### **9-6. Water Heater and Heated Storage Vessel Seismic Support**

Water heaters and other heated fluid storage vessels shall be anchored or strapped in the upper one-third and in the lower one-third of the appliance to resist a horizontal force equal to one-third of the operating weight of the water heater, acting in any horizontal direction, or in accordance with the appliance manufacturer's recommendations.

## **9-7. Supply**

No additives of any kind may be added to the water in the team's supply tank. This water is not for consumption at any time. Teams will be required to provide the tank and support this tank so that it does not damage the competition site.

## **9-8. Waste**

All substances used in combination with water to clean the house, dishes, utensils, etc., must be nontoxic and preferably biodegradable. Teams may incur a point penalty for any toxic substances that are found in the wastewater tank.

## **9-9. Water Feature Safety**

- a. Water features shall not exceed a depth of 2 ft (61 cm).
- b. For water features >1 ft but <2 ft (>30.5 cm but <61 cm), there shall be a representative from the team positioned at the water feature when open to the public to monitor the area and act as a lifeguard if necessary. During times when the area is not open to the public, the water feature shall be covered or guarded in a manner to prevent access.
- c. To ensure safe access, a 44 in. (111.8 cm) accessible surface shall be maintained all around the water feature.
- d. Visitor flow patterns shall be considered in the placement of the water feature.
- e. The water feature should have sufficient circulation/treatment/measures taken to ensure the water does not become stagnant and a nuisance hazard.

## **9-10. Rainwater Harvesting**

Teams may demonstrate or actively engage in harvesting and utilizing captured rainwater provided that the rainwater harvesting system meets the following minimum criteria:

- a. The act of harvesting rainwater must be permitted within the jurisdiction where the competition is being held.
- b. The act of harvesting rainwater must be permitted within the jurisdiction where the house is intended to be permanently placed. Authorization and approval for rainwater harvesting by Solar Decathlon organizers shall in no way constitute permission to harvest and use rainwater in any other location aside from the competition event location. Permission and regulatory oversight must be obtained from the local authority having jurisdiction to ensure compliance when the house is permanently placed following competition. If a final location for the house is unknown, the team should be prepared to eliminate the entire harvesting system and connected piping.
- c. The rainwater harvesting system must comply with the Solar Decathlon Building Code and its adopted International Residential Code

### **Rainwater Harvesting for Non-Potable Irrigation Use**

Rainwater harvesting systems used exclusively for irrigation or other non-potable purposes shall comply with the gray water recycling provisions contained in International Residential Code Section P3009.

Roof gutters or downspout entrances providing captured rainwater intended to be processed and used shall be provided with an effective means to prevent leaf and other roof debris from entering the collection piping. Screening providing ¼ inch (6mm) maximum openings located immediately upstream of conveyance piping including exterior downspouts shall be deemed compliant.

### **Rainwater Harvesting for Potable Use**

Rainwater harvesting systems used for potable and combination potable and non-potable applications must comply with this section.

- a. Leaf and Debris Screens. Roof gutters or downspout entrances shall be provided with an effective means to prevent leaf and other roof debris from entering the collection piping. Screening providing  $\frac{1}{4}$  inch (6mm) maximum openings located immediately upstream of conveyance piping including exterior downspouts shall be deemed compliant.
- b. Initial Discharge Diversion System. Rainwater collection systems shall be provided with an initial discharge diversion (first flush) system to reduce collection of accumulated roof surface contaminants. The system shall incorporate an adequately sized standpipe or other approved collection container with a floating ball shut-off or other approved separating mechanism providing the minimum collection volume as follows:
  - i. Serving a Low Slope Roof with 2:12 Pitch or Less: 2 gallons (7.5 liters) per 100 square feet ( $9.3\text{m}^2$ ) of projected roof surface.
  - ii. Serving a High Slope Roof with Greater Than 2:12 Pitch: 1 gallon (3.75 liters) per 100 square feet ( $9.3\text{m}^2$ ) of projected roof surface.
- c. The team shall produce construction documents with calculations necessary to show the projected area of roof being discharged into the rainwater collection system, the pitch of the roof, the calculated and provided volume capacity of the initial diversion standpipe, and all associated connecting piping to the point of entry into the potable water piping or gray water recycling system.
- d. Water collected within the initial discharge diversion system shall be permitted to be used as part of a gray water recycling system in accordance with International Residential Code Section P3009. Clear water passing after the initial discharge diversion system shall not be connected to a gray water recycling system unless provided with an air gap or other approved cross contamination backflow prevention device.
- e. Drinking Water Treatment System. Rainwater system piping upstream of an approved drinking water treatment system shall not be connected to any portion of the house's potable water system. Rainwater shall only be permitted to be used within the potable water piping system provided that it is first treated by an approved drinking water treatment system complying with International Residential Code Section P2908. An approved backflow prevention method shall be provided immediately downstream of the drinking water treatment system unless provided integrally within a listed and approved treatment unit.
- f. Roofing Materials. Roof cladding surfaces, gutters and downspouts used for potable rainwater collection systems must be comprised of metal or other impermeable surfaces that are unlikely to release toxic products that will negatively affect water quality. Roofs containing asphalt, wood products or similar materials shall not be used for potable rainwater harvesting systems. Roofs, gutters and downspouts using plastics or flexible membranes shall be permitted when sufficient evidence is submitted by the team to show that the surface materials will not discharge harmful contaminants into the collected rainwater.

## ***Section 10. Material Safety***

### **10-1. Thermal Storage**

All thermal storage devices (“mass”) must be made of stable, nontoxic materials. For all heat-transfer fluids, Material Safety Data Sheets (MSDS) must be submitted for approval. All liquid-based thermal storage systems must be marked with the NFPA’s hazard warning diamond appropriate to the technology.

## 10-2. Paint Disposal

Teams are not permitted to dispose of paint on the competition site. Teams may either take unused paint home or find a local facility that disposes of or recycles paint.

## 10-3. Material Safety Data Sheets (MSDS)

MSDS are required for all potentially hazardous materials to be used at the event, such as cleaning solvents, glycol, rubber cement, rubbing alcohol, etc.

# *Section 11. Moveable Features*

Teams planning to move or transform major components of their houses beyond the assembly and disassembly phases are required to obtain special approval from a Solar Decathlon safety officer. Possible design features meeting this description include large, unusual, and potentially dangerous features such as moveable rooms and walls, changeable façades, collapsible spaces, and folding beds. This requirement does not apply to smaller, more typical house features that may be reconfigured, such as awnings, operable windows and window coverings, and doors. The following rules apply to qualifying features:

- a. After the houses are assembled on the competition site, the safety officer will inspect every house and inform each team whether it has any qualifying features.
- b. Teams wanting to determine before the event whether their house has any qualifying features should contact [sdrules@nrel.gov](mailto:sdrules@nrel.gov).
- c. The safety officer cannot thoroughly evaluate the safety of a particular house feature until it is seen in operation; however, the safety officer will try to indicate with a reasonable degree of confidence whether certain features are subject to these rules.
- d. Qualifying features shall not be reconfigured during impound.
- e. Qualifying features shall not be reconfigured during public exhibit hours unless approved by the Solar Decathlon safety officer. To receive approval, a team must:
- f. Include in its Health and Safety Plan an explanation of how it will ensure safety during the movement of qualifying features.
- g. Demonstrate the successful execution of the safety plan for qualifying features at some point before public exhibit hours begin.
- h. Continue to demonstrate the successful execution of the safety plan for qualifying features during public exhibit hours.
- i. If, at any time, the safety officer witnesses unsafe conditions, the movement of qualifying features during public tours may be prohibited for the duration of the event.