Department of Energy Solar Decathlon 2015

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ABSTRACT

The goal of the Department of Energy (DOE) Solar Decathlon 2015 project is to design, build, and operate a zero-net energy solar-photovoltaic (solar-PV) powered residence. It is an international competition taking place in the fall of 2015 in Irvine, California. The design needs to be attractive, energy-efficient, innovative, and affordable. The Cal Poly team includes students from a variety of majors, including Architecture, Mechanical Engineering, Electrical Engineering, and many more. The different disciplines need to work together to create a functional and cohesive design. For our senior project, we will be designing the electrical systems in the home, including the power, lighting, solar-PV systems. The design flow has four stages, Schematic Design (SD), Design Documents (DD), Construction Documents (CD), and Construction Administration (CA). Models were created using the AutoDesk software Revit, which is a building information modeling program with real-time 3D rendering. Our electrical design must comply with state and national building codes, such as the California Electrical Code (CEC) and National Electrical Code (NEC).

INTRODUCTION

The Department of Energy Solar Decathlon is a competition between collegiate teams to design, construct, and operate a energy net-zero home. The competition challenges various aspects of the home, including aesthetic appeal, market appeal, cost-effectiveness, engineering efficiency, and passive architecture design efficiency. Cal Poly has been accepted into the 2015 competition against 16 other teams, including:

- California State University, Sacramento
- Clemson University
- Crowder College and Drury University
- Missouri University of Science and Technology
- New York City College of Technology
- State University of New York at Alfred College of Technology and Alfred University
- Stevens Institute of Technology
- University of Florida, National University of Singapore, and Santa Fe College
- The University of Texas at Austin and Technische Universitaet Muenchen
- University at Buffalo, The State University of New York
- University of California, Davis
- University of California, Irvine; Saddleback College; Chapman University; and Irvine Valley College
- Vanderbilt University and Middle Tennessee State University
- West Virginia University and University of Roma Tor Vergata
- Western New England University, Universidad Tecnológica de Panamá, and Universidad Tecnológica Centroamericana
- Yale University

Cal Poly's team, dubbed Solar Cal Poly, consists of majors from nearly every discipline. As electrical engineers, coordination must be made often and clearly with mechanical engineers, architects, landscape managers, construction managers, and marketing analysts to ensure the home's electrical systems will not interfere with other systems or cause the house to go over budget. The last time Cal Poly was apart of the Solar Decathlon competition was in 2005, where we placed third, so we hope to bring back the first place trophy for the 2015 competition.

Our EE team is responsible for designing the lighting, power distribution, layout of instrumentation, telecommunication, and photovoltaic system for the house. The lighting system has been designed in conjunction with an architecture interior design team, making sure that the lighting complements the tasks of the homeowner and the aesthetics of the interior. The power distribution plans lays out the location of the electrical equipment such as the service panel, and the locations of the circuits of receptacles and mechanical equipment in the home. The photovoltaic plans outlines the panels and inverter used, the energy production, and how the system will be wired back to the bidirectional utility meter. All of these designs have been done

in the building information modeling software Revit.

The Solar Decathlon gets its name from the ten competition objectives that it is judged on. Judging occurs during a public showing of the house, where tours are also given to general attendees to the Solar Decathlon Competition in October 2015. The contests, and our approach to meeting their objectives, are explained in more detail below:

Contest 1: Architecture
The Architecture contest gauges the architectural concept, design approach, implementation, and innovation of our house.

Contest 2: Market Appeal
The market appeal aspect of the competition measures the ability to design a responsive living space tailored to the needs of the target client.

Contest 3: Engineering
For the engineering contest, a jury of professional engineers judges each house on its functionality, innovative design, efficiency, and reliability. The engineering in this project is a combined effort from the electrical, mechanical, structural, and architectural engineering students working together to create the most effective systems for our Solar House..

Contest 4: Communications
For the communications contest, each team is evaluated on their ability to convey their design message and educate the public through digital and printed media.

Contest 5: Affordability
The affordability contest encourages teams to create an affordable home, specifically total expenses being less than $250,000.

Contest 6: Comfort Zone
The comfort zone contest awards teams for keeping a relatively constant temperature (71-75 degrees F) and humidity in their houses.

Contest 7: Appliances
The appliances contest is a judgement of how well each house is designed to mimic the average appliances in a U.S. home, including common appliances such as refrigerator, washer dryer, dishwasher, etc. Energy Star Appliances will be used when readily available and all appliances will be strategically placed to suit the needs and wants of prospective consumers and be flexible for future changes the consumers may want. Key appliances that will affect this competition are refrigerator and freezer, washer and dryer, stove, and dishwasher.

Contest 8: Home Life

The home life contest requires the house occupants to run normal home operations, such as having lights on and a computer and a television operating for specific amounts of time. Also required are a movie night and two dinner parties.

Contest 9: Commuting

The solar decathlon requires each team to charge and drive a fully electric car. Our house will supply electricity to power the vehicle for eight 25 miles trips. The car used in the competition must meet all the requirements under Rule 4-8 including:

- Must be electric
- Movement prohibited 1/2 hour prior to, during, and after public exhibition periods
- Prototype must include infrastructure required to charge vehicle
- Must be commercially available to all teams and listed on DOE Energy Efficiency & Renewable Energy all-electric vehicle website.
- 4 Wheels and 2 Seats
- Licensed, Registered and insured as required by Orange County, CA roadways.

Contest 10: Energy Balance

For full points in the energy balance competition, each team must produce and consume a designated amount of energy, most importantly producing more energy than is consumed over the 10 day competition. The competition also specifies that 175 kWh or less be consumed throughout the competition, including the charging of the electric car.

In addition to meeting these competition objectives, there are rules and guidelines we must meet outside of National Electric Codes, which are set by the DOE and can be viewed in full in Appendix C.

MARKET RESEARCH

The competition's purpose is to explore and showcase various architecture and engineering design options that can push the boundaries of sustainability and innovation in the building market, specifically the residential building market. The competition markets towards an audience of progressive and environmentally minded homeowners who wish to observe and understand new technologies and implementation methods.

The push for innovation in the sustainable housing market is largely caused by population growth. With population growth comes a higher demand for energy usage and utilization of space at affordable costs. The electrical systems designed for Solar Cal Poly's 2015 entry to the Solar Decathlon offers these solutions through the following methods:

- Smart home automation systems, including sensor input and mobile app interface.
- Net-zero energy design
    - Passive building design to achieve max efficiency; use of architecture design to achieve as much daylighting and passive heating/cooling as possible.
    - Hybrid Solar PV system using Monocrystalline and bifacial Building Integrated PV panels, and solar thermal collectors for energy generation.
- High efficiency LED lighting system with multiple controllable parameters, such as color, brightness, and occupancy sensing.
- Integrated electric vehicle charging station.

While these systems must perform to meet all engineering expectations, they must also be at an affordable cost to the homeowner. As a result, the house is limited $250,000 per required by the Solar Decathlon 2015 competition. The correlation between sustainability and cost are mutual, offering an attractive alternative to those inclined to traditional housing. The Solar Cal Poly team will offer innovative sustainable designs to separate from current architectural firms that can be replicated faster and easier from traditional housing to meet gaps in the market demand as homeowners increase the purchase of houses by 200,000 annually [1].

The sustainable housing market is addressed by MEP (Mechanical Electrical Plumbing) design firms. There are many competitors in the residential MEP engineering market. The industry generated 6.38 billion dollars last fiscal year in MEP design revenue [2]. The top firms in gross annual revenue in MEP design last year were Jacobs, Aecom Technology Corp, and Black and Veatch [2]. Many MEP design firms in industry are consultants, hired by architecture firms to complete the MEP design. A key area of strength we as designers for the Solar Cal Poly House have is that we have all parties of the design "in-house." For example, we have architects, mechanical engineers, and construction management students all working together to create a design.

Some of the key partners we need to engage to make our housing design a success would be a general contractor for the house construction, including wiring installations. In addition, over the course of the design we have sought help from companies in Industry, who know more of the ins-and-outs of code requirements. One example is SunPower, who reviewed our design and gave comments on various requirements that were left out of our construction drawings. There are other companies that have offered material donations as well. Other key partners for our team include a number of the Faculty Advisors who are overseeing the Solar Decathlon, namely Dale Dolan, Richard Beller, Sandy Stannard, Kim Shollenberger, and John Clements.

As part of the market research, we have compared various equipment options to decide which best suits our needs. Figure 1, below, shows our preliminary comparison process for selecting solar modules by comparing costs and efficiencies to implement them.

Figure 1: Comparison of Solar Modules

Based on comparisons of this type and input on feasibility from other disciplines, we have determined a finalized list of equipment we expect to use for the electrical systems in the competition. This list is shown below in Figure 2.

Brief Description	Detailed Description	Qty
Distribution (outlets and switches)		41
Typical Load Panel	Load centers, 1 phase, 3 wire, main lugs, indoor, 120/240 V, 225 amp, 20 circuits, incl 20 A 1 pole plug-in breakers	1
Rule of thumb, Typical PV Rough in electrical system		1
Generic PV Mounting Rack, per solar panel	SnapNRack, 5.5” standoff	6
Electrical Inverter - Conventional	SMA Sunny Boy 4000TL-US	1
Electrical Inverter - Bifacial	SMA Sunny Boy 5000TL-U	1
Photovoltaic Collectors	SunPower E20/435 41"x81", 435 Watt	10
Photovoltaic Collectors - Bi-Facial	Sunpreme GxB 350W	14
Energy Management Unit	EG3000 eGauge System	2
Car Charging Station	Wallbox PURE Charging Station	1
Occupancy Sensors	Wattstopper DT-355	12
Ambient Light Sensors	Sharp Microelectronics 852-Ga1a2S100SS	7
Ambient Temperature Sensor	Maxdetext SEN-10167	4
User Interface Tablet	Samsung SM-T530NZWA	2
Ammeter (on-wire)	20A and 50A Magnelab CTs	27
Exterior Sconce Light	Lutron Ivalo Silvus 24"	3
Recessed LED Lighting	Tech Lighting Elemt 3" Fixed	24
Kitchen Counter Suspended Light	Juno Lighting Group LC4c-084	2
Bar Lighting	Acuity Brands Lighting ZI2N	3

Figure 2: Equipment and Brand List for Electrical Systems

To better understand the market needs and requirements, we must observe the housing market at a more general level. Home residences still rely on the electrical grid for energy. The majority of energy generated and sent through the grid come from non renewable energy sources, such as coal, natural gas, and petroleum. In the year 2013, coal accounted for 39% of electricity generation, with natural gas having 27% and petroleum accounting for a small 1% of electricity generation [5]. By using these fuels, pollutants are being released into the environment that detrimentally affect the planet on a global scale.

By resorting to net zero energy residences with an emphasis on sustainable energy sources, the effect on the environment is minimized and preserves our finite amount of fuels. Power generation is independent from the grid where the grid acts as a backup source of energy. By decentralizing the power grid, homeowners can be less reliant on the grid, resulting in a lower demand of energy produced by the energy companies and in a reduced need for burning coal, natural gas, and petroleum. Transmission losses could be minimized since there would be less power that would have to be generated and transmitted through power lines for residences that will, most of the time, be far from the generation site. It would also be cheaper for homeowners to install a photovoltaic system on their homes in the long run due to these systems having a desired payback period of less than 25 years.

There is also a Federal Mandate for all residences after 2020 to be net-zero. This mandate is an overall benefit to the United States construction industry. An article written by cleantechnica titled “California’s Net Zero Energy Building Mandate To Reshape US Construction Industry” states five reasons why this mandate is beneficial. The first reason is the increase in the adoption of building energy codes. Following the energy codes contributes to a better energy performance for residences.The second reason is that it helps speed the development of building monitoring and management technologies. Being able to see how much power the building is using will lend itself to the creation of “smart” buildings. The third reason is that it will accelerate on-site energy storage. Through the usage of on-site energy storage, the resilience of the electricity grid will be vastly improved. The fourth reason is the reduction of cost for high performance buildings. Investing in high performance technology, renewable energy in this case, will help lower the costs of running a high performance building. Finally, the mandate is an overall benefit because it creates competition for architects to create high performance buildings. Net zero energy goals will put pressure on architects and engineers to always deliver the expected result of net zero energy usage

There are a couple drawbacks to integrating a solar panel array onto a residential structure. First, solar panels rely on the sun to produce energy. This means that during the night, solar panels would not be able to produce energy at all, so electricity would still be drawn from the electrical grid. If enough consumers switched over to having a solar house, the peak hours

might shift from the afternoon to night time and power companies would charge more per kWh during the night. The other downside of installing solar arrays is that the feasibility of solar panels differs between regions. There are areas in Arkansas, for instance, served by the utility SWEPCO where the the most expensive kWh is $0.0534 [4]. In central coast California, the price for electricity is much more expensive than that of Arkansas, reaching peak prices of $0.3596 under utility rates for PG&E [3]. For Arkansas, cheap electricity prices means that it would usually be cheaper to stay fully dependent on the grid rather than investing the capital to install a solar array. Since our project will be implemented in California, solar generation is easily justifiable as the payback period will be relatively short compared to other regions.

PROJECT MANAGEMENT PLAN

The timeline for this project is strict. The Department of Energy had set many overarching deadlines, including an 80% DD submittal, an 80% DD re-submittal after receiving DOE input, a 100% DD Submittal, an 80% CD Submittal, an 80% CD Re-submittal, and a 95% CD submittal. On top of this, the student project managers and faculty set additional meeting times and iterative deadline dates for interdisciplinary aggregation. Additionally, the EE team also conducted weekly meetings to discuss the direction of project and distribute work required for the submissions. The project started in February of 2014, and will continue through October 2015, through our involvement in terms of our senior project ends at the end of the spring academic term in 2015. The following Gantt charts shows the timeline for the project through the end of the academic year in June 2015.

Electrical Team Deliverables	FALL 2014		Start Date:	September 22, 2014	
DOE Solar Decathlon 2015					
Task	**Start Date**	**End Date**	**Progress Date**	**Duration (Weeks)**	**Percent Complete**
Date:					
1.0 Planning	4/20/14	12/12/14		34	100.00%
Requirements and Specs. I	4/20/14	10/27/14	10/27/2014	27	100.00%
Project Management Plan	9/22/14	10/27/14	10/27/2014	5	100.00%
Gantt Chart	9/22/14	10/27/14	10/27/2014	5	100.00%
One Line Diagram	10/6/14	11/10/14	11/10/2014	5	100.00%
Cost Estimate	10/13/14	11/24/14	11/24/2014	6	100.00%
Requirements and Specs. II	10/27/14	11/24/14	11/24/2014	4	100.00%
Weekly EE Team Meetings	4/20/14	12/12/14	12/12/2014	34	100.00%
Weekly Project Team Meetings	4/20/14	12/8/14	12/8/2014	33	100.00%
2.0 Design	9/22/14	11/3/14		6	100.00%
EE Drawings 25% Submission	9/22/14	10/26/14	10/26/2014	5	100.00%
EE Drawings 50% Submission	10/13/14	11/1/14	11/1/2014	3	100.00%
EE Drawings 80% Submission	10/20/14	11/3/14	11/3/2014	2	100.00%

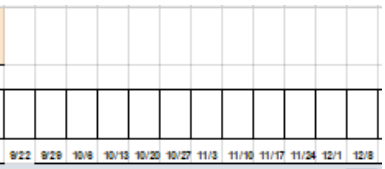

Figure 3: Fall Gantt Chart

Electrical Team Deliverables	WINTER 2015		Start Date:	January 6, 2015	
DOE Solar Decathlon 2015					
Task	**Start Date**	**End Date**	**Progress Date**	**Duration (Weeks)**	**Percent Complete**
Date:					
1.0 Planning	1/6/15	3/12/15		9	100.00%
Report Revision I	1/6/15	1/16/15	1/16/15	1	100.00%
Report Revision II	3/3/15	3/12/15	3/12/15	1	100.00%
Weekly EE Team Meetings	1/6/15	3/12/15	3/12/15	9	100.00%
Weekly Project Team Meetings	1/6/15	3/12/15	3/12/15	9	100.00%
2.0 Design	1/6/15	3/12/15		9	100.00%
EE Drawings 100% Submission	1/6/15	1/30/15	1/30/15	3	100.00%
Photovoltaic System Design	1/13/15	3/12/15	3/12/15	8	100.00%
Physical Arrangement Design	1/13/15	3/12/15	3/12/15	8	100.00%
Energy Monitoring System Testing and Design	1/27/15	3/12/15	3/12/15	6	100.00%

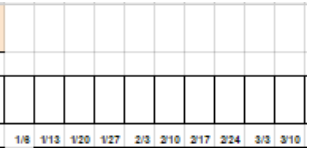

Figure 4: Winter Gantt Chart

Electrical Team Deliverables	Spring 2015		Start Date:	March 30, 2015	
DOE Solar Decathlon 2015					
Task	Start Date	End Date	Progress Date	Duration (Weeks)	Percent Complete
Date:					
1.0 Planning	3/30/15	6/2/15		9	100.00%
Report Revision III	4/21/15	4/28/15	4/28/15	1	100.00%
Report Revision IV	5/19/15	5/26/15	5/26/15	1	100.00%
Weekly EE Team Meetings	3/30/15	6/2/15	6/2/15	9	100.00%
Weekly Project Team Meetings	3/30/15	6/2/15	6/2/15	9	100.00%
2.0 Design	3/30/15	6/8/15		10	100.00%
Photovoltaic System Design	3/30/15	5/11/15	5/11/15	6	100.00%
Physical Arrangement Design	3/30/15	5/11/15	5/11/15	6	100.00%
Energy Monitoring System Testing and Design	3/30/15	5/11/15	5/11/15	6	100.00%
Aquaponics System Research	3/30/15	5/15/15	5/15/15	7	100.00%
Bifacial Testing Frame	5/11/15	6/8/15	6/8/15	4	100.00%

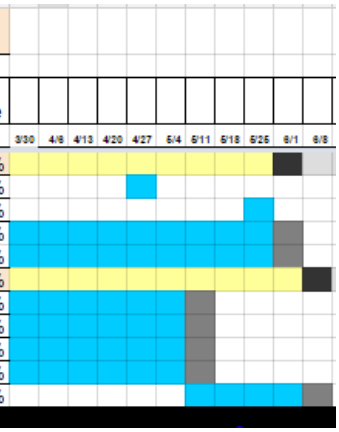

Figure 5: Spring Gantt Chart

These schedules do not include the finished construction of that house that will be completed during the Summer 2015 quarter, since this falls after our completion of the senior project requirement.

Cost Estimation

In addition to organizing meetings and distributing workloads, it is also the duty in the planning of this project to include cost estimations. Though for the actual competition, the cost of the house is judged based on a third party's cost estimation, we have kept track of expected costs of equipment we plan to use. Our cost estimates for the expected electrical system equipment is shown below.

Equipment	Quantity	Cost Per Unit	Cost
Instrumentation Equipment	-	$1,500	$1,500
SunPower E20/435	10	$700	$7,000
Sunpreme GxB 350W	12	$350	$4,200
SMA Sunny Boy 4000TL-US	1	$2,000	$2,000
SMA Sunny Boy 5000TL-US	1	$2,000	$2,000
3/4 EMT Conduit, 10 AWG wire , 16 AWG wire	-	-	$5,000
Combiner Box	2	$100	$200
AC/DC Disconnects	2	$100	$200
Receptacles/ Outlets	41	$32	$640
LED lighting system (Switches, fixtures)	-	-	$8,000
Electrical Distribution Panel	1	$165	
Breakers (15A)	3	$8.04	$24.12
Breakers (20A)	20	$4.56	$91.20
Breakers (50A)	6	$10.13	$60.78

Total Cost	$30,916.1
20% Contingency	$6,183.22
Total Cost w/ Contingency	$37,099.32

Figure 6: Cost Estimation Table

COMPETITION REQUIREMENTS RELEVANT TO EE TEAM

Though there are many competitions and rules in the Solar Decathlon, it is important when leading the direction of the project to understand some of the main rules most applicable to the EE team. The following rules are what we consider particularly important for our design:

- House must use less than 175 kilowatt hours over the length of the competition
- Solar-PV system must generate more energy than the house consumes
- House must charge and drive an electric car for 25 miles 8 times (for a total of 200 miles driven)
- House must maintain a temperature in the range of 71 to 75 degrees Fahrenheit.
- House area is approximately 1000 square feet
- 120/240V, 150A service provided
- Only commercially available electrical equipment may be used
- Cost of house under $250,000
- Follow requirements of the NEC
- No Battery Storage, grid interconnection required
- Lighting must be on for approximately 25 hours over the course of the competition
- Cooking appliances must be used for two dinner parties
- A computer must be on for a total of 32 hours over the course of the competition

VERIFICATION OF PROJECT

The house will be put to competition in October 2015 in Irvine, California. During this time, we will be awarded and deducted points based on the ten competitions mentioned previously. At the end, we will receive a total score and a ranking among the other schools competing. Given that our goal is to win the competition, our verification will be based on the points we are awarded that are relevant to the EE aspects of the design such as energy balance. In addition to points, another form of verification will be that our systems function properly over the eight days of the competition. If lights are flickering or solar generation is poor, we will know that we have issues in our design or installation.

DESIGN PROGRESSION

Our project has been through numerous design phases. With discussions of all of the various options for equipment and the coordination of different house designs provided by the architects, the project then moved into the Design Development (DD) phase. The documents created during this phase include the block diagrams of the electrical systems of the house, load calculations as specified by the National Electric Code, Solar PV wiring and mounting plans, distribution wiring plans, and telecommunication wiring plans. These documents began the process of understanding the construction of the house and served as the precursor to our Construction Drawing (CD) set that is required for the contractor to accurately construct the house. To understand the progression of the project, sections of the electrical design from when they began will be discussed separately.

Solar PV System

With the knowledge that our house will be completely powered by solar generation and any excess power will be transferred to the grid, we began to calculate and compare a plethora of solar array options. While batteries are not allowed for storage, the grid is essentially our battery through a Net Energy Metering agreement (NEM), which will allow us to be energy net-zero by producing enough energy during the day to cover our energy consumption during the day and night.

The EE team went through calculations on various iterations of prototypes of the original design. We tried various module models along with different tilt-angles on our array. Some of the prototype house designs are shown in Figures 7 and 8. An example of the initial array calculations we did is shown in Figure 10. As can be seen, our main concern at this point was checking the minimum physical footprint (square feet) required by the array and comparing this with the rooftop areas made available by the architects. We did this for 3 other panels, the SunPower E20/435, the SunPower X21 345, and the Yingli YL-300P-35b, and applied this to all house designs for various tilts, depending on the tilt of the roof of the design. At the time, we thought we also needed to meet the National Fire Code requirement of a 3 foot setback from edges of the room, so that is included in the example calculation (we later found out that the competition does not follow this rule). We also performed some calculations for arrays that included rows of panels individually tilted over a flat roof surface, but ultimately decided that there was not enough roof space to allow this type of design with houses of this smaller size.

Figure 7

Figure 8

Yingli YL-250P-29b 250W Panel Specifications	
Pmax	250
Voc (V)	37.6
Isc (A)	8.92
Vpmax (V)	29.8
Ipmax (A)	8.39
Length (ft)	5.413
Width (ft)	3.248
Area (ft^2)	17.581424

Figure 9: Panel Specifications

# of Modules in Array	24
DC Array Size (kW)	6
Tilt (Degrees)	33
Dimensions (ft^2)	593.7346944
Strings	2
Modules per String	12
Voc of String (V)	312
Total Isc (A)	17.84
Strings	4
Modules per String	7
Voc of String (V)	263.2
Total Isc (A)	35.68

Figure 10: Array Modules

Moving forward from these prototypes, the studio chose to move forward with the design shown below in Figure 11. It is shown that this house design had a tilted roof, which increased the efficiency and power output of our panels without a complex racking system. This design included only 12 Sunpower E20 435W panels, in three strings of 4 modules, which after doing energy load calculations didn't end up being sufficient to cover the total electrical load of the home.

Figure11: Initial PV Design Example from Summer Studio

A few months after this design was progressing, the design abruptly changed to the house shown in Figure 12. This was the design that would eventually evolve into our final, current design. The first is a 6.5 kW roof mounted system using SunPower E20 435W panels. This layout required 15 panels and uses a string inverter. With the string inverter, a configuration of 3 strings of 5 panels was used.

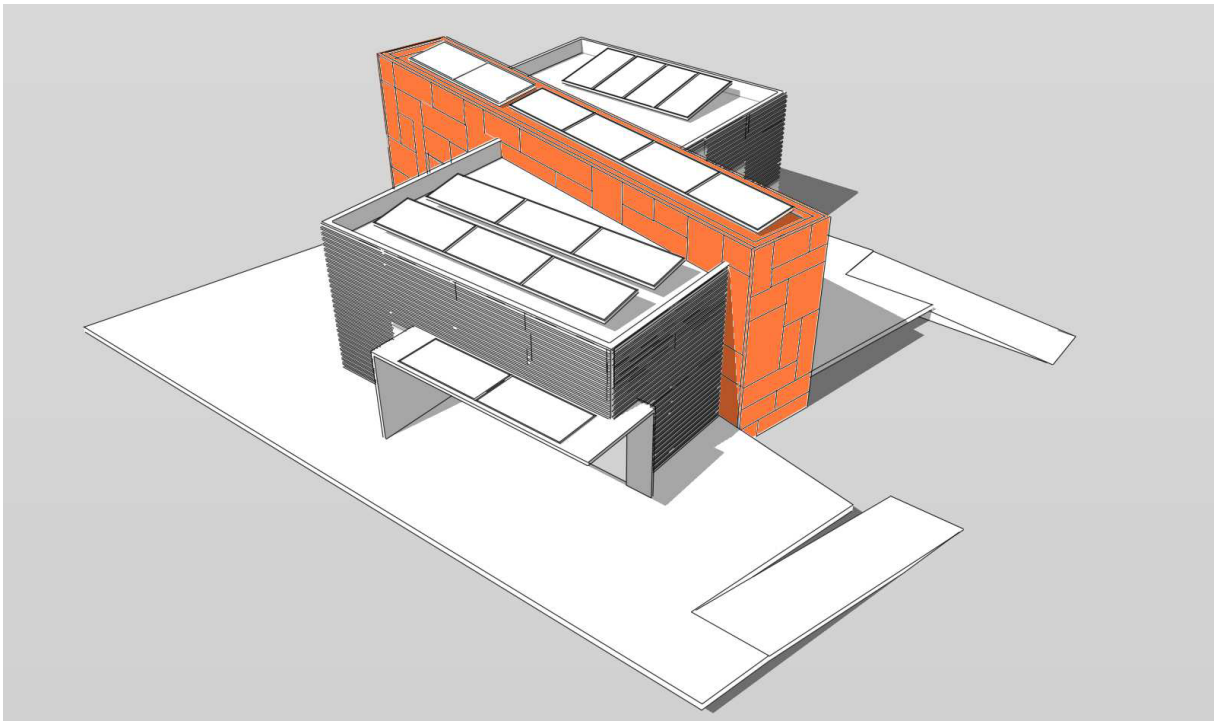

Figure 12: Roof mounted solar shade study at 12pm in October in Irvine

Soon after the introduction of this house design, the idea of using a hybrid PV system became a leading concept. The hybrid PV system is a combination of bifacial PV panels and monofacial PV panels. By using bifacial panels in conjunction with the monofacial SunPower panels, we could free up roof space and reduce the messiness of trying to string the SunPower panels across separate sections of the roof by implementing a canopy of bifacial panels over the south deck. The main reason for moving forward with this design was the aesthetic impact of the diffused light shining through the glass frames of the bifacial panels onto the deck below. Not only would this create positive visual impact, but it would be a visual representation of the architecture design and engineering generation integrating into the same design. Additionally, the backside of the bifacial panels have the potential to generate up to an additional 30% power generation per panel if the underside reflection conditions are ideal. The main disadvantage would be the added complexity and cost of a canopy structure to support the panels, but it was decided that it would be worth it in the end. Below shown in Figure 13 was one of the first renderings of the bifacial canopy structure being incorporated into the design.

Figure 13: Bifacial Canopy Rendering

This system considered the use of 12 Sanyo HIP 195DA3 bifacial panels. However, these are not the panels that ended up being our final consideration. We eventually decided to use 14 Sunpreme GxB 350W panels (4.9 kW) in conjunction with 10 SunPower E20/435 panels (4.35 kW) to comprise our total DC system size of 9.25 kW. At first, all panels would be set flat with

no tilt on the flat roof. However, after much back-and-forth with the architects, and after creating various comparisons of systems that included tilts, no tilts, and differing amount of modules as shown below in Figure 14, they were convinced to allow a 10 degree tilt on the monofacial panels when combined with the fact that the mechanical engineerings required a tilt for their solar thermal panels to operate. A final 3D rendering of our solar PV system can be seen on the house in Figure 15.

SOLAR DECATHLON - SOLAR PV SYSTEM OUTPUTS

Energy Budget	175	kWh	
Production Goal (20% Overhead)	210	kWh	
8.82 kW System Production @ 0 Degree Tilt	204.75	kWh	Note: 8.82 kW DC System Size from 12 SunPower Panels (12*435W) + 10 Sunpreme (10*360W)
8.67 kW System Production w/ SunPowers @ 20 Degree Tilt	221.99	kWh	Note: 8.82 kW DC System Size from 10 SunPower Panels (10*435W) + 12 Sunpreme (10*360W). Energy Production from 20 Degree tilted SunPowers is 121.7 kWh, compared to 100.98 kWh when they are untilted.
8.69 kW System Production w/ SunPowers @ 10 Degree tilt	213.82	kWh	Note: 8.69 kW DC System Size from 10 SunPower Panels (10*435W) + 14 Sunpreme (10*310W). Energy Production from 10 Degree tilted Sunpowers is 112.84 kWh compared to 100.98 kWh when they are untilted.
8.69 kW System Production w/ SunPowers @ 0 Degree tilt	201.72	kWh	Note: 8.69 kW DC System Size from 10 SunPower Panels (10*435W) + 14 Sunpreme (10*310W).
8.69 kW System Production w/ SunPowers @ 30 Degree tilt	228.51	kWh	Note: 8.69 kW DC System Size from 10 SunPower Panels (10*435W) + 14 Sunpreme (10*310W). Energy Production from 10 Degree tilted Sunpowers is 127.53 kWh compared to 100.98 kWh when they are untilted.
8.925 kW System Production @ 0 Degree Tilt	207.2	kWh	Note: 8.925 kW DC System Size from 15 SunPower Panels (15*435W) + 12 Prism Bifacial Panels (12*200W)

Figure 14: Solar PV System Outputs

Figure 15: Current PV System Rendering

After reaching this design conclusion, Dr. Dolan recommended we design and build a testing frame for the Sunpreme GxB 290W bifacial panel he procured for testing purposes. As a team, we discussed various designs and framing materials. The concept was to provide a tall enough frame in order to simulate different albedos, of ground reflectivity, underneath the module. We wanted it to be 8 feet tall, but with the materials available, we ended up making a 6 foot tall frame. We created a testing frame the size of the module, about 3 feet wide, 6 feet long, and six feet tall. Given the length of the beams, triangular corner supports were necessary to make the frame more stable. A concern with this racking system was the upward wind load the module may experience, so by ballasting the frame the concern of upforce was alleviated. This process was challenging for a group of EEs because it was a full mechanical design and static forces and torque needed to be considered. We decided to use zinc plated steel angle beams, which were the best available metal beams found at home depot. Nuts, washers, and bolts, were used to connected adjacent beams to one another and to more steel support pieces. The metal beams weren't quite the right size, and the holes on each beam didn't quite line up, so Dion and Jenna needed to use their red tag certification to cut and drill some of the beams. Luckily for us, the frame construction essentially worked on our first assembly, and the frame was even strong enough to hold Joey (170 pounds) hanging on the frame. We mounted the bifacial module, as shown in the Figure 16 below.

Originally, we were planning to use the Solmetric PV Analyzer in order to measure the module's power production with different reflective surfaces placed underneath, in order to get an idea of the potential backside production. Since we were preoccupied with updates to the documents, this testing wasn't able to be completed during the Spring Quarter. Looking forward, the bifacial frame can perhaps be used as a teaching tool for Dolan's PV graduate course EE 520.

Figure 16: Bifacial Solar Panel Frame

Lighting System

The design of the lighting system is still very volatile since it is intimately involved with the interior design, and with the floor plan still yet to be finalized, all lighting is still in the concept stage. Certain aspects of the lighting are fairly certain, such as that all lighting will be LED and there will be some form of controls for the system. A variety of luminaires will likely be incorporated to complement the space, such as pendant fixtures, uplights above the cabinets in the kitchens, and RGB LED strips possibly in the bedroom and living room.Exterior lights will also be added to the facade of the house, and in the landscape. Shown below in Figure 17 is one of the preliminary concept lighting plans done by the EE team. Shown on the drawings are occupancy sensors, which may be in the design along with photocells to detect natural light entering the home through windows and doors. The key concept is to use the least amount of power for lighting, so more of the energy produced by the photovoltaic system can be used for larger loads. Another aspect of lighting design is the location and types of switches used. For example, rooms like bedrooms often have dimmer switches for mood lighting, and living rooms often have multiple switches controlling the same light fixtures. The most important part of designing a switch system is the location of the switches for ease of access, and having the correct switches controlling a reasonable number of luminaires.

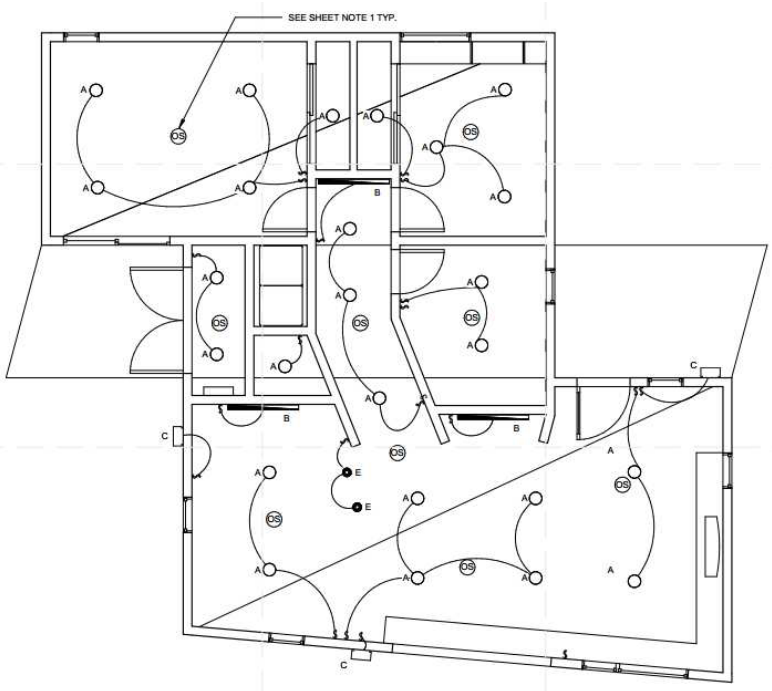

Figure 17: Preliminary Lighting Design

For the DD documents, the EE team was in charge of the design of the lighting system. Simon designed the lighting system, downloading LED fixture families off of lighting company websites and placing them in the revit document. The preliminary design in Figure 17 is this design, which incorporating LED strips, downlights, and pendant fixtures above the kitchen counter, along with exterior sconces near the doors. Using all LED lighting is hyper efficient, with a better

levelized cost of energy, or total cost of lighting system over energy produced over its lifetime. Although initially more expensive than CFLs, they last much longer, making them the smarter investment. The main idea in Simon's design is function over fashion, and luminaires were distributed to provide 35-40 foot-candles to the work planes, with more in the kitchen and bathroom. Upon submitting the design documents to the DOE, no comments were written by the DOE engineer, meaning the lighting design was to code.

After the DD submittal, the lighting design was usurped by the architectural interior design/lighting team, advised by Sandy Stannard. From this point forward, the responsibility of the EE team was to take PDFs provided by the architecture lighting team, and add the luminaire symbols and provided luminaire schedule to the revit model. The EE team was also to consider the limits of the energy budget for the lighting system. Below in Figure 18 is an example of a spreadsheet Casey made to calculate energy the lighting would use in the house for the specific competition periods.

LIGHTING ENERGY BUDGET CALCULATION SPREADSHEET		Day Start ***	Comp start	Comp End	Imp End	Imp Start	Day End	JUDGE PERIODS(100% USAGE)			JUDGED HOURS	kWh per PERIOD	NON-JUDGED HOURS
Total Number of Lamps	37	11	19	23		23	24	Day 11	7:00 PM	11:00 PM	4	1.702	8.00
Watt Per Lamp Average (W)	11.5	0			7	23	24	Day 12	NONE (MOVIE NIGHT		0	0	16.00
NON-JUDGED USAGE (W)*	50	0	19	23	7	23	24	Day 13	7:00 PM	11:00 PM	4	1.702	12.00
IMPOUND USAGE (W)**	0	0	19.5	22.5	7	23	24	Day 14	7:30 PM	10:30 PM	3	1.2765	13.00
		0	19	23	7	23	24	Day 15	7:00 PM	11:00 PM	4	1.702	12.00
		0	19	23	7	23	24	Day 16	7:00 PM	11:00 PM	4	1.702	12.00
POWER CONSUMED AT 100% USE (W)	425.5	0	19	23	7	23	24	Day 17	7:00 PM	11:00 PM	4	1.702	12.00
		0	19.5	22.5	7	23	24	Day 18	7:30 PM	10:30 PM	3	1.2765	13.00
		0			7		11	Day 19	NONE		0	0	4.00
								SUBTOTAL			26	11.063	102
								TOTAL LIGHTING KWH			16.163		
NOTES													
* Usage during 7am-11pm, excluding judged periods													
**Usage during 11pm-7am													
***Data marked in light grey are hours on a 24 hour clock, used to calculate non-judged period hours													
CELLS FORMATTED THIS WAY ARE THE ONLY CHANGING INPUTS													

Figure 18: Lighting Energy Budget Calculations

Edits to the lighting design were made both by Richard and the lighting team even after the 100% CD submittal. Coordination with the architectural team was needed to get the load calculations for the lighting system, and to coordinate the locations of switches in the house, and which switches should control which luminaires.

Instrumentation System

Our involvement in the instrumentation system offers the homeowner(s) better active control of the house through energy monitoring along with occupancy, lighting, humidity and temperature detection.

Along with the Mechanical Engineering and Computer Science team, the Electrical Engineering team originally proposed using an Arduino Mini(s), a Raspberry PI, sensors and a mini Xbee wireless adapter to communicate to a centralized hub that can send data to a tablet device the homeowner can monitor and control. Alternative hardware choices include replacing the Arduino Mini(s) with Teensy 3.1 and replacing the Raspberry Pi with the BeagleBone, featured comparison are seen below (Fig.14 and 15). The house will be controlled centrally through a

capacitive touch tablet. The Mechanical Engineering team became responsible for the networking design at the beginning of Winter Quarter 2015. The Computer Science became responsible for the tablet interfacing at the beginning of Winter Quarter 2015. The Electrical Engineering team took control of the design for an energy monitoring system with the discussion of our involvement below.

Energy monitoring is achieved through current sensor modules for 24 out of the 39 circuits in the home. Recommendations from the energy monitoring system will be made for the homeowner to adjust their behavior in the house for lower energy usage. The merits of a commercially available energy monitoring system to a custom designed energy monitoring system were discussed within our group and project advisor. A custom designed system was considered as shown in Figure 22. Our research into energy monitoring systems led us to choose the eGauge System. The system was chosen because it serves as an energy monitor, data logger and a web server all-in-one. The model chosen was the EG3000 eGauge System. The EG3000 eGauge System can measure electric AC power up to 12 circuits. We plan to have two eGauge Systems for a total up to 24 circuits measured. Through our testing of the eGauge System, we were able to understand how to configure the wireless connection and connect the device to the internet. Our first connection measured the power consumption of the eGauge System itself and a screenshot of the eGauge GUI data logger is shown below in Figure 19. We found how the information coming from the eGauge can be obtained through its open API software and how a CSV excel file can be derived in real-time. This method was discovered alongside the Computer Science team and the numerical information in the CSV file was interpreted. The Computer Science team had enough information from us for use for their tablet interface application and our role for the Instrumentation Systems was accomplished.

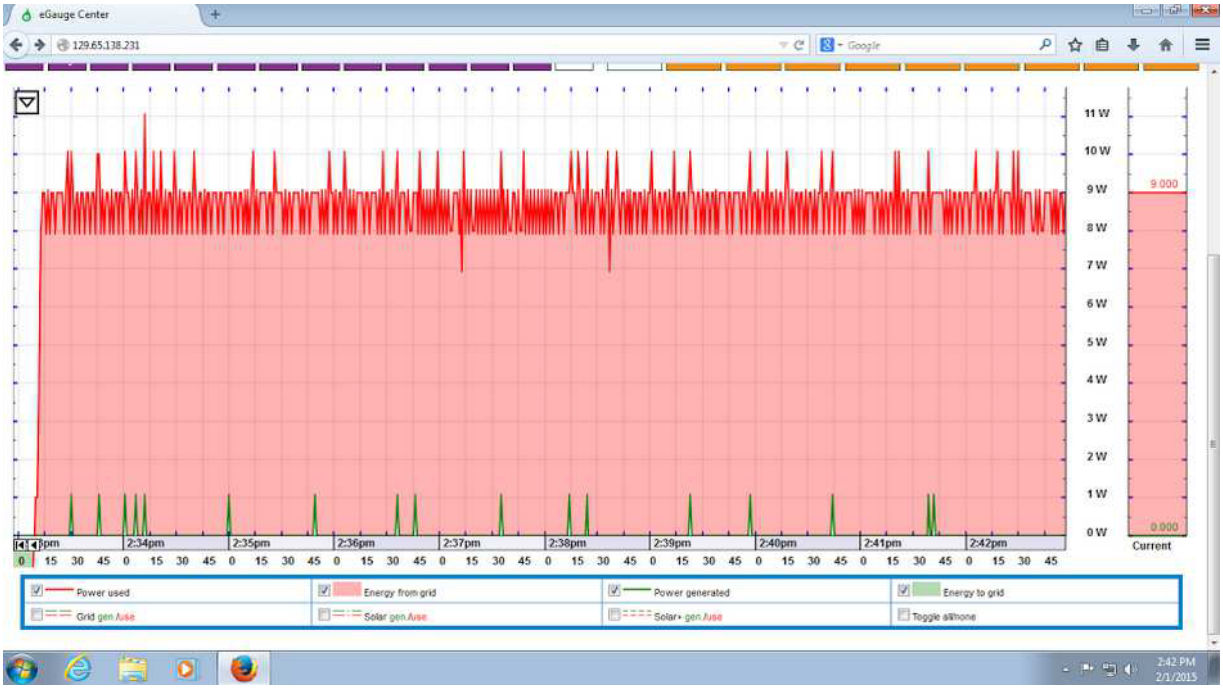

Figure 19: eGauge datalogger testing

Microcontroller	Arduino Mini 	Teensy 3.1 
Voltage Range	5-12V	1.71-3.6 V
Max Current Output	150mA	100mA
Microprocessor	ATMega328 16MHz	32 bit ARM Cortex-M4 72 MHz
Analog Pins	8	21
Digital Pins	14	34
Memory Transfer Capabilities	-	Dedicated Direct Memory Access
Cost	$9.95	$19.95

Figure 20: Sensor Microcontroller Alternatives

‘Master’ Microcontroller	Raspberry Pi 	Beaglebone 
Voltage	5V	5V
Data Storage	requires external SD memory	4GB Internal Memory
Processor	700 MHz ARM1176JZF-S core CPU	AM3358 1GHz ARM® Cortex-A8 Processor
Software Compatibility	Debian GNU/Linux, Fedora, Arch Linux, RISC OS	Angstrom Linux, Android, Ubuntu, Cloud9 IDE on Node.js with BoneScript
Cost	$35	$55

Figure 21: Single Board Computer Alternatives

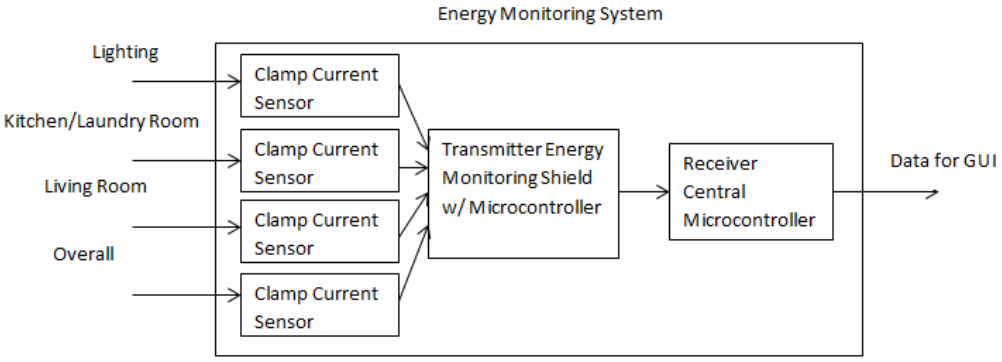

Figure 22: Functional Diagram for Custom Energy Monitoring

Electrical Vehicle

Choosing an electric vehicle for the competition is a very important consideration. Since the electric car is the single largest expected load out of all others, paying attention to the efficiency of the car is particularly important. Shown below in Figure 23 is a comparison of many commercially available vehicles' EPA fuel efficiency ratings. For the competition, we have 2 hours to drive 25 miles each of the eight times, so we should be able to complete the competitions at very slow speeds for the most part. This means the city rating for efficiency is more applicable than the overall rating for our considerations. With this in mind, we have chosen to pursue the BMW i3 as our first choice, since it has one of the highest city ratings, but also has the best combined ratings just in case we do need to traverse faster moving roads such as a highway. If this pursuit is successful, we will have kept our energy budget at a much more manageable level.

Comparison of Efficiency for Electric Vehicles

COMBINED RATING							
VEHICLE	MODEL YR	EPA Rated City fuel economy mpge	EPA RATED Combined mpge	kWh/100mi (city)	kWh /100mi (combined)	kWh PER PERIOD (Combined Rating, 25 miles)	kWh FOR COMPETITION (Combined Rating
BMW i3	2014	137	124	24.599	27.177	6.794	54.355
Scion iQ	2013	138	121	24.420	27.851	6.963	55.702
Chevrolet Spark	2014	128	119	26.328	28.319	7.080	56.639
Honda Fit EV	2014	132	118	25.530	28.559	7.140	57.119
Fiat 500e	2013	122	116	27.623	29.052	7.263	58.103
Nissan Leaf	2013	129	116	26.124	29.052	7.263	58.103
Volkswagen e-Golf	2015	126	116	26.746	29.052	7.263	58.103
Ford Focus	2012	110	105	30.636	32.095	8.024	64.190
Tesla Model S	2014	94	95	35.851	35.474	8.868	70.947
CITY RATING							
						kWh PER PERIOD (City Rating, 25 miles)	kWh FOR COMPETITION (City Rating)
BMW i3						6.150	49.197
Scion iQ						6.105	48.841
Chevrolet Spark						6.582	52.656
Honda Fit EV						6.383	51.061
Fiat 500e						6.906	55.246
Nissan Leaf						6.531	52.248
Volkswagen e-Golf						6.687	53.492
Ford Focus						7.659	61.273
Tesla Model S						8.963	71.702

Figure 23: Electric Vehicle Comparison

Sponsorship

Based on the efficiency comparison for the electric vehicles, the team set out to find an electric car for the competition. With the BMW i3 as the first choice, Jenna Denhaan, with the support of Natalie Jo Schaefer (head of sponsorship), made a plan to call BMW San Luis Obispo. After BMW SLO showed no interest in a donation, the team went with their backup plan—BMW Santa Maria. Contacting the General Manager there, Mark Bachman, BMW Santa Maria agreed to donate the i3 for the length of the competition. Additionally, they would provide the electric car charging station as well as the vehicle's transportation from Santa Maria to Irvine and back. In the worst case scenario that all of the BMW i3s were sold during the time of the competition, BMW Santa Maria agreed to provide a Volkswagen e-Golf as a backup. Although this car was not the first choice, it was still under the energy budget of 64kWh initially set by the team, making it an adequate backup electric vehicle.

Additionally, Professor Dale Dolan secured the bifacial panels from Sunpreme to be used for the bifacial canopy. For inverters, Robert Johnson from SunPower, who was Cal Poly's lead EE for the Decathlon in 2005, attempted to get a donation. However, this donation did not come to fruition. Instead, Gabe Davis from Sunrun, who has worked extensively with Cal Poly on solar projects, expressed interest in donating both the racking system and inverters for the PV system.

Short Form Specifications

For the benefit of the contractors, a short form specification packet needed to be created. Jenna Denhaan and Dante Carrillo were responsible for learning how to write three-part short form specifications for the electrical systems and assembling the electrical Division 16 packet for submittal to the contractors. Before writing any of the specifications, we had to become familiar with the Construction Specifications Institute (CSI) MasterFormat, which is used to organize information about the house's construction requirements and associated activities. MasterFormat is arranged into major Divisions and then subdivided into sections. Electrical systems fall under Division 16 and were categorized further based on system function.

Each short form specification outlined general information and installation requirements for the solar panels, the inverters, the racking system, and the electric vehicle car charging station. As a result, information was provided for the SunPower E20/435 panels, the Sunpreme GxB 350W panels, the SnapNrack system, the SMA inverters, and the Wallbox PURE charging station for the BMW i3. For each of these electrical systems to be installed by the contractors, a short form specification, product datasheet, product installation manual, material safety data sheets (if applicable), and product invoice needed to be submitted within the packet. This way, the team was able to ensure that the contractors were supplied all details needed for correct and safe implementation of these systems into the house.

Aquaponics System

Although it has since been decided that the aquaponics unit will not be implemented within the Solar Decathlon home, Christian Ferrer and Audrey Rempher designed a simple PV and battery storage system to accommodate the Osmobot Sensor used to monitor the unit's water health. The main components that were going to go into the system were a 30W solar panel that charges a battery. In this case, the power rating of the solar panel can be as high as we want, we just chose to go with a 30 W panel as it is fairly cheap while still being able to charge the battery at a reasonable rate. As for the battery, there was a limiting factor that had to be considered. According to the Solar Decathlon rules, the aggregate battery capacity of all off grid systems has to be less than 100 Wh. Thus, a 12V wheelchair battery with an 8 Amp-hour rating was chosen as the Wh rating for this battery is less than 100 Wh. A charge controller is also needed as it regulates the amount of charge going into the battery while protecting it from overcharging. Thus, a 7 A charge controller operating at 12V was chosen. Lastly, a DC/DC converter, connected between the battery and the Osmobot unit, will step down the voltage from 12V to 6V, as the Osmobot required 6V to operate. A wire gauge was determined as well, which turns out that a 14 AWG wire, with an ampacity of 5.9 A, is able to be used for all the connections in the system while having enough leeway for any fluctuations in current. Though the aquaponics system was not included into the house and the solar system for the Osmobot unit was not actually built, going through the design process allowed these two students to gain valuable experience in designing small off-grid PV systems with battery storage.

CONSTRUCTION DOCUMENTS

(All Construction Documents are available in Appendix B)

Electrical Symbols and Notes (E-001)

The first sheet in the EE CDs (Construction Documents) defines all the acronyms and symbols used in the proceeding documents. This is the first sheet found in Appendix B. It also includes the overall general notes for the EE section, which is a general overview in the guidelines of using these documents by the contractors during construction. Lastly, there is a table of contents for all the documents in the EE section.

Power Distribution System (E-101)

This system will handle layout of the power receptacles and how each will be circuited together according to the ratings on our circuit breakers and the standards set by the NEC 2014. A screenshot of the power distribution system as designed using Revit is shown in Document E-101 in Appendix B. The power distribution system has to be designed with safety and convenience in mind. We placed the receptacles so that there is enough coverage in that the homeowners can easily have access to power without having to walk some distance to be in proximity of a receptacle. However, these are limited by certain constraints, as in there cannot be receptacles within 6 feet of a door and that in the bathroom, receptacles cannot be more than 3 feet away from the sink. Other considerations include determining which receptacles will be wired to which circuit. Again, there are guidelines from the NEC 2014 that must be addressed. For example, the receptacles that provide power to the washer and dryer must be powered by their own private circuit. To top it off, all receptacles must be of a certain type. These "types" refer to the kinds of electrical protection that an outlet will provide and the type is determined by looking at what room they are placed in and what kind of load the receptacle will be providing power to.

There are six types of protection for the outlets: AFCI (Arc Fault Circuit Interrupter), GFCI (Ground Fault Circuit Interrupter), tamper resistant, weather-proof, dedicated, and 40" AFF (Above Finished Flooring). First off, all receptacles are supposed to be tamper resistant. Tamper resistant receptacles have spring-loaded shutters that prevent individuals, primarily children, from inserting an object into the outlet and getting electrocuted. Receptacles in bathrooms, near countertops, and outdoors must have GFCI protection as receptacles in these rooms can become shorted since they are near water sources. Receptacles that do not have GFCI protection will have AFCI protection, which protects users from arc faults. Receptacles located outdoors must be weather-proofed so they can operate safely in inclement weather without hurting the users. These receptacles will be powering the greywater, blackwater, and water heater pumps as these pumps have to be situated outside. There are also receptacles that are dedicated, meaning they have their own dedicated branch circuit. These receptacles power relatively large loads, which are the refrigerator, dishwasher, dryer and washer, and stove top. Finally, there are the 40" AFF receptacles. These receptacles are those that have to

be set 40” from the ground, like those on kitchen countertops, compared to the normal height of 18”.

All-in-all, the power distribution system is a critical piece of our design as these are the pathways that provide electricity to the homeowners.

PV Wiring Plan (E-102)

The PV Wiring plan, as can be seen on sheet E-102 in Appendix B, shows the layout of the solar PV system and their string connections. 2 strings of 5 SunPower panels are shown, as well as 2 strings of 7 Sunpreme bifacial panels. The panels are depicted to run to a combiner box that then runs in conduit back to the inverters in the mechanical room. The Sunpower E20/435 modules run to the SMA Sunny Boy 4000TL-US, and the Sunpreme GxB 350W panels run to the SMA Sunny Boy 5000TL-US. In addition to the layouts of the panels, there is also a brief summary of each module’s specifications on the side of the sheet.

Lighting Plan (E-103)

Referring to E-103 in Appendix B, an overhead view displaying the locations of lighting fixtures, with “wires” representing their connection to switches. In reality, these wire runs take place in the framing in the walls, but to more clearly communicate connections, the wires are displayed within the rooms. Next to each light fixture, a fixture tag, or light-type label, can be found. These correspond to the luminaire schedule found on E-604, where each fixture tag refers to a specific luminaire type. This lighting plan and its luminaire schedule were dictated by the architectural lighting team. As EEs, we were essentially liaisons to display their design on the official documents.

Electrical Elevations (E-201)

The Electrical Elevations, shown in sheet E-201 in Appendix B, shows the physical layout of equipment in the mechanical room. The equipment shown is not just electrical, but also mechanical, so as to show that there is no interference between layouts. Additionally, a view of the racking system with measurements detailed out is shown on this sheet to provide clear detail of the equipment used in the racking system and the mounting locations.

Site Plan (E-401)

The Site Plan, E-401 in Appendix B, shows the location of the organizer utility panel, and where and how it connects to the utility meter. The cable runs through the western-most room of the Solar House. As the power through the utility panel is large, a large cable was used to connect to the utility meter. The cable used was a 3 - #2/0 +1 - #4 bond copper cable. The site plan also includes an enclosure for the string inverters, main service panel, and telecommunications control.

One-Line Diagram (E-601)

The One-Line Diagram, which can be seen in Appendix B, represents the simple power flow of our three-phase system using a single line to model the conductors between modules. In simple terms, this is a block diagram of power flow; it includes flow from both the bifacial panel array and the SunPower panel array. The solar panels will generate DC power, which will go into a junction box to then be converted by DC-AC SMA inverters. The AC power is connected to the main service panel which distributes power to the house's subsidiary circuits. Additionally, the main panel connects to the energy meter which connects to the grid for the competition. In this way, generated power from the solar panels can flow into the grid, and the grid can supply power to the house.

Three-Line Diagram (E-602)

The Three-Line Diagram, located in Appendix B, is an electrical system drawing that depicts the power flow of our three-phase system and details its interconnections. Within the three-line diagram, the positive, negative, and ground cables of the DC system are depicted along with the L1, L2, and L3 (3-phase), Neutral, and Ground cables of the AC system. Each of these lines are represented by a single line. Whereas the connection from the PV modules to the inverter is represented with only one line on the single-line diagram, the same connection is detailed with three lines (positive, negative, and ground) within the three-line diagram.

Schedules (E-603)

Sheet E-603 in Appendix B shows the schedules for the distribution panel and the Solar PV system. The main panel schedule listed on the left side of E-603 lists the circuits, the sizes of the relay breakers for the circuits, the rated voltages of Phases A and B and the circuit numbers associated with the Power Distribution System (E101). The main panel of our system is a 42 space, 200A Siemens #P4040B1200CU Indoor Load Center. Our design uses 39 out of the 42 open spaces available with 3 open spaces available. The 39 used spaces consist of HVAC equipment, household appliances, receptacles, vehicle charging, fire alarm circuit, lighting and two photovoltaic inverters.

The PV System Schedule gives a short description of each of the two arrays that comprise the complete system. It shows the open circuit voltage per panel, per string, and also per string at the minimum temperature for the Irvine region so that the max possible voltage is being considered into the safety of the system. Lastly, the max input voltage and current is shown on the inputs of the inverter for each array to show that the inverter's specifications will not be exceeded.

Luminaire Schedule (E-604)

The Luminaire Schedule, as seen on sheet E-604 in Appendix B, lists a detailed breakdown of each lighting fixture used in the interior and exterior of the house. It describes the brand, finish of the fixture, type of lamp, quantity of each light, and a tag relating the light to a corresponding symbol on the Lighting Plan (E-103) sheet.

Electrical Load Calculations (E-605)

The Electric Load Calculations are listed on the left side of E-604 and list the predicted load demands of the house so that the appropriate wiring, panel size and breakers can be designed correctly in accordance to the National Electric Code (NEC) 2014 edition. The Electric Load Calculations lists all loads in the house under three categories: 'General Loads', 'Electrical Vehicle Charging Loads' and 'Heating and Air Conditioning Loads'. The Voltage (V), Power Rating (VA) and Total Power (VA) are listed with a 'Notes' section on the right-most column to indicate the section of the NEC to which the loads calculations abide by. The 'General Loads' section uses 220.82(B) of the NEC to calculate its load demand. The 'Electrical Vehicle Charging Load' uses 625.41(B) of the NEC to calculate its load demand. The 'Heating and Air Conditioning Loads' uses 220.82(C) of the NEC to calculate its load demand. The loads are added up to determine the total Feeder Load and Current. The Total Feeder Current is 122 A and with consideration for overcurrent up to 125%, the 200 A main panel meets the requirements of the NEC with enough power from the 150A service feed. The Neutral Load Current, 92 A, is calculated separately using the sum of the loads of the phase with the highest rated power rating, Phase B, and dividing by 120V.

Individual Roles

Role of Simon Hauser

Simon's initial contribution to the Electrical Engineering Team's involvement in the Solar Decathlon was to help teach the members the basics of laying out an electrical system in the architectural modelling software Revit. Simon learned revit as an intern at a engineering consulting firm the previous summer. Once the team was up to speed, Simon took the lead on the more complex aspects in creating NEC-standard construction documents, such as circuiting loads, drawing the details for the one-line and three-line documents, and checking the documents for printable-consistency of font and header sizes. Simon was also one of the main contributors in sizing the PV system on the house along with deciding on Balance-of-Systems components and sizing, as shown on the one-line and three-line documents. Coordination with architects and mechanical engineers was vital in determining the allocated roof space for the PV array. Simon presented the original PV design to representatives from Sunpower and First Solar and received feedback/advice on how to better implement the system.

Simon also helped to interface the eGauge monitoring system with a router to form a LAN, allowing access to the current data measured with the current transformer's inputting into the eGauge. Meeting with the computer science students working on the back-end of the home automation, data from the eGauge IP was able to be pulled in the form of a .CSV file.

Most recently, Simon and other senior project group members designed and built a racking system for the Sunpreme bifacial modules. Simon helped to solidify the design, and purchased the steel beams for the construction. Simon and Joey, among others, constructed the 6-foot tall rack, and with the module mounted different material underneath with varying albedo's should result in varying power production from the module. Further testing needs to be completed with the Solmetric PV Analyzer. The hope is that the bifacial module with racking system will be used as a teaching tool for Dr. Dolan's EE-520 PV System Design course.

Role of Christian Ferrer

I am one of the members of the Electrical Engineering team for 2015 Solar Decathlon.

My part in the Solar Decathlon Project is to help layout the distribution plan for the house as well as the lighting plan using the program Revit. For the distribution plan, we have determined the placement of the power receptacles as well as arranging into circuits where each circuit must not exceed the rated ampacity of the breaker they are attached to. We have also had to determine which loads must have their own dedicated branch circuit, as well as determining the types of receptacle to be used for a particular location. Similarly for the lighting plan, we determine what the type of fixtures and light bulb had to be used in addition to assigning a location of the lighting fixtures. All this has been done according to the rules and regulations as stated in the NEC 2014 code, as this is what the Department of Energy requires and will ensure

that the design being implemented will be as safe as possible. Not to be looked over, but a big part of this project was learning how to use the program Revit, as it allows us to draft the electrical system and that all documents submitted to the Department of Energy is to be made through Revit. Additionally, I have played a part in editing and formatting the documents as updates and corrections coming from the architecture team and the Department of Energy were communicated to our team.

The team and I also have designed and assembled a test frame for one of the bifacial solar panels that we would use on the roof of the solar house. This frame securely holds the bifacial panel about 6 feet high with the flat side parallel to the floor. This is to stimulate the operating conditions of the bifacial panel being elevated while receiving reflected light on its back panel, thus giving us a more accurate data set on the amount of power it produces when we were testing the performance of the bifacial panel.

Finally, my fellow team member Audrey and I spent some time on designing a solar system to power the Osmobot sensor, a device that monitors the water used in an aquaponics system. Unfortunately, the idea of having an aquaponics system with the house was scrapped; although, it was a good learning experience in learning how components must be selected while taking into consideration of the power/voltage/current ratings of other components so that nothing will be running past their proper operating point while still being able to perform the desired task.

Role of Casey Smith

I am the Team Contact and an Electrical Engineering Lead on the Solar Decathlon project. My role on the project includes managing all electrical design documents, distributing tasks and organizing meetings between all electrical team members, and handling interdisciplinary communication between the various teams, particularly architecture and mechanical engineering students.

My expertise is particularly with the Solar PV systems; I have lead nearly all Solar PV design iterations, starting with the various prototype design houses created by the architects in early Spring 2014. Using PVWatts (open-source solar estimation software released by NREL), I have calculated many different PV system sizes and their contribution to our generation goal of 175 kWh over the competition period when considering variable parameters such as panel tilt and panel type. This included various inverter configuration assessments, and shading and footprint assessments for given roof spaces. I served as the main consultant for the considerations and feasibility studies for the decisions made concerning the bifacial canopy and rooftop mounted solar systems. I have conducted cost estimates, baseline energy analysis, and assessment of possible equipment/structural requirements. In addition to my focus on the PV System, I created spreadsheets to calculate the energy budget for the lighting system, electric vehicle, and cooking appliances.

One of the biggest challenges of the project was moving into the DD stage of the project; this mainly involved learning the program Revit and many sections of the NEC, as well as rules of

thumb associated with the requirements to make electrical DD drawings. I organized a presentation with Reid Johnson, an AutoCAD representative, to come in and give the EE team a run down of the Revit software, but we all still spent a large amount of time learning to use and navigate the program on our own time. After learning the basics of Revit, I assisted the completion of the Electrical Symbols and Notes, Electrical Distribution Plan, PV Wiring Plan, Lighting Plan, Electrical Elevations, Site Plan, One-Line Diagram, Three-Line Diagram, PV System Schedule, and Electrical Load Calculations for our DD phase. I also coordinated with Tim Ambrose for the completion of the Telecommunication documents.

Moving forward into the CD phase, I focused my efforts on the Electrical Distribution Plan, PV Wiring Plan, Electrical Elevations, Site Plan, One-Line Diagram, Three-Line Diagram, and the PV System Schedule. Through both the various DD and CD submissions, it was my duty to handle last-minute corrections, update our drawings with models and templates received from the architects, and compile all of the Revit and PDF files to hand to the Project Managers. It was also my duty to write summaries of changes as our design progressed for the Project Manual and fill out the Grid Interconnection Form for these submissions.

The most time consuming part of the project was the aspect of relaying and receiving information between the various teams and using that information to make decisions. I spent many hours in the architecture studio discussing solar PV layouts, electrical equipment codes and cost comparisons, lighting fixture placements, and wiring runs. I also spent some time conversing with the Computer Science team to figure out how to set up the eGauge for their desires, and how they could best retrieve information about the appliances and display them in helpful ways. Additionally, coordination between the Mechanical Engineers for equipment layout and energy budget calculations was handled by me. I was responsible for attending all weekly student-faculty meetings and team contact meetings, as well as organizing weekly EE team meetings.

Role of Dion Celebrado

I am the instrumentation contact for the Solar Cal Poly team. I was the initial intermediate between hardware designs from the Electrical and Mechanical team to the software designs presented by the Computer Science/ Engineering students in the Solar Cal Poly team and helped organize initial proposals and brainstormed instrumentation systems in the house as shown under the Instrumentation Systems section. I proposed the energy monitoring system, temperature / humidity sensors and tablet interface to the combined teams and tasks were separated amongst the teams. I decided with the Electrical team to use a commercial energy monitoring system recommended by Prof. Dolan known as the “eGauge Monitoring System”.

My work then shifted towards drafting and editing drawings on Revit 2014. I worked mainly on the Electrical Symbols and Notes Sheet, Load Calculations, Panel Schedule and Power Distribution CD’s. As architectural and HVAC decisions changed the house, I accounted the effects they had on the Panel Schedule and Power Distribution drawings in Revit 2014 and edited them accordingly. I referenced appliances and various loads specified, sized breakers

and the main panel accordingly to the National Electric Code. I machined the parts needed for the bifacial testing frame with Jenna Denhaan by cutting and drilling them so that the team could assemble their design.

The multiple submittal deadlines assigned by the Department of Energy and student Project Managers, Lisa Marie and Alyssa Parr, made the project challenging and relatable to real-world electrical consulting projects I would be interested working in.

Role of Joseph Rohrer

Joseph's role in the solar decathlon included various responsibilities and tasks. Being part of the electrical engineering team, I worked with different teams such as the architecture and mechanical engineering team to bring this project to life. Attending weekly meetings allowed the whole team to stay on pace throughout the whole year to finish the design and get enough materials for the house. Initially, I was unfamiliar with our programming software from Autodesk, Revit. After countless hours of updating the electrical documents including but not limited to PV design, lighting plan, one line diagram, three line diagram, luminaire schedule, and electrical load calculations. Also, in the middle of the quarter, I was able to attend a Revit workshop from an autodesk employee, Reid Johnson. In this workshop we designed different parts of common houses to get us more familiar and efficient with Revit.

Along with designing the electrical systems in Revit, the team and I wanted to give the household owners a way to view their energy consumption in real time and in an easy way. We decided on using eGauge Energy Monitoring System to accomplish this task. Using 20A and 40A current transformers at the Main Service Panel, we can measure the energy usage for different appliances in the house. This allows the users to know what in their house is using the most electricity and what to focus more attention on when turning their appliances off. We began testing eGauge and the current transformers using the high voltage power desk in the solar room. I helped figure out how the eGauge works, how it is connected, and how to access the software online through a LAN connection using a router.

Another task I contributed to is building a bifacial solar panel frame for use in future testing. I began building after the design was made and we had the necessary materials. After running into a few complications, I proposed different solutions. Jenna and Dion drilled necessary holes and cut beams at the hangar to allow the screws to fit in the holes of the beams. I helped design the frame so that the bifacial solar panel could lay on the sides of the frame giving more support, as well as using clamps on the front and back. This was carefully measured so none of the actual panel cells were covered by the frame. The frame ended up being very sturdy and was able to hold the frame as well as my weight (170lbs).

Role of Dante Carrillo

I first joined the electrical engineering Solar Decathlon team in February of 2015 where I attended weekly meetings with the architecture and mechanical teams. In the meetings, we researched and collaborated on the design of the house, the PV system that would be implemented, and what was necessary to live in a house, which included lighting, warm water, and outlets for the mechanical equipment, among other things.

During the construction documents phase, I was in first placed in charge of the site plan. Here, I worked with cable sizing, where to place the electrical box, panel, and utility meter, and where to station the organizer utility panel. All this was done in Revit, which was a program I had never worked with before and was required to learn to work on the site plan. Another portion of the construction documents I worked on were the one line and three line diagrams. At the weekly meetings, I worked with the architecture and mechanical teams to determine the practicality of implementing a bifacial solar system. When the idea of a bifacial system was accepted, I worked with Casey to make the correct changes to reflect what was discussed at the meeting. These changes included altering the rating of the panel, selecting a new inverter, and adding more panels to the strings. To make sure our documents were in order, I attended meetings where representatives from Sunpower visited to discuss our documents. The Sunpower representatives created redlines for us, which we were able to review and make necessary changes to our construction documents. Once we neared the end of the selection for material we would use for the Solar House, I attended a meeting with Jenna to learn the process in creating short-form specification documents. We worked on the short-form specifications for the racking system, solar panels, inverters, and the BMW charging station. We created a packed of all the short-form specification documents we created and submitted to the architecture team.

In order to test the efficiency of the bifacial panels, we needed to create a bifacial frame that would be, at least, six feet in height and strong enough to support a solar panel on its own. I worked on measurements for the bifacial frame, which dealt with where to cut the metal, how to support the solar panel most efficiently, and where to secure the metal together.

One of the research projects I worked on was creating a pathway to the door of the house that would light up when necessary. The first idea I came up with involved piezoelectricity. A person would walk on the piezoelectric floor, which would power on the lights that were embedded in the walkway ramp. However, because piezoelectricity is a relatively new form of renewable energy, the cost to implement it would outweigh the benefits. Another idea I came up with was the use of the QRD1114 sensor. This sensor uses an infrared emitted diode combined with an infrared phototransistor to detect the reflected infrared signal. Ideally, when a person passes the sensor, the QRD1114, paired with a microcontroller, would ‘turn on’ the lights that were embedded in the walkway ramp. However, due to other purchases for the Solar House, budget constraints were an issue.

Role of Audrey Rempher

My role in the Solar Decathlon Senior Project began in Spring of 2014 when I, along with a couple other members of the Electrical Engineering team, attended the architectural studio sessions in order to advise the architects on various solar designs as well as system placement within their various architectural designs.

In order to create and edit the design and construction documents for the electrical systems within the house, it was necessary to learn the architectural modeling software Revit. In the interest of learning the ins and outs of this program, I attended a Revit workshop hosted by Reid Johnson, an AutoDesk representative. After learning the required functions of Revit as well as reviewing circuit wiring codes and the NEC, Jenna Denhaan and I began the design development of the one-line and three-line diagrams for the PV system of the house. I also contributed to the design development of the PV Wiring Diagram. After moving further into the design process, I worked with Joey Rohrer and Simon Hauser to edit and perfect the lighting schedule construction document per the architect's instructions. Throughout the design process, it was necessary to communicate the new design developments with the architects and mechanical engineers as well as report to and coordinate with Richard Beller. This constant communication proved to be an incredibly important aspect of the project in ensuring that the various engineering and architectural teams working on the Solar Decathlon remain cohesive and well-informed of eachother's efforts. Coordination with the architects and mechanical engineers was especially critical in securing the roof space necessary to accommodate the PV array.

Professor Braun introduced me via email to SunPower employee Robert Johnson, a Cal Poly alumni who was the Electrical Engineering lead on the Solar Decathlon team when Cal Poly last entered the competition 10 years ago. Establishing this professional contact provided the Electrical Engineering team with the invaluable asset of Robert's professional experience and guidance throughout the design process.

Christian Ferrer and I designed a separate PV and battery storage system intended to accommodate the aquaponics system by powering the Osmobot, a device used to monitor the health of the water within the tank. Though the system design was completed, the system will not be implemented within the house since the aquaponics system will no longer be included within the home design. Most recently, our team designed and built a racking system to be used for testing the Sunpreme bifacial solar modules. I purchased some of the steel beams used in building the frame and aided in the design of the frame. After we constructed the frame, we conducted tests and ensured that it was stable and could support the bifacial panels 6 feet above the ground. This frame will allow us to collect accurate data for the performance of the panel. Throughout the quarter I also took meeting minutes during the weekly Electrical Engineering team meetings.

Role of Jenna Denhaan

One major step in the Solar Decathlon process revolved around the Construction Document submittals to the DOE for all of our electrical systems. Audrey and I were responsible for the initial one-line and three-line diagrams, as well as creating these documents in Revit. Additionally, I did the initial electrical load calculations which would eventually be handed off to Dion and Casey. This involved sorting through the NEC to find all applicable codes and regulations related to load calculations and finding electrical specs for the appliances chosen by the ME's. Much of this information was also used in creating the panel schedule. Additionally, I contributed research about heights of receptacles, distribution panels, inverters, etc. to help Dion and Casey create the electrical elevation diagram of the mechanical room in Revit. All of these documents had to be edited and eventually evolved into our final designs based on corrections we had to make after the documents were returned to us from the DOE. In addition to these items, Casey and I did the energy calculations for cooking two dinners during the competition and discussed electric vehicle efficiency calculations. I also provided a wireless router, helped setup a LAN to be used by the eGauge energy monitoring system, and purchased current transformers for the system.

Another role I filled for the senior project team was sponsorship contact. I attended sponsorship meetings every Friday to update the other teams on the EE team's progress in getting materials donated. I was in charge of securing an electrical vehicle and its charging station to be used for the duration of the competition. I met with Natalie Jo Schaefer, head of sponsorship for the Solar Decathlon, and we laid out a plan to find an electric car. Based on efficiency calculations, the EE team chose the BMW i3 as our first choice for an electric vehicle. Based on this, I originally contacted BMW San Luis Obispo for a donation to no avail. Then, with the help of Natalie, we got in contact with Mark Bachman from BMW Santa Maria, who agreed to donate a BMW i3 (as long as they were not all sold during the competition), its charging station, and transportation to Irvine and back. As a backup, he agreed to donate a Volkswagen e-Golf in the worst case scenario that all i3's were sold.

One other project that Dante and I worked on was making the short form specifications to be submitted to the contractors. To do so, we had to learn how to write the three-part short form specifications by attending a workshop and also learn CSI MasterFormat to organize our documents. From there I wrote the specs for the solar panels, bifacial panels, and electric car charging station while Dante wrote the specs for the inverter and racking system. We then compiled all product datasheets, installation guides, short form specs, invoices, and MSDS's to create the electrical Division 16 packet to be submitted to the contractors. This ensured that all electrical systems would be safely implemented into the house by the contractors.

Towards the end of the quarter, the team made a bifacial testing frame. Dion and I used our red tag certifications to machine the parts for the frame. This included cutting and filing all of the steel beams as well as drilling holes in all of the supporting L-beams so that the frame could fit the dimensions of the bifacial panel.

Analysis of Senior Project Design

Below describes an analysis of our senior project in a holistic view and the impacts it has over its complete life cycle, as required by Appendix D in the Electrical Engineering Senior Project Handbook [6].

- **Summary of Functional Requirements**
  - Describe the overall capabilities or functions of your project or design. Describe what your project does. (Do not describe how you designed it).
    - The Solar Decathlon Team is designing a fully functional and livable house that is completely powered using solar panels. The house will also be equipped with modern technology that provide easy and comfortable living. It is to be an example of the future potentials of sustainable housing and its attainability for the average consumer.

- **Primary Constraints**
  - Describe significant challenges or difficulties associated with your project or implementation. For example, what were the limiting factors, or other issues that impacted your approach?
    - The biggest challenge with this project was learning to design all of the required documents for the design and construction of the house in the software Revit 2015. Since no CAD experience was introduced to Electrical Engineering students in coursework, it was a very arduous process to learn the program on our own time and then attempt to create professional engineering documents with it.

- **Economic**
  - What economic impacts result?
    - This project results in many different economic impacts including increased grid interconnection and maintenance equipment and labor, no electric cost to the household owner, jobs created to build a solar house, and revenue generated by the large list of equipment needed for the project completion. In addition, the project pushes the market for innovative and sustainable electrical home systems, which has a large economic impact on the consumer purchasing trends.

  - When and where do costs and benefits accrue throughout the project's lifecycle?
    - Costs begin to accrue as soon as the house is active on a site. Water utility payments must be made at a minimum on a monthly basis. Ideally, no electrical utility payments are required, but may be necessary for some months when the house underperforms. Additionally, at about 10 years into the life of the project, expected maintenance costs will begin to occur (inverter replacements, deck repairs, etc.)

- What inputs does the experiment require? How much does the project cost? Who pays?
  - Inputs include water utility infrastructure, electrical grid infrastructure, and moving equipment if the house is being transported. The expected project cost is around $250,000 in materials, but labor has not been priced for our project since it has been donated work. Payment comes in the form of pro-bono contractor labor, material donations, expertise support, and miscellaneous funding from various sources. Cash procurements are handled through the University. In a real world setting, the homeowner would be the one who pays for the end product.

- How much does your project earn? Who profits?
  - This project does not earn profit, though it could be said that the homeowner profits on a monthly basis by not having to pay an electricity bill most months.
- Timing:
  - This project might emerge five times per year if a contractor's sole purpose was to build this house for specialty customers. Products are expected to last as long as they are maintained. Maintenance costs are extremely variable, depending on when and how often the house is upkept. An expected value might be $1,000 per year at later stages in the project's life.

- **If Manufactured on a Commercial Basis**
  - Estimated houses built per year: Approximately 5
  - Estimated manufacturing cost: $250,000
  - Estimated purchase price: $500,000
  - Estimated profit: $250,000
  - Estimated operational costs (for homeowner): $700 per year

- **Environmental**
  - This house supports sustainability by using alternative forms of energy. Using solar power instead of running solely off a mainly coal, natural gas, and oil powered grid is a positive step in being environmentally friendly. The house also promotes the idea of passive energy efficiency through inherent building design. The house also makes use of reclaimed materials in some of its exterior construction, which introduces sustainable design from the start of its life. Since the house does not have a sizeable water collection system, most of its environmental impact may come from the fact that it draws water from the grid. Additionally, in the case of equipment failures such as inverters, it may occasionally produce environmentally unfriendly waste.

- **Manufacturability**
  - To build the house we have sent the completed Revit design documents to a contracted construction team. This contractor will verify and coordinate efforts between the various documents submitted by different disciplines and ensure no conflicts arise.

- **Sustainability**
  - Describe any issues or challenges associated with maintaining the completed device, or system.
    - In general, the house is designed and built for longevity. Bamboo flooring and SIP walls ensure long lasting structure. The electrical system requires little maintenance, however, the solar PV system will require inverter replacements every 10 years and module replacement every 25 years, according to accepted industry standards.

  - Describe any upgrades that would improve the design of the project.
    - Creating a more in depth energy monitoring system to allow individual appliance monitoring, and lighting controls to allow individual bulb control. Currently, the budget limits this advancement.

  - Describe any issues or challenges associated with upgrading the design.
    - In general, retrofitting the house will be somewhat challenging, as the electrical and mechanical system implemented in the house are a unique, specialized design that will not easily follow industry standards. Upgrades will be costly as they will likely require changes to other components in the system.

- **Ethical**
  - Describe ethical implications relating to the design, manufacture, use, or misuse of the project. Analyze using one or more ethical frameworks in addition to the IEEE Code of Ethics.
    - This project has positive ethical implications allowing consumers to live comfortably and use no grid power. Being environmentally sustainable is important for an ethical citizen and building a solar house allows people to do so.

- **Health and Safety**
    - Describe any health and safety concerns associated with design, manufacture, or use of the project.
        - Building a house can be dangerous if the safety measures aren't followed correctly. A professional team of construction workers and managers will have to manufacture the house.
        - The design of the house follows all national code requirements such as the NEC to provide the highest possible safety.

- **Social and Political**
    - Renewable energy and sustainability is currently under much legislative back-and-forth, and this creates a volatile base for renewable energy systems, where legislative restrictions could heavily affect the implementation of the budget and implementation of the house. Also, since this house is an example of a changing housing market, legislation affecting residential housing at any location it might be implemented could affect its availability. Contractors are also responsible for the construction of this project, so labor issues could potentially come into play during its construction.

- **Development**
    - Describe any new tools or techniques, used for either development or analysis that you learned independently during the course of your project.
        - Revit 2015 is used to design the entire solar house, and additional PV modeling software is used to assist with calculations, such as PVWatts
        - The Department of Energy reviews our partial submittals of our current designs to make sure they fit code regulations and design requirements.

Appendix A

References:

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[2] Razgus, Amara. "MEP Giants Continue to Diversify." Consulting-Specifying Engineer. N.p., 14 Aug. 2014. Web. 25 Oct. 2014. http://www.csemag.com/single-article/mep-giants-continue-to-diversify/0eb50f3b066273c78d915002f9e09f3e.html

[3] "Pacific Gas & Electric - PG&E." *Pacific Gas & Electric*. N.p., n.d. Web. 27 Oct. 2014. http://www.pge.com/tariffs/electric.shtml

[4] “Residential Service: Sheet No. R-2.1” Arkansas Public Service Commission N.p. N.d. Web. 27 Oct. 2014 https://www.swepco.com/global/utilities/lib/docs/ratesandtariffs/Arkansas/Arkansas1_12-01-2009.pdf

[5] “What is U.S. electricity generation by energy source?” U.S. Energy Information and Administration. N.p. N.d. Web. 27 Oct. 2014 http://www.eia.gov/tools/faqs/faq.cfm?id=427&t=3

[6] “Senior Project Hanbook.” Electrical Engineering Department. California Polytechnic State University, 08 Aug. 2011. Web. 06 Jun. 2015. http://www.ee.calpoly.edu/media/uploads/Senior_Project_Handbook2011-2012-10-19-2011Update.pdf

Appendix B: Construction Documents

SYMBOL LEGEND	
ELECTRICAL EQUIPMENT AND DEVICES	
	DUPLEX RECEPTACLE
	DUPLEX RECEPTACLE (AFCI, TR)
	DUPLEX RECEPTACLE (GFCI, TR)
	DUPLEX RECEPTACLE (GFCI, TR, WP)
	DUPLEX RECEPTACLE (GFCI, TR, DEDICATED 20A)
	DUPLEX RECEPTACLE (GFCI, TR, DEDICATED 50A)
	DUPLEX RECEPTACLE (GFCI, TR, +40")
	QUADRAPLEX RECEPTACLE
	QUADRAPLEX RECEPTACLE (AFCI, TR)
	QUADRAPLEX RECEPTACLE (GFCI, TR)
J	JUNCTION BOX
	CIRCUIT BREAKER
	WATER PUMP
SWITCHES	
$	SINGLE POLE LIGHT SWITCH
$LKP	LUTRON 6-BUTTON KEYPAD

TABLE OF ABBREVIATIONS	
AFCI	ARC FAULT CIRCUIT INTERRUPTER
AFF	ABOVE FINISHED FLOOR
EWH	ELECTRIC WATER HEATER
GFCI	GROUND FAULT CIRCUIT INTERRUPTER
MP	MAIN PANEL
PV	PHOTOVOLTAIC
TR	TAMPER RESISTANT
WP	WEATHER PROOF

GENERAL NOTES (ELECTRICAL)

1. ALL ELECTRICAL WORK PERFORMED UNDER THIS CONTRACT SHALL COMPLY WITH THE ENFORCED VERSION OF THE NATIONAL ELECTRIC CODE.
2. REFER TO ARCHITECTURAL AND MECHANICAL DRAWINGS, CEILING PLANS, ELEVATIONS, AND DETAILS FOR LOCATION OF ALL CEILING ELEMENTS AND OTHER WALL MOUNTED DEVICES NOT INCLUDED IN ELECTRICAL DRAWINGS.
3. EXTERIOR RECEPTACLES SHALL BE A GFCI TYPE DEVICE IN A WEATHER PROOF COVER.
4. THE ELECTRICAL SYSTEM SHOWN ON THE DRAWINGS IS ONLY GRAPHICAL AND NECESSARY CIRCUITRY SHALL BE PROVIDED TO MAKE THE SYSTEM COMPLETE AND IN SAFE WORKING ORDER, AND SHALL BE COORDINATED WITH OTHER TRADES.
5. POWER RECEPTACLES WITHIN 6 FEET DISTANCE FROM ANY PLUMBING FIXTURE AND/OR SINK SHALL BE EQUIPPED WITH GFCI.
6. ALL WORKING CLEARANCES AROUND ELECTRICAL EQUIPMENT SHALL BE MAINTAINED IN ACCORDANCE WITH NATIONAL ELECTRIC CODE.
7. ALL PENETRATIONS OF WALLS OR CEILINGS SHALL BE SLEEVED AND SEALED TO COMPLY WITH BUILDING CODE REQUIREMENTS.
8. SEE F-101 FOR SMOKE DETECTOR AND FIRE ALARM PLAN PLACEMENT.
9. SEE T-602 FOR SENSOR PLACEMENT AND DATA WIRING.
10. THE BUILDING SHALL BE WIRED AS TO ALLOW FOR MODULAR CONSTRUCTION AND TRANSPORTATION. JUNCTION BOXES SHALL SERVE AS THE CONNECTION POINT BETWEEN ALL WIRES DISCONNECTED BETWEEN MODULES.
11. STRUCTURALLY INTEGRATED PANELS IN CEILINGS AND WALLS WILL REQUIRE WIRE CHASES AND WIRE WILL BE FED THROUGH THE FLOOR UP INTO THE WIRE CHASES.
12. MOUNTING HEIGHTS FOR RECEPTICLES SHALL BE 12" AFF. MOUNTING HEIGHTS FOR SWITCHES SHALL BE 44" AFF, UNLESS NOTED OTHERWISE.
13. PRIOR TO ROUGH-IN, CONTRACTOR SHALL VERIFY ALL MOUNTING, HEIGHTS, FIXTURE LOCATIONS, APPLIANCE SPECS, EXACT LOCATION OF FIXTURES, SPLASHES, DOOR AND WINDOW TREATMENTS/TRIM WITH OWNER. ALL DEVICES SHALL BE PLACED TO AVOID CONFLICTS WITH SPLASHES, SHELVING, TRIM.
14. COORDINATE AND INSTALL ALL ELECTRICAL DEVICES INSTALLED IN CABINETRY, SHELVES AND SPACES BY OTHERS.
15. ALL GENERAL BUILDING WIRING CONDUCTORS TO BE THHN/THWN.
16. ALL CONDUCTORS REGARDLESS OF SIZE WILL BE ORDERED AND INSTALLED IN THEIR CORRESPONDING PHASE COLOR. PHASE TAPE IS NOT ACCEPTABLE. THE FOLLOWING COLOR CODE WILL BE ADHERED TO: BLACK FOR PHASE A, RED FOR PHASE B, WHITE FOR NUETRAL, PINK OR PURPLE FOR SWITCH LEG/TRAVELERS, GREEN FOR GROUND.

TABLE OF CONTENTS (ELECTRICAL)

1 ELECTRICAL SYMBOLS AND NOTES
1/4" = 1'-0"

SOLAR CAL POLY

TEAM NAME: SOLAR CALPOLY
ADDRESS: CALIFORNIA POLYTECHNIC STATE UNIVERSITY SAN LUIS OBISPO, CA 93407
CONTACT: SOLARCALPOLY@GMAIL.COM WWW.CALPOLYSOLARDECATHLON.ORG

CONSULTANTS

CLIENT
U.S. DEPARTMENT OF ENERGY
SOLAR DECATHLON 2015
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U.S. DEPARTMENT OF ENERGY SOLAR DECATHLON

Revision Schedule

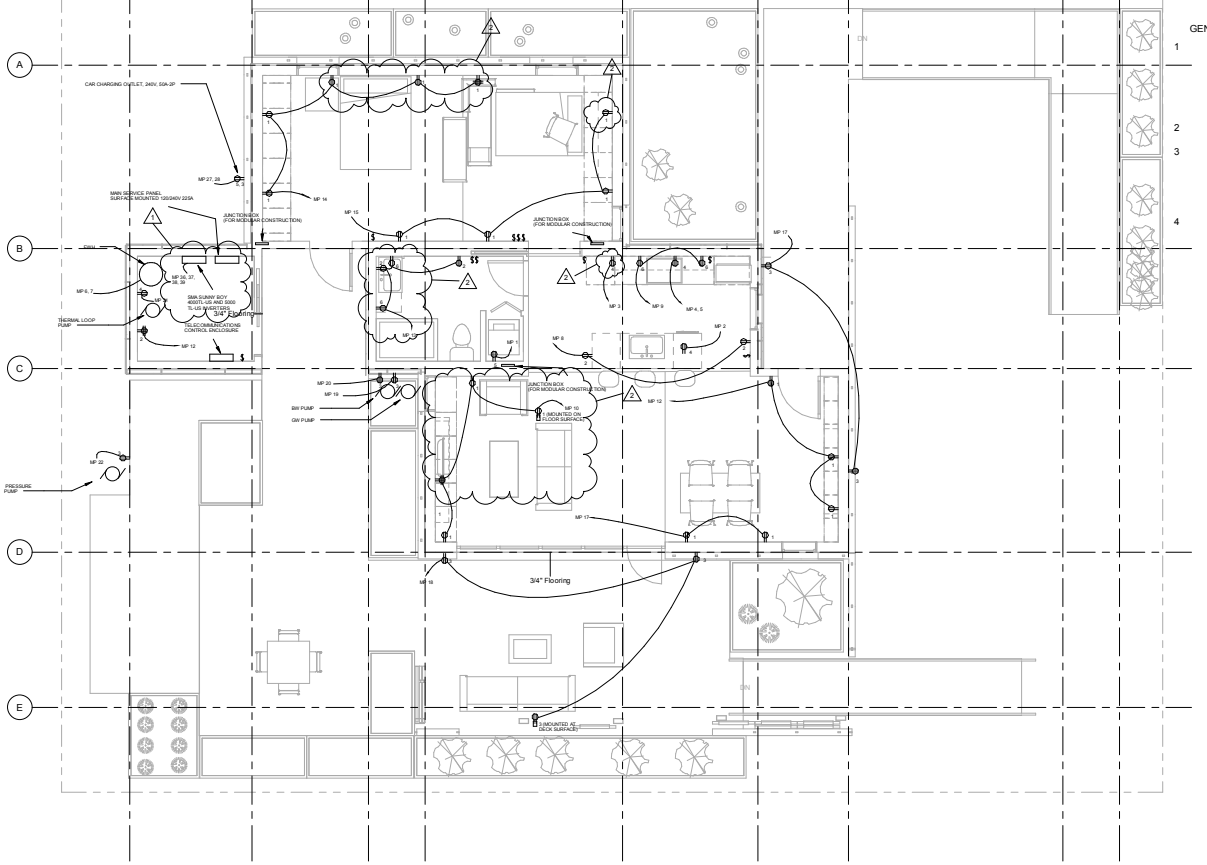
Revision Number	Revision Description	Revision Date
1	5-11-15 PLAN CHECK CORRECTIONS	MAY 11, 2015
2	6-01-15 PLAN CHECK CORRECTIONS	JUNE 01, 2015

LOT NUMBER: 107
DRAWN BY:
CHECKED BY:

SHEET TITLE
ELECTRICAL SYMBOLS AND NOTES

MAY 11, 2015

E-001



1 FIRST FLOOR ELECTRICAL
1/4" = 1'-0"

GENERAL SHEET NOTES (DISTRIBUTION PLAN)

1. ALL BRANCH CIRCUITS WITH RECEPTACLES RUNNING AT 120 V, 15 A, AND 20 A WILL BE WILL HAVE AFCI PROTECTION IMPLEMENTED BY HAVING THE FIRST OUTLET IN THE BRANCH CIRCUIT BE AN AFCI RECEPTACLE [NEC 210.12(A)
2. INSTALL PV INVERTERS AS PER MANUFACTURER'S SPECIFICATIONS
3. ALL JUNCTION BOXES FOR CONSTRUCTABILITY OF MODULE SEPARATION ARE 5 FEET FROM FLOOR TO BOTTOM OF BOX. SIZE OF BOX APPROXIMATELY 1.63" DEEP BY 4.5" HIGH BY 10.44" WIDE
4. INVERTERS IN THE MECHANICAL ROOM ARE STACKED ON TOP OF EACH OTHER

RECEPTACLES							
RECEPTACLE TYPE MARK	AFCI	GFCI	TAMPER RESISTANT	WEATHER-PROOF	DEDICATED (20A)	DEDICATED (50A)	+40" AFF
1	X		X				
2		X	X				
3		X	X	X			
4		X	X		X		
5		X	X			X	
6		X	X				X

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2	6-01-15 PLAN CHECK CORRECTIONS	JUNE 01, 2015

LOT NUMBER: 107
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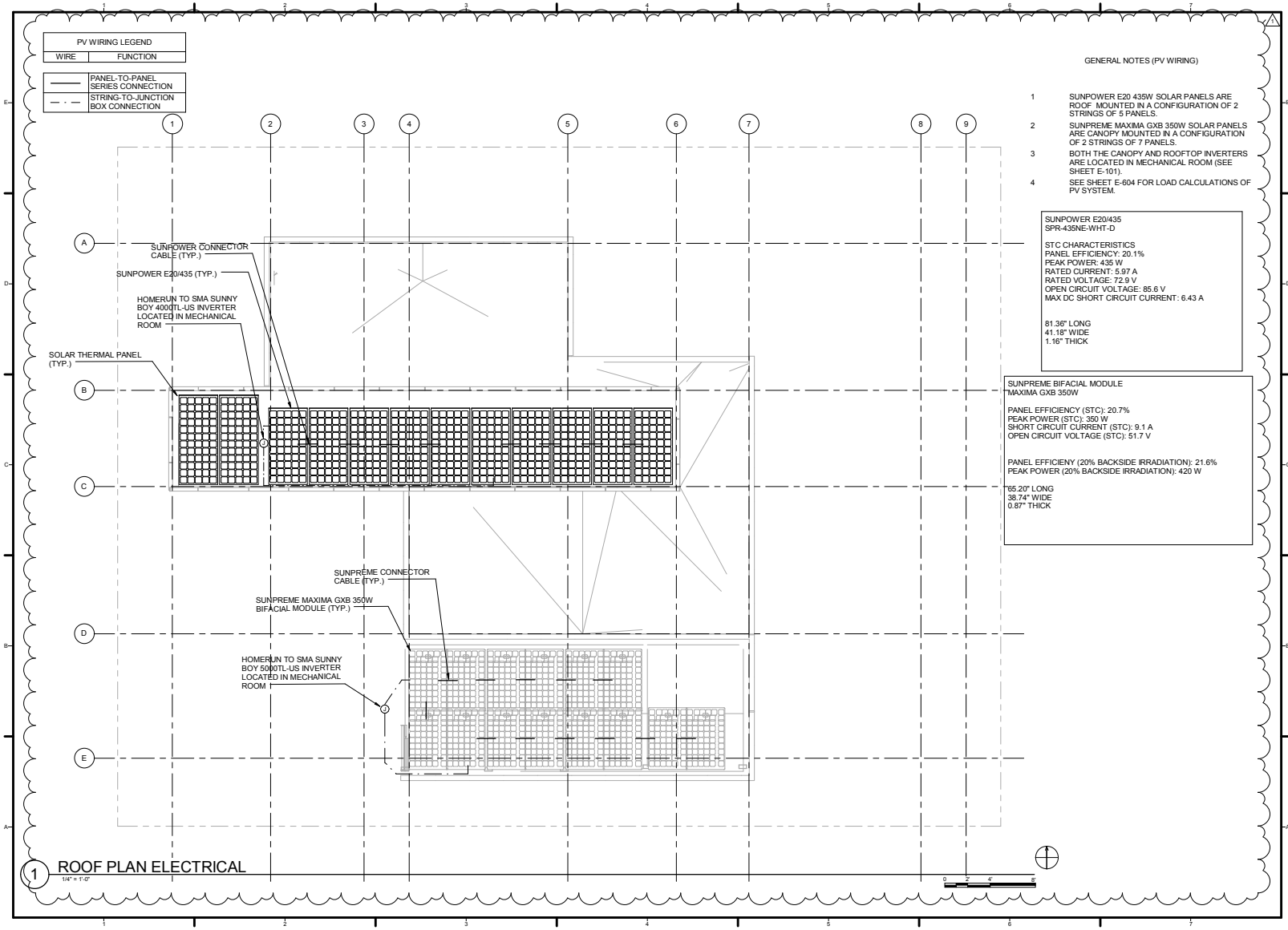
ELECTRICAL DISTRIBUTION PLAN

MAY 11, 2015

E-101



GENERAL NOTES (PV WIRING)

1. SUNPOWER E20 435W SOLAR PANELS ARE ROOF MOUNTED IN A CONFIGURATION OF 2 STRINGS OF 5 PANELS.
2. SUNPREME MAXIMA GXB 350W SOLAR PANELS ARE CANOPY MOUNTED IN A CONFIGURATION OF 2 STRINGS OF 7 PANELS.
3. BOTH THE CANOPY AND ROOFTOP INVERTERS ARE LOCATED IN MECHANICAL ROOM (SEE SHEET E-101).
4. SEE SHEET E-604 FOR LOAD CALCULATIONS OF PV SYSTEM.

SUNPOWER E20/435
SPR-435NE-WHT-D

STC CHARACTERISTICS
PANEL EFFICIENCY: 20.1%
PEAK POWER: 435 W
RATED CURRENT: 5.97 A
RATED VOLTAGE: 72.9 V
OPEN CIRCUIT VOLTAGE: 85.6 V
MAX DC SHORT CIRCUIT CURRENT: 6.43 A

81.36" LONG
41.18" WIDE
1.16" THICK

SUNPREME BIFACIAL MODULE
MAXIMA GXB 350W

PANEL EFFICIENCY (STC): 20.7%
PEAK POWER (STC): 350 W
SHORT CIRCUIT CURRENT (STC): 9.1 A
OPEN CIRCUIT VOLTAGE (STC): 51.7 V

PANEL EFFICIENY (20% BACKSIDE IRRADIATION): 21.6%
PEAK POWER (20% BACKSIDE IRRADIATION): 420 W

65.20" LONG
38.74" WIDE
0.87" THICK

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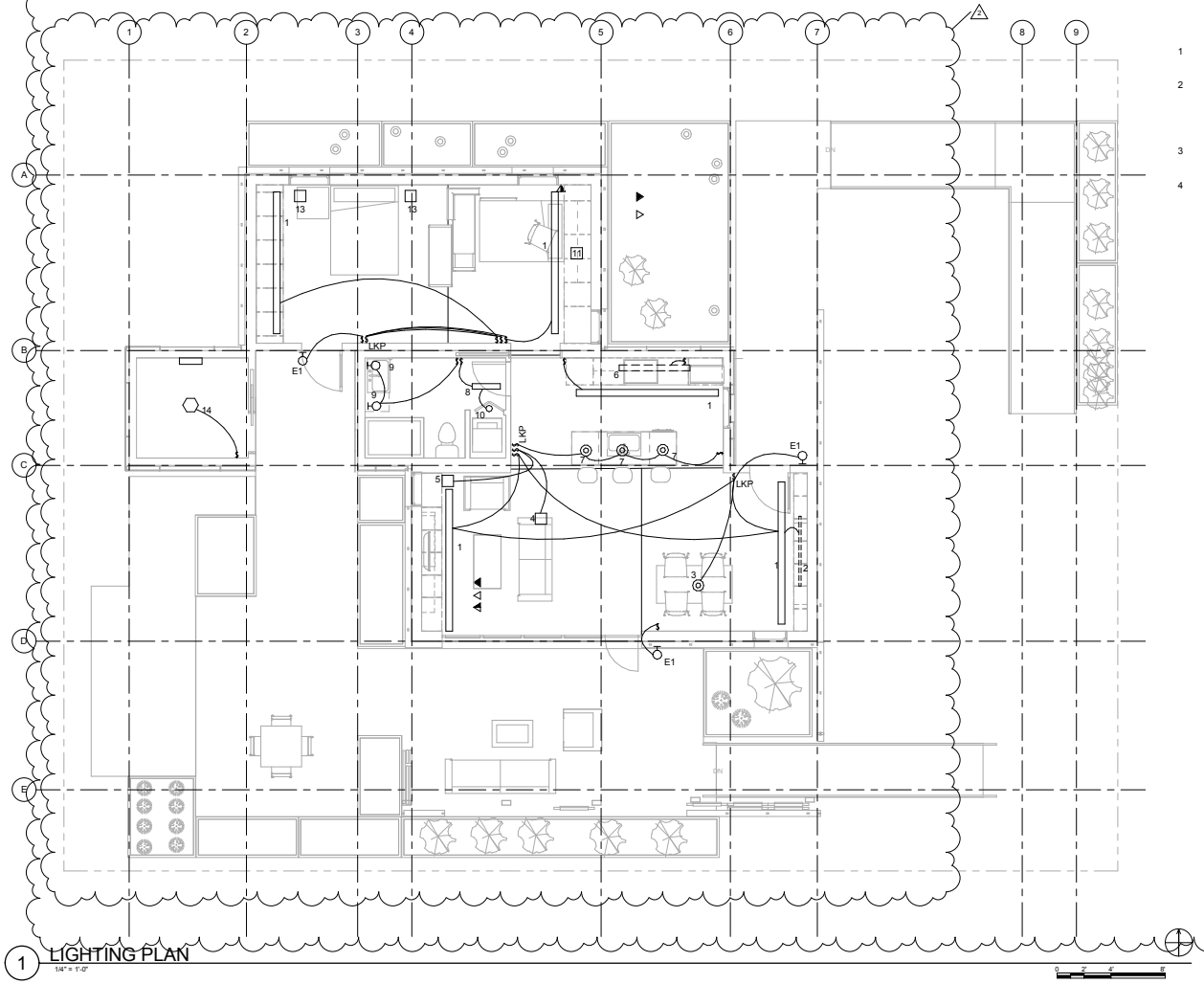
PV WIRING PLAN

MAY 11, 2015

E-102



1 LIGHTING PLAN
1/4" = 1'-0"

GENERAL NOTES (LIGHTING PLAN)

1 EXTERIOR LIGHTING OUTLETS INCLUDED AS DICTATED BY NEC 210.70(A)(2)(b)

2 ALL LIGHTING FIXTURES WILL BE CONTROLLED BY THE MANUAL LUTRON DIMMER SWITCHES SHOWN WHICH ARE REMOTE-CONTROLLABLE (IN WIRELESS COMMUNICATION WITH LUTRON CONTROL SYSTEM).

3 ALL LIGHTING FIXTURES WITH WIRING NOT SHOWN SHALL BE POWERED BY INSTALLED WALL RECEPTACLES.

4 FIXTURE TAGS CORRESPOND TO LUMINAIRE SCHEDULE ON SHEET E-603

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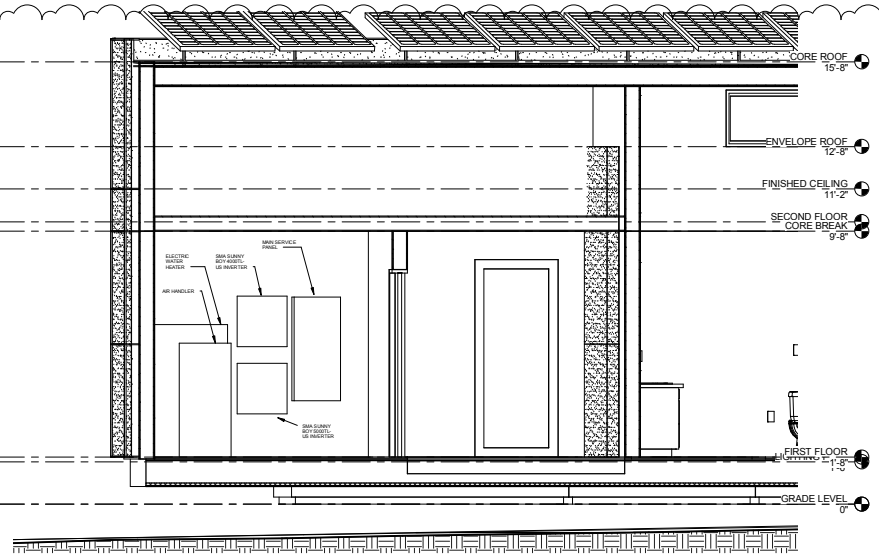
SHEET TITLE
LIGHTING PLAN

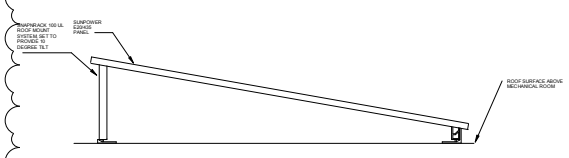
MAY 11, 2015

E-103



3 ELEVATION MECHANICAL ROOM (FROM NORTH)

1/2" = 1'-0"



1 ROOFTOP PV RACKING DETAIL (FROM WEST)

1" = 1'-0"

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ELECTRICAL ELEVATIONS

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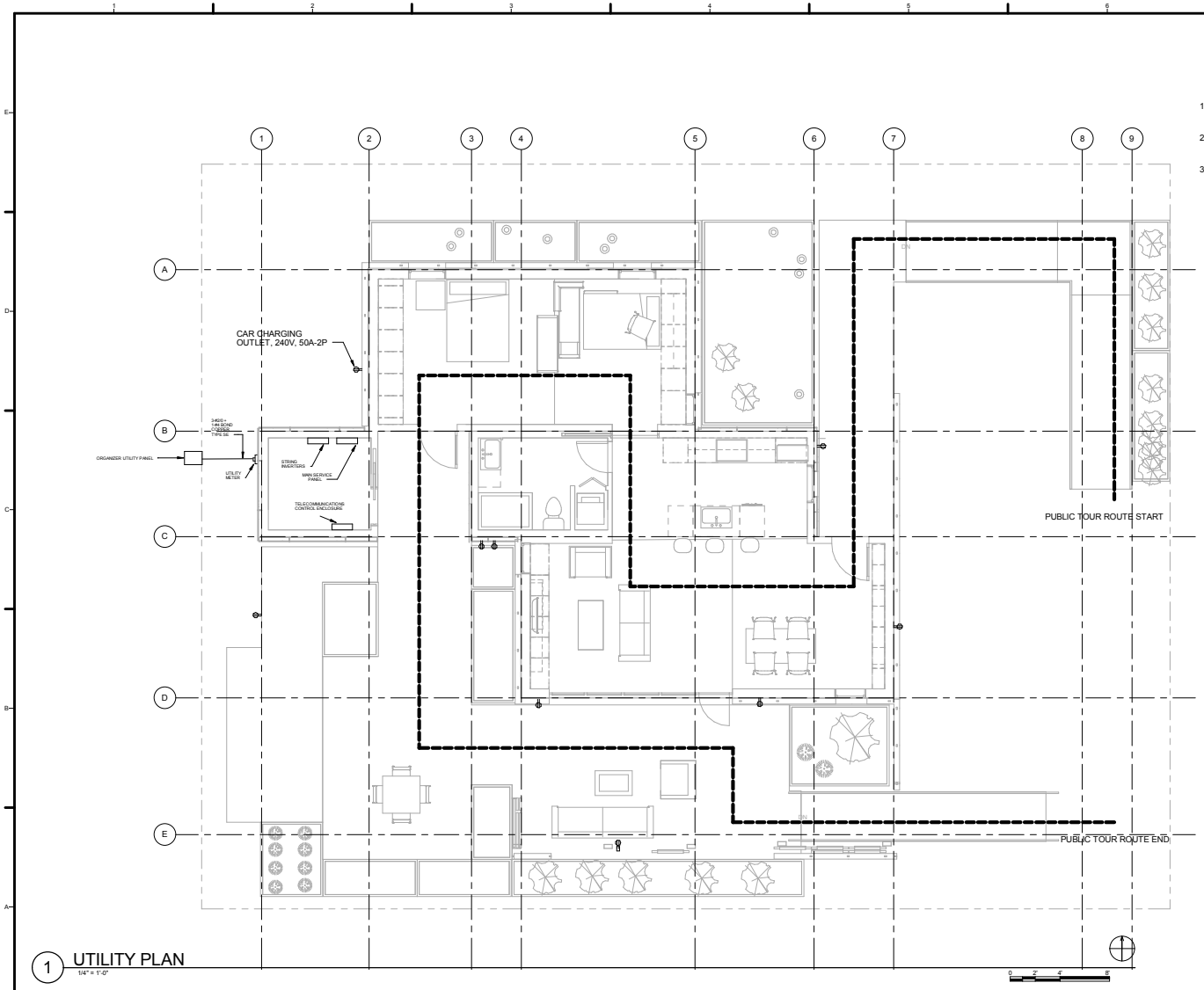
E-201



1 UTILITY PLAN
1/4" = 1'-0"

GENERAL NOTES (SITE PLAN)

1 ALL CABLE ROUTING SHALL AVOID TOUR ROUTES AND OTHER WALKWAYS.

2 UTILITY PANEL AND GRID INTERCONNECTION TO BE DETERMINED BY ORGANIZER.

3 AC AND DC DISCONNECTS ARE INTEGRATED INTO INVERTER ENCLOSURE.

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SITE PLAN

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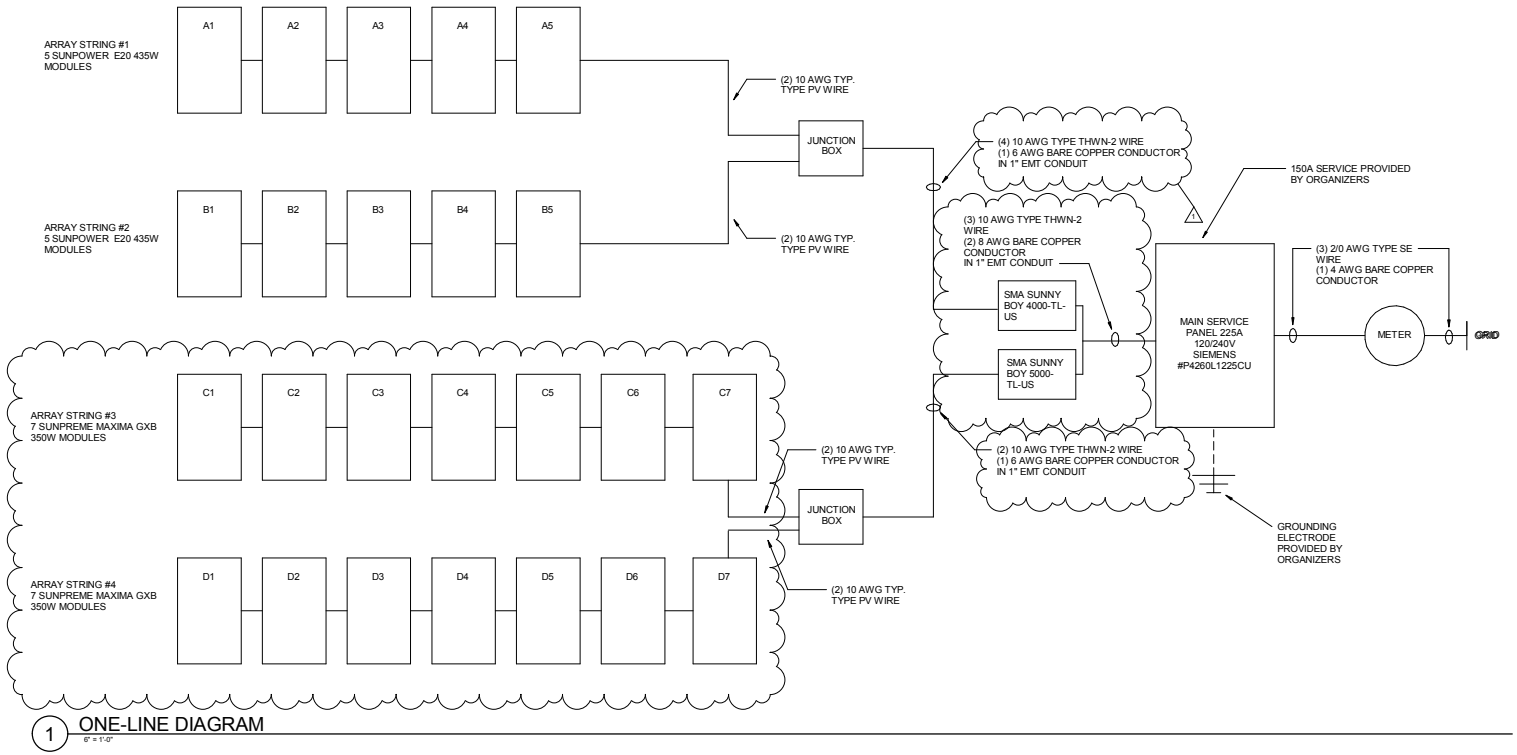
E-401



1 ONE-LINE DIAGRAM
6" = 1'-0"

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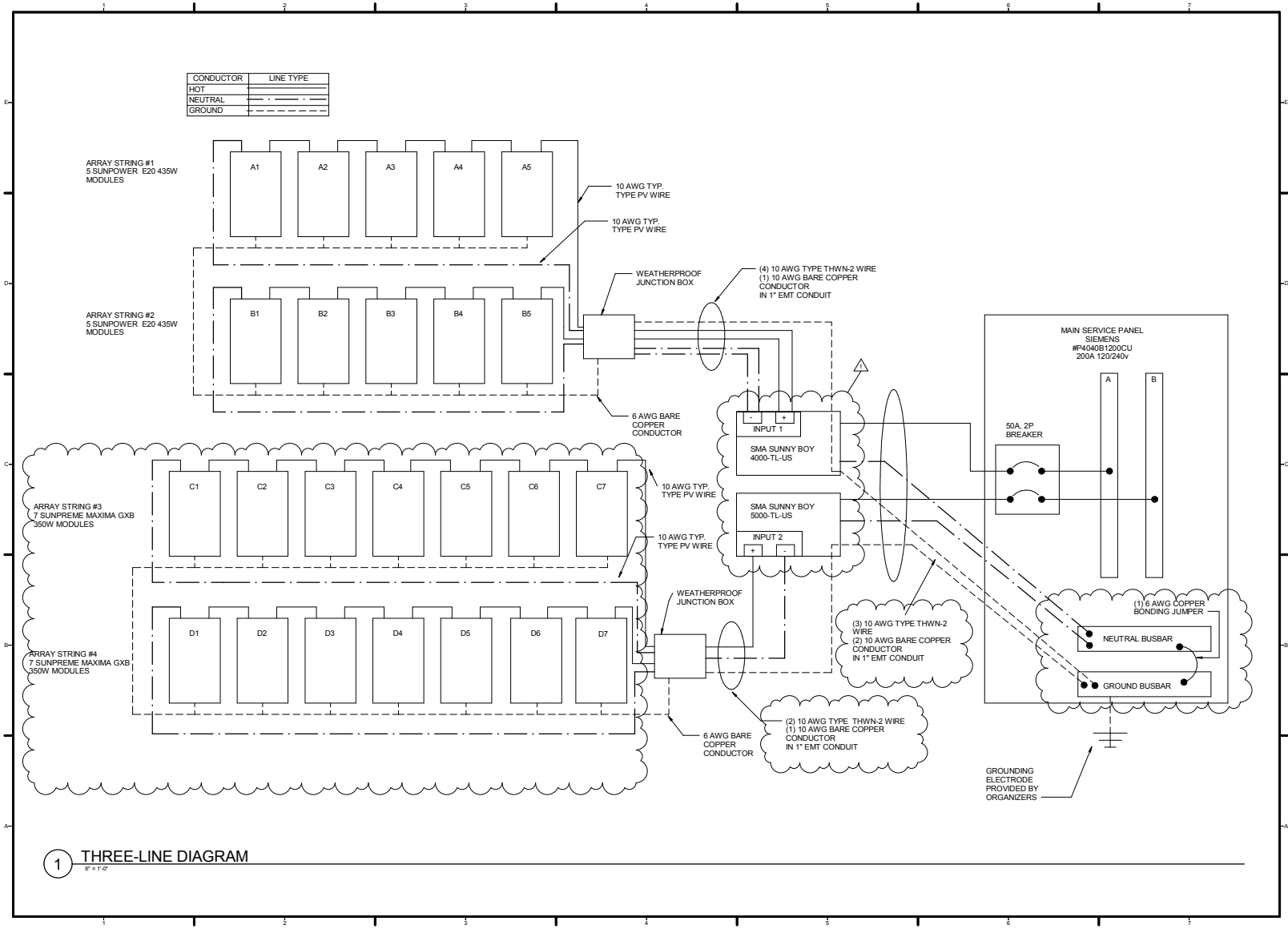
ONE-LINE DIAGRAM

MAY 11, 2015

E-601



1 THREE-LINE DIAGRAM
6" = 1'-0"

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SHEET TITLE
THREE-LINE DIAGRAM

MAY 11, 2015

E-602

PANEL SCHEDULE

BREAKER LOAD	A (KVA)	B (KVA)	BREAKER	CIRCUIT
DRYER/WASHER	5	0	50A-1P	1
DISHWASHER	0	1.08	20A-1P	2
REFRIGERATOR	1.35	0	20A-1P	3
INDUCTION STOVE	0	2.9	50A-2P	4
	2.9	0		5
EWH SOLAR WATER HEATER	0	3.6	50A-2P	6
	3.6	0		7
KITCHEN RECEPS 1	0	1.5	20A-1P	8
KITCHEN RECEPS 2	0	1.5	20A-1P	9
LIVING RECEPS	0	0.54	20A-1P	10
DINING RECEPS 1	1.5	0	20A-1P	11
DINING RECEPS 2	0	1.5	20A-1P	12
BATHROOM RECEPS	0	0.36	20A-1P	13
BEDROOM RECEPS 1	0	0.9	20A-1P	14
BEDROOM RECEPS 2	0.54	0	20A-1P	15
MECHANICAL RECEPS	0	0.18	20A-1P	16
ENTRY RECEPS	0	0.36	20A-1P	17
EXTERIOR RECEPS	0	0.54	20A-1P	18
GREY WATER PUMP RECEP	0	0.23	20A-1P	19
BLACK WATER PUMP RECEP	0	0.23	20A-1P	20
THERMAL LOOP PUMP RECEP	0	0.1	20A-1P	21
WATER SUPPLY PUMP RECEP	0	0.34	20A-1P	22
WATER SUPPLY BOOSTER PUMP RECEP	0	0.373	20A-2P	25
	0.373	0		26
VEHICLE CHARGIING RECEP	0	3.6	50A-2P	27
	3.6	0		28
HEAT PUMP RECEP	1.725	0	20A-2P	29
	0	1.725		30
AIR HANDLER RECEP	0.322	0	20A-2P	31
	0	0.322		32
LIGHTING 1	1.57	0	15A-1P	33
LIGHTING 2	0	1.57	15A-1P	34
FIRE ALARM CIRCUIT	0	0.03	15A-1P	35
PV INVERTER 1	2.1	0	50A-2P	36
	0	2.1		37
PV INVERTER 2	2.65	0	50A-2P	38
	0	2.65		39
SPARE				40
SPARE				41
SPARE				42
PHASE A	22.48			
PHASE B		23.48		
TOTAL KVA		45.96		

PV SYSTEM SCHEDULE

SHORT ARRAY DESCRIPTION	PANEL OPEN CIRCUIT VOLTAGE (V)	STRING OPEN CIRCUIT VOLTAGE (V)	STRING OPEN CIRCUIT VOLTAGE @ MIN T FOR IRVINE REGION (V)	INVERTER	MAX INVERTER DC INPUT VOLTAGE (V)	MAX INVERTER AC CURRENT OUT (A)	COMMENTS
10 SUNPOWER E20/435, ROOFTOP	85.6	428	455.1	SMA SUNNY BOY 4000TL-US	600	20	
14 SUNPREME MAXIMA GXB 350W, CANOPY	51.7	361.9	380.2	SMA SUNNY BOY 5000TL-US	600	22	ASSUMING STC RATING (NO BACKSIDE IRRADIANCE)

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SCHEDULES

MAY 11, 2015

E-603

LIGHTING FIXTURE SCHEDULE						
ITEM NUMBER	DESCRIPTION	MANUFACTURER	QTY	MODEL NUMBER	FINISH	LAMP
	EXTERIOR LIGHTING					
E1	MINI-MICRO™ TWIN CYLINDER SOLID STATE...	BK LIGHTING	3			
E1 ALT	CATSKILL SERIES™ SOLID STATE (BKSSL®)					
	INTERIOR LIGHTING					
1	BOOKEND WALL WASH 2SE-WG-1 WALLWASH MIRAGE	LUCIFER LIGHTING	18	FIXTURE EXTENSION MODEL NUMBER: 2SE-WG-1-WH-95X-07B-30-2 -I-1; HOUSING EX. MODEL...	WHITE	LED SOURCE 95+ CRI 3000 K
2	FEATURE LIGHT - DEPENDENT ON LIGHTING BUDGET	COLOR KINETICS/...				
3	DINING PENDENT GLIDE WOOD LINEAR SUSPENSION HTTP://WWW.LIGHTOLOGY.COM/INDEX.PHP?MODULE=PROD_DETAIL&PROD_ID=167539&CAT_ID=109	EDGE LIGHTING	1	GL-D1-C-60IN-27K-WE-SN EDG201138	WOOD ESPRESSO/ SATIN NICKEL	LED 3000K, 82CRI LEDS
3 ALT	DINING PENDENT STILETTO 32"" LED PENDENT HTTP://SHOP.FERGUSON.COM/PRODUCT/SONNEMAN-LIGHTING-SON2346-SATIN-BLACK-848092?TB=	SONNEMAN	1	S234625	SATIN BLACK	LED 1050 LUMENS 3000 K 80 CRI DIMMABLE BY ELV
4	READING LAMP IN LIVING ROOM SALFORD FLOOR LAMP HTTP://WWW.LIGHTOLOGY.COM/INDEX.PHP?MODULE=PROD_DETAIL&PROD_ID=213498&CAT_ID=43	DIAMOND LIGHTING	1	D2121-LED DMD213498	SATIN NICKEL/ WHITE	LED 1 X A19/MEDIUM (E26)/9.5W/120V NOT DIMMABLE 900 LUMENS 3000K...
5	BAR PENDENTS GRAPES LED PENDANT W/ MICRO - DOME CANOPY DIMENSIONS: LRG: 3 3/4"" H X 3 3/4"" DIA HTTP://WWW.SONNEMANAWAYOFLIGHT.COM/GRAPESLARGELEDPENDANTWMICRODOME-P-987.HTML	SONNEMAN	3	2910.01-LRG	SATIN NICKEL	LED 3000K 80CRI LUMENS/WATT: 40.91
5 ALT	CANDLE PLUS LED PENDENT HTTP://WWW.SONNEMANAWAYOFLIGHT.COM/CANDLEPLUSLEDPENDANT-P-287.HTML	SONNEMAN	3	3025.01	POLISHED CHROME / WHITE &...	LED 80 CRI 3000K
6	VODE WING RAIL ZIPPER CLEAR LENS 8FT (TOTAL); HTTP://VODE.COM/WINGRAIL-CEILING-WALL-ARM-LED-107	VODE LIGHTING	1	107-WG-01-4-48-WA-24-IP-?? POWER TYPE [LUTRON QUESTION]-1-0-Z-SO-30-0-0-WH-0	WHITE PAINTED	LED 3000K
7	UNDER CABINET KITCHEN LIGHTING WUNDERCAB HTTP://WWW.BRUCKLIGHTING.COM/PRODUCTS/LIGHTS/LINEAR-SYSTEMS/123456-UNDERCAB-DETAIL	BRUCK	3 (24.17" EACH)	138 - 544 - WH - 3 DIRECT WIRE (138521WH) 6"" FLEXIBLE CONNECTOR	WHITE	LED SDCM OF 3 IN 3000 KELVIN FOR 250 LUMENS PER FOOT
7 ALT	UNDER CABINET KITCHEN LIGHTING; HTTP://WWW.ACUITYBRANDS.COM/PRODUCTS/DETAIL/122065/LITHONIA-LIGHTING/LINKABLE-LED-CABI...	LITHONIA	3	UCLD-24-WH DIRECT WIRE UCD JB SPLICE BOX - ALLOWS FOR QUICK AND...	WHITE	LED, 3000K, COMES WITH DIMMABLE DRIVER [LUTRON COMPATIBLE] 83 CRI
8	TRACK LIGHTING STEP BAFFLE BR20 LED TRACK HTTP://WWW.ACUITYBRANDS.COM/PRODUCTS/DETAIL/248474/LITHONIA-LIGHTING/STEP-BAFFLE-BR20-LED-TRACK/LED-LAMP-HEAD/	ACUITY BRANDS LIGHTING	1	HEAD: LTHSTBF BR20 LED KIT: LTKSTBF BR20 LED	MATTE WHITE	LED LUMEN OUTPUT : 500 LM, 850 LM 2700 K 80 CRI HIGH EFFICIENCY INTEGRAL DRIVER 110-120VAC.
9	MIRROR LIGHTS STILETTO 24-INCH LED BATH BAR HTTP://WWW.YLIGHTING.COM/CUTSHEETS/SONNE...	SONNEMAN	2	2340- STILETTO 24-INCH	BRIGHT SATIN ALUMINUM	LED 3000K 80 CRI...
10	LAUNDRY LIGHT 6"" LED GIMBAL MODULE HTTP://WWW.ACUITYBRANDS.COM/PRODUCTS/DETAIL/196907/LITHONIA-LIGHTING/6-GIMBAL-LED-MODULES/LED-INGRADE-CANS	ACUITY BRANDS LIGHTING	1	6G1MW LED L7XLED T24	MATTE WHITE	GIMBAL LED MODULES 3000 K LUMEN OUTPUT: 620 LM
11	DESK LIGHT IN FLEX SPACE FLEX LED DESK LAMP HTTP://WWW.CIELUX.COM/PRODUCTS/FLEX.PHP	CIELUX	1	FLEX - BK - BA	BLACK	LED 3200 K INPUT VOLTAGE: 24 VDC
12	BEDSIDE LAMP CERNO ALO TABLE LIGHT - DESIGNER IS A CAL POLY GRAD!!! HTTP://WWW.OLIGHTING.COM/CERNO-ALO-TABLE-LIGHT.HTML...	CERNO	2	CERNO-ALO-TABLE-LIGHT 02-130-AWW	BRUSHED ALUMINUM AND CONCRETE	LED 3000 K 420 LUMENS 82 CRI FULLY DIMMABLE, NO FLICKER
13	MECHANICAL ROOM LIGHT; LITHONIA 2FT WRAP AROUNDLED ; HTTP://WWW.ACUITYBRANDS.COM/PRODUCTS/DETAIL/347674/LITHONIA-LIGHTING/LBL-LED/LB-SERIES-CONFIGURABLE-LED-WRAPAROUND/-/MEDIA/PRODUCTS/LITHONIA_LIGHTING/347674/DOCUMENT/LBL...	LITHONIA	1	LBL2LP835	WHITE	3500K
13 ALT	MECHANICAL ROOM LIGHT; LITHONIA 4FT WRAP AROUNDLED ; HTTP://WWW.ACUITYBRANDS.COM/PRODUCTS/DETAIL/347674/LITHONIA-LIGHTING/LBL-LED/LB-SERIES-...	LITHONIA	1	LBL4LP835	WHITE	3500K

<LIGHTING FIXTURE SCHEDULE CONTINUED>					
ITEM NUMBER	WATTS	TOTAL WATTS	VOLTS	COMMENTS	REP
	EXTERIOR LIGHTING				
E1					
E1 ALT					
	INTERIOR LIGHTING				
1	9.2	165.6	120	PUBLIC SPACE FLEX SPACE	PRUDENTIAL LIGHTING PRODUCTS SANTA BARBRA (805) 715-6400
2					
3	37.5	37.5	24	DINING ROOM	FERGUSON SAN LUIS OBISPO TIM WEST (805) 541-2241
3 ALT	12	12	120VAC INPUT WITH...	DINING ROOM	FERGUSON SAN LUIS OBISPO TIM WEST...
4	9.5	9.5	120	LIVING ROOM	
5	6	16	120	KITCHEN	FERGUSON SAN LUIS OBISPO TIM WEST (805) 541-2241
5 ALT	5	15	120	KITCHEN	FERGUSON SAN LUIS OBISPO TIM WEST...
6	26.8	26.8	120	KITCHEN-ABOVE CABINETS	ALR LIGHTING
7	8	24	120	KITCHEN	FERGUSON SAN LUIS OBISPO TIM WEST (805) 541-2241
7 ALT	11.8	35.4	120		
8	8	8	120	BATHROOM	FERGUSON SAN LUIS OBISPO TIM WEST (805) 541-2241
9	8	16	120	BATHROOM	FERGUSON SAN LUIS OBISPO TIM WEST (805) 541-2241
10	10.8	10.8	120	BATHROOM	FERGUSON SAN LUIS OBISPO TIM WEST (805) 541-2241
11	13	13	100-240 VAC	FLEX SPACE	RICHMOND, CALIFORNIA (510) 620-5154
12	8.3	16.6	12	FLEX SPACE	
13	23	23	120	MECHANICAL ROOM	HOME DEPOT
13 ALT	41	41	120	MECHANICAL ROOM	HOME DEPOT
	TOTAL (NOT...	368.8			

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SHEET TITLE
LUMINAIRE SCHEDULE

MAY 11, 2015

E-604

ELECTRICAL LOAD CALCULATIONS					
	VOLTAGE (V)	RATING (VA)		TOTAL (VA)	NOTES
GENERAL LOADS					220.82(B)
LIGHTING AND GENERAL USE				3137.67	1045.87 SQFT x 3VA/SQFT
SMALL APPLIANCES				3000	2 x 1500VA/CRCT
LAUNDRY CIRCUIT				1500	1 x 1500VA/CRCT
DISHWASHER	120	1800		1800	
ELECTRIC WATER HEATER	240	7200		7200	
DRYER/WASHER	120	1440		1440	
COOKTOP	240	5800		5800	
REFRIDGERATOR	120	1800		1800	
MICROWAVE	120	1080		1080	
BATHROOM VENT	120	36.2		36.2	
KITCHEN FUME HOOD	120	180		180	
BLACK WATER PUMP	120	230		230	
GREY WATER PUMP	120	230		230	
WATER SUPPLY PUMP	120	250		250	
WATER SUPPLY BOOSTER PUMP	240	746		746	
SOLAR THERMAL CIRCULATION PUMP	120	63		63	
			GENERAL LOAD SUBTOTAL	28492.81	
			FIRST 10 KVA AT 100%	10000	
			REMAINDER AT 40%	7397.12	
			NET GENERAL LOAD TOTAL	17397.12	
ELECTRICAL VEHICLE CHARGING LOADS					625.41(B)
CHARGING STATION	240	7200		7200	
HEATING AND AIR CONDITIONING LOADS					220.82(C)
HEAT RECOVERY VENTILATOR	240	204		204	
HEAT PUMP	240	3450		3450	
AIR HANDLER	240	920		644	
			HVAC LOAD SUBTOTAL	4298	
FEEDER LOAD TOTAL				28895.12	FEEDER LOAD CURRENT:121 A
NEUTRAL LOAD					220.61
LIGHTING AND GENERAL USE				1570	
DISHWASHER				1080	
COOKTOP				2520	220.61(B)
PUMPS				2998	
VEHICLE CHARGING				3600	
AIR HANDLER				323	
FIRE ALARM				30	
NUETRAL LOAD TOTAL				11041	NEUTRAL LOAD CURRENT: 92 A

1

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ELECTRICAL LOAD CALCULATIONS

MAY 11, 2015

E-605

U.S. DEPARTMENT OF ENERGY
SOLAR DECATHLON

RULES

Last Updated: September 23, 2014

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SECTION I: DEFINITIONS

Assembly
The period of time between the allowed arrival of trucks on site and the beginning of the contests on the competition site

Communications manager
The organizer responsible for the project's public outreach and communications activities

Communications materials
All printed or electronic publications designed to convey information to the public

Competition
All aspects of the Solar Decathlon related to the contests and the scoring of those contests

Competition manager
The organizer responsible for writing and enforcing the rules and conducting a fair and compelling competition

Competition prototype
The complete assembly of physical components installed within the solar envelope

Competition site
The area provided by the organizers containing all solar envelopes, pedestrian walkways, and associated organizer equipment, structures, and infrastructure

Contest
The Solar Decathlon competition consists of 10 separately scored contests

Contest official
An organizer selected by the competition manager to officiate one or more of the contests; a contest official is only authorized to interpret the rules of the contest(s) to which he or she is assigned

Contest week
The 9-day period on the competition site when some or all contests are in progress

Decathlete
A team member who meets the decathlete eligibility rules outlined in the file posted in the "/Files/Rules" folder on the Yahoo Group

Decision
The rules officials' interpretation or clarification of a rule

Decisions on the Solar Decathlon Rules
The compilation of all decisions made by the rules officials during the project

Director
The organizer representing the U.S. Department of Energy who has final decision-making authority regarding all aspects of the project

Disassembly
The period of time between the closing of the public exhibit and the completion of competition site cleanup; Rule 8-2 does not apply during disassembly

Event
The activities that take place on the competition site including, but not limited to, registration, assembly, inspections, contests, special events, public exhibits, and disassembly

Event production manager
The organizer responsible for the project's special events and volunteer activities who is also considered a rules official

Event sponsor
An entity selected by the director to support the Solar Decathlon—a project of the U.S. Department of Energy (DOE), which partners with other institutions, such as its National Renewable Energy Laboratory (NREL), to help ensure the success of the project

Faculty advisor
A team member who is the lead faculty member and primary representative of a participating school in the project; also provides guidance to the team on an as-needed basis throughout the project

Grid-tie assembly
The period of time during assembly after the house has been connected to the village grid (interconnected); Rule 8-2 applies during grid-tie assembly

Interconnection application
Submitted in the project manual by the team's electrical engineer, this form provides the technical details needed to determine the suitability of the team's electrical system for interconnection to the village grid

Juried contest
A contest based on a jury evaluation

Juror
An organizer selected by the director to make subjective evaluations of specific aspects of each team's competition prototype

Jury
A group of jurors evaluating a specific aspect of each team's competition prototype

Measured subcontest
A subcontest based on task completion or monitored performance

Observer
An organizer, assigned by the competition manager to observe team activities during contest week, who reports observed rules infractions to the rules officials and records the results of specific contest tasks, but does not provide interpretations of the rules

Organizer
A DOE or NREL employee, subcontractor, juror or observer working on the project

Project
All activities related to the U.S. Department of Energy Solar Decathlon 2015—from the issuance of the request for proposals through the closing of subcontracts

Protest resolution committee
A group of three organizers selected by the director to resolve team protests during the competition

Public exhibit
Areas of the competition site open to the public during designated hours

Qualified Electrical Worker
A team member who has met OSHA 29 CFR Part 1910, Subpart S Electrical 1910.399 requirements for qualified electrical work on the competition site; only qualified electrical workers will be permitted to work on teams' electrical systems on the competition site

Rule
A principle or regulation governing conduct, action, procedure, arrangement, etc., for the duration of the project

Rules official
An organizer authorized to interpret the rules; the competition manager is the lead rules official

Safety officer
An organizer whose primary responsibilities are to evaluate the teams' construction documents and the teams' competition site activities for compliance with Rule 3-3

Scored period
Any 15-minute period beginning at 0, 15, 30, or 45 minutes after the hour during which a particular monitored contest is in progress

Scorekeeper
An organizer selected by the competition manager to operate the scoring server during the competition

Scoring server
A server that collects data from the central datalogger server and calculates composite scores; includes forms for manually entering juried and task-based measured contest results

Site operations manager
The organizer responsible for all event site operations, such as implementation and management of the village grid and movement of construction vehicles, except those listed as responsibilities of the competition manager and event production manager

Solar Decathlon Building Code
A set of design and construction standards set forth and enforced by the Solar Decathlon building official for the protection of public health and safety during the event

Solar Decathlon building official
The rules official responsible for writing, interpreting, and enforcing the Solar Decathlon Building Code

Solar envelope
The area, as defined by Rule 5, containing the competition prototype

Stand-alone assembly
The period of time during assembly before the house has been interconnected to the village grid; Rule 8-2 does not apply during stand-alone assembly

Staff
An individual working for the organizers on the project whose role is not described elsewhere in these definitions.

Subcontest
An individually scored element within a contest

Team
The combination of team members, including team crew and decathletes, representing a single entry to the competition

Team crew
A team member who is involved with a team's project who may be unaffiliated with a participating school; school staff, contractors, volunteers, team media, and sponsors represent team crew examples

Team member
An enrolled student, recent graduate, faculty member, or other person who is affiliated with one of the participating schools and is integrally involved with a team's project activities; decathletes, faculty advisors, and team crew are all considered team members

Village grid

The bi-directional, 60-hz AC electrical network on the competition site to which each house has an individually metered connection

Volunteer

An individual selected by the volunteer coordinator to support activities on the competition site but who is not affiliated with a team and whose role is not described elsewhere in these definitions

Volunteer coordinator

An organizer selected by the event production manager to manage volunteer activities on the competition site

Yahoo Group

A community website that includes official communications suitable for viewing by all teams and organizers

SECTION II: GENERAL RULES

Rule 1. Authority

1-1. Director

The director represents the U.S. Department of Energy and has the final decision-making authority in all aspects of the project.

1-2. Competition Manager

The competition manager is the only rules official authorized to write and modify the rules.

1-3. Rules Officials

The rules officials are the only organizers authorized to interpret the rules. Each rules official is authorized to revise the project schedule, change a team's score, and enforce the rules in any manner that is, in his or her sole judgment, required for the fair and efficient operation or safety of the competition.

a. If there is any doubt or ambiguity as to the wording or intent of these rules, the decision of the rules officials shall prevail.

b. Printed, electronic, and verbal communications from the rules officials shall be considered part of, and shall have the same validity as, these rules.

1-4. Staff

Solar Decathlon staff are not authorized to revise the project schedule, change a team's score, or enforce the rules under any circumstances.

Rule 2. Administration

2-1. Precedence

If there is a conflict between two or more rules, the rule having the later date takes precedence.

2-2. Violations of Intent

A violation of the intent of a rule is considered a violation of the rule itself.

2-3. Effective Date

The latest version of the rules posted in the "/Files/Rules" folder on the Yahoo Group[1] and dated for the year of the event represents the rules in effect.

2-4. Official Communications

It is the team's responsibility to stay current with official project communications. Official communications between the teams and the organizers occur through, but are not limited to, one or more of the following:

a. **Yahoo Group** (http://groups.yahoo.com/group/SD2015): Official communications suitable for viewing by all teams and organizers are posted on the Yahoo Group message board. The Yahoo Group includes a section for posting files. If files are too large for the Yahoo Group, they are posted on the FTP site or in the uplink, and the teams are notified of the exact location of file(s) via the Yahoo Group. Other Yahoo Group features are used for various purposes. Instructions for joining the Yahoo Group are provided to each team immediately following the selection of teams.

[1] Members of the public without access to the Yahoo Group who are interested in receiving the rules and any documents referenced by the rules may email a request to the competition manager at sdrules@nrel.gov.

b. **Competition manager's email** (sdrules@nrel.gov): For confidential communications or the transfer of small (<5 MB), confidential files, teams may email the competition manager. The content of communications sent to this email address remains confidential, unless the team grants permission to the competition manager to divulge the content of these communications to the other teams. See the exception in Rule 2-5 for more information about confidentiality.

c. **Uplink** (http://hightail.com/u/solardecathlon): The uplink is used by the organizers and teams to transfer large or confidential files. Notification of or requests for file transfers are made via the Yahoo Group or email.

d. **Conference calls**: Teams are expected to participate in regularly scheduled conference calls with the organizers. Invitations and instructions for participation in conference calls are provided via the Yahoo Group.

e. **Meetings**: Before the event, the teams and organizers have one or more in-person meetings. Notification of the date(s) and agenda(s) for these meetings is made via the Yahoo Group. A meeting is held the day before assembly begins. Meetings are also held on a daily basis throughout the event.

f. **Email**: For expediency and to protect confidentiality, the organizers may choose to communicate with teams via team members' email addresses listed in the Yahoo Group database. However, most official communication occurs via the Yahoo Group message board.

2-5. Decisions on the Rules

The Decisions on the Rules database on the Yahoo Group offers interpretations of the rules contained in this document, the Solar Decathlon Rules.

After the rules officials make a decision that may, in their opinion, directly or indirectly affect the strategies of all teams, the rules officials add the decision to the Decisions on the Rules and notify the teams of the addition via the Yahoo Group.

Exception: If such a notification would unfairly reveal the strategies of one or more individual teams, the organizers may, depending on the circumstances, refrain from notifying all teams of the decision.

2-6. Self-Reporting

Teams shall self-report obvious or suspected rules infractions that have occurred or may occur.

a. The Solar Decathlon Rules do not address every possible scenario that may arise during the competition. Therefore, a team considering an action that is not explicitly permitted by the rules should ask the rules officials for a decision before proceeding with the action. If the team does not ask for an official decision, it puts itself at risk of incurring a penalty.

b. The rules officials and director exercise discretion when determining the penalty for a rules infraction. Rules infractions observed by rules officials, organizers, or other teams that are not self-reported by the team committing the infraction may be subject to more severe penalties than self-reported rules infractions.

2-7. Penalties

Teams committing rules infractions are subject to one or more of the following penalties, depending on the severity of the infraction: 1) point penalty applied to one or more contests; 2) disqualification from part, or all, of one or more subcontests; or 3) disqualification from the competition.

a. The rules officials shall determine the severity of rules infractions and classify them as **minor** or **major**.

b. The rules officials are authorized to apply point penalties and disqualify a team from part, or all, of one or more subcontests as a consequence of **minor** rules infractions.

c. The rules officials shall report to the director all **major** rules infractions. The director is solely authorized to apply point penalties or disqualify a team from the competition or from part, or all, of one or more subcontests for **major** rules infractions.

d. Disqualification from the competition requires prior notice to the team and an opportunity for the team to make an oral or written statement on its behalf.

e. The competition manager shall notify all teams via the Yahoo Group and update the scoring server when a penalty has been assessed against any team. The notification shall include the identity of the team receiving the penalty; an indication of the specific rule violation; a brief description of the infraction, including its severity; and the penalty to be applied.

2-8. Protests

a. Official written protests may be filed by a team for any reason during the contest week. A filing fee of up to 10 points may be assessed to the team filing the protest if the protest is deemed by the protest resolution committee to be frivolous.

b. Teams are encouraged to communicate with the rules officials to resolve issues and complaints before resorting to the protest process. Protests should be filed only if a) the team and the rules officials are unable to resolve the dispute themselves; or b) the team or the rules officials are too busy to engage in discussions that may result in resolution of the dispute without a protest.

c. Protests shall be submitted between 8 a.m. and 6 p.m., and within 24 hours of the action being protested. The final opportunity to file a protest is 5 p.m. Pacific Time on the final day of contest week.

d. **Exception**: The results of one or more contests or subcontests may be announced during the final awards ceremony. The results of contests or subcontests announced during the final awards ceremony may not be protested.

e. The protest shall be submitted to a rules official in a sealed envelope or emailed to the competition manager at sdrules@nrel.gov. If submitted electronically, the protest shall be attached as a PDF to the email and the email subject should include "Solar Decathlon 2015 Protest" and the name of the team submitting the protest. The protest shall include the name and signature of a decathlete, the date of the protest submission, an acknowledgment that a 10-point filing fee may be assessed, and a clear description of the action being protested.

f. Following the receipt of a protest, the protest resolution procedure will occur as follows:

   i. The competition manager convenes the protest resolution committee.

   ii. The competition manager submits the team's protest to the committee. Unless the competition manager is called by the committee to testify, the competition manager is not permitted to read the protest until after the protest resolution committee has submitted its written decision.

   iii. The committee reads the protest in private. No appearance by the competition manager, rules officials, or team members is authorized during the committee's private deliberations. No right to counsel by organizers or team members is authorized.

   iv. The committee shall call the decathlete who submitted the protest for testimony to fully understand the protest. The committee may choose to call additional individuals for testimony, including the competition manager, after speaking with the decathlete who filed the protest.

   v. Testimony is provided by individuals called by the committee.

   vi. The committee notifies the competition manager of its decision in writing and indicates how many points shall be assessed as a filing fee, if any. The decision of the committee is final and no further appeals are allowed. The director may not modify the decision of the committee.

   vii. If the decision involves changes to a team's score or the assessment of a filing fee, the competition manager notifies the scorekeeper of the changes, and the scorekeeper applies the changes to the scoring server.

   viii. The competition manager posts a copy of the written protest and decision on the Yahoo Group.

Rule 3. Participation

3-1. Entry

The project is open to colleges, universities, and other post-secondary educational institutions. Entry is determined through a proposal process. All proposals are reviewed, scored, and ranked. Subject to the quantity and quality of proposals, a limited number of teams will be selected for entry.

3-2. Contact Information

Each team shall provide contact information via the Yahoo Group for the team officers listed in Table 1 and shall keep the contact information current for the duration of the project.

a. If a team's internal officer titles do not exactly match those listed in Table 1, each team shall still provide the contact information for the person fulfilling each of the areas of responsibility described in the second column.
b. Teams shall provide the contact information for only one person in each officer position; these individuals are responsible for forwarding information to any "co-officers," as necessary.
c. An individual may have multiple officer titles; however, the same individual may not fulfill the project manager, construction manager, or health and safety officer roles.
d. Teams shall enter required contact information into the "Team Officer Contact Info" Yahoo Group database.
e. Faculty members are only eligible to fill the "faculty advisor" team officer position. Decathletes must fill all other team officer positions.

Table 1: Team officers

Title	Responsibilities
Primary student contact	Ensures that official communications from the organizers are routed to the appropriate team member(s)
Project manager	Responsible for planning and executing the project and ultimately responsible for the overall health and safety of the project
Public relations contact	Works in conjunction with DOE's Public Affairs office to coordinate the team's interactions with the media
Construction manager	Responsible for planning and executing the construction, transport, assembly, and disassembly of the house, including providing the necessary oversight on construction activities to ensure that construction work is performed in compliance with the Health and Safety Plan
Architecture project manager	Responsible for the architectural design effort; license not required
Project engineer	Responsible for the engineering design effort; license not required
Measured contest captain	Serves as the primary strategist and coordinator of tasks in Contests 6 through 10; is responsible for demonstrating the compliance of appliances with the Rules
Health and safety officer	Responsible for developing the team's Health and Safety Plan, for providing health and safety oversight to the project and advising the project manager and construction manager, as necessary, on project health and safety issues; responsible for the team's life safety during the event, including the fire watch, public safety within the team's solar envelope, and evacuation procedures
Instrumentation contact	Collaborates with the organizers' instrumentation team and the team's construction manager to accommodate the organizers' equipment
Electrical engineer	Completes the Interconnection Application and works in conjunction with the site operations manager to interconnect the house to the village grid on the competition site; license not required
Faculty advisor	Serves as the lead faculty member and primary representative of a participating school in the project; also provides guidance to the team throughout the project
Sponsorship manager	Responsible for recruiting team sponsors and for team compliance with Rule 10-3

3-3. Safety

Each team is responsible for the safety of its operations.

a. Each team member and team crew member shall work in a safe manner at all times during the project in accordance with the requirements identified in the rules and approved team Health and Safety Plan.
b. Each team shall supply all necessary personal protective equipment (PPE) and safety equipment for all of the team's workers during the project.

c. During assembly and disassembly, a minimum level of PPE—hard hat (ANSI Z89.1 or equivalent, Type I, Class G or better), safety glasses with side shields (ANSI Z87.1 or equivalent), shirt with sleeves at least 3 in. (7.6 cm) long, long pants (the bottoms of the pant legs shall, at a minimum, touch the top of the boots when standing), and safety boots (ANSI Z41 PT99 or equivalent) with ankle support—shall be used by each team member and team crew member. Additional PPE or safety equipment shall be used if required for the task being performed.
d. Individuals under the age of 18 are not permitted to be on the competition site during assembly and disassembly.
e. Smoking is not permitted within the competition site at any time during assembly or disassembly.
f. Pets and other animals are not permitted on the competition site during assembly or disassembly with the exception of registered service animals.
g. Organizers may issue a stop work order at any time during the project if a hazardous condition is identified.
h. Failure to follow the procedures and requirements outlined in each team's Health and Safety Plan is considered a rule violation subject to Rule 2-7, and violations are subject to penalty points. All electrical work on the competition site shall meet electrical lockout/tagout requirements indicated in each team's approved Health and Safety Plan.

3-4. Conduct

Improper conduct, the use of alcohol, and the use of illegal substances will not be tolerated and will be considered a rules violation subject to Rule 2-7. Improper conduct may include, but is not limited to, improper language, unsportsmanlike conduct, unsafe behavior, distribution of inappropriate media, and cheating.

3-5. Use of Likeness, Content, and Images

Team members agree to the use of their names, likenesses, content, graphics, and photos in any communications materials issued by the organizers and event sponsors.

a. Content and images (graphics and photos), and any publications in which the content and images appear, may be viewable and made available to the general public via DOE's, NREL's, and the event sponsors' websites with unrestricted use.
b. The organizers and event sponsors will make all reasonable efforts to credit the sources of content and images, although they may be published without credit. To ensure proper usage of and credit for images, teams should submit photos and graphics by following the instructions located in Appendix F.

Exception: The deliverable status sheet posted in the "/Files/Deliverable Status Sheet" folder on the Yahoo Group indicates which deliverables will remain confidential through the completion of the project. All other competition deliverables may be made publicly available any time after their receipt by the organizers.

3-6. Withdrawals

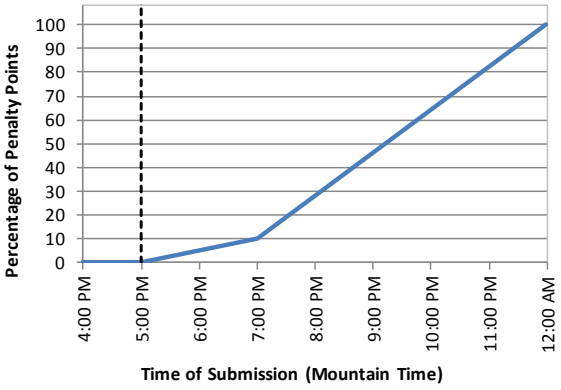
Any team wishing to withdraw from the project must notify the competition manager in writing. Teams considering withdrawal are encouraged to communicate early and frequently with the competition manager. All written withdrawals signed by a faculty advisor are final.

3-7. Deliverables

Teams are required to submit all deliverables associated with the project as described in Appendix D and summarized in the "Deliverable Status Sheet"[2] available on the Yahoo Group. All deliverables shall be submitted on time and complete. All deliverables are due by 5 p.m. Mountain Time on the dates indicated within the "Deliverable Status Sheet." Following initial submission, organizers will review the deliverables and provide comments to teams approximately 3 weeks after submission. For deliverables that allow resubmission, revised deliverables that correct all issues will be due at 5 p.m. Mountain Time 14 days after receipt of comments. Eventual approval of all deliverables is required for competition participation.

[2] The Deliverable Status Sheet is available on the Yahoo Group and is updated throughout the project to indicate receipt and approval status

Penalty points for late submissions still received on the due date are scaled linearly, as shown in Figure 1. The penalty associated with same-day late submission of each deliverable is indicated on the "Deliverable Status Sheet"; however, additional penalty points may be assigned for failure to meet submission requirements beyond the scenarios indicated in Figure 1, including incomplete but on-time deliverables and deliverables received after the due date.



Additional penalty points:		Time of Receipt ≥	11:59:00 PM
Reduced (steep):	11:59:00 PM >	Time of Receipt ≥	7:00:00 PM
Reduced (shallow):	7:00:00 PM >	Time of Receipt ≥	5:00:00 PM
No Penalty points:		Time of Receipt ≤	5:00:00 PM

* Time of Receipt relates only to date of required submission.
* Submission after 11:59 PM on the due date will result in additional penalty points of a severity to be deterimed by competition management.
* All times indicated are Mountain Time (standard or daylight savings, depending on time of year).

Figure 1: Scoring function for deliverables

Rule 4. Site Operations

4-1. Damage Liability

Each team is financially responsible for any damage it causes to the competition site, except as allowed under Rule 4-3.

4-2. Construction Equipment

a. Truck-mounted cranes, trailers, semi-trailer trucks, etc., are limited to the paved surfaces of the competition site.
b. Track-mounted equipment, such as vehicles, cranes, and forklifts, are prohibited at all times.
c. Teams shall not permit the use of any equipment or tools on the competition site that are not safe and/or do not comply with applicable requirements of the Occupational Safety and Health Administration (OSHA) and/or other related regulatory standards.

4-3. Ground Penetration

Ground penetration is permitted only for the approved method for tie-downs needed to meet wind loading and seismic requirements. Ground penetrations should be minimized and must be approved by the organizers prior to arrival at the competition site. All other ground penetrations shall not be permitted.

a. Grounding means shall be installed in accordance with the Solar Decathlon Building Code.

4-4. Impact on the Competition Site

Low-impact footings shall be used to support all house and site components.

a. Properly designed footings shall comply with the bearing pressure criteria specified in the Solar Decathlon Building Code.

4-5. Generators

Generators are permitted to power tools and construction lights during stand-alone assembly and stand-alone disassembly.

a. Engine generators shall not exceed 60 dB (A) at 50 ft (15 m) under full load per the manufacturer's listed sound rating. Operation and refueling of generators are limited to times approved by the organizers.

4-6. Spill Containment

a. Generators must be equipped with secondary containment systems that can accommodate all of the oil, fuel, and coolant that the generator contains at maximum capacities.
b. The release of water or other liquids onto the competition site or into nearby storm drains is prohibited.

4-7. Lot Conditions

A vertical elevation change of up to 22 in. (55.88 cm) may exist across a lot. Organizers will provide topographical maps of the site and indication of team lot location. Exact placement of team lots may vary by up to 5 ft. (1.524 m) and lots may vary within the tolerances of a 6 in. (15.24 cm) topographical survey. Teams must design adjustable foundations and plan accordingly to meet the specific conditions of the site.

4-8. Electric Vehicles

Teams are expected to provide an electric vehicle within their solar envelopes during contest week.

a. The vehicle must be electric. Hybrid vehicles and non-electric vehicles are not permitted.
b. Movement of the vehicle on and off the competition site is prohibited one half hour prior to, one half hour after, and throughout all public exhibit periods.
c. The competition prototype house must include the infrastructure required to charge the vehicle.
d. Any vehicle used must be commercially available to all teams at the beginning of contest week.
e. The vehicle must be listed on the DOE Energy Efficiency & Renewable Energy all-electric vehicles website.
f. The vehicle must have four wheels and, at a minimum, seat two individuals side by side.
g. The vehicle must be licensed, registered, and insured as required for operation on Orange County, CA, roadways.

Rule 5. The Solar Envelope

5-1. Lot Size

Lots are 78 ft. (23.8 m) east to west by 60 ft. (18.3 m) north to south.

5-2. Solar Envelope Dimensions

The house and all site components on a team's lot must stay within the 18 ft. (5.486 m) height of the solar envelope shown in Figure 2. The north, south, east, and west planes of the solar envelope are vertical, i.e., slope of 90 degrees from horizontal.

a. The official height of a site component or set of contiguous site components is the vertical distance from the point of highest grade along the outside perimeter of the site component(s) to the highest point of the site component(s).
b. Small weather stations, antennas, air vents, and other similar components may be specifically exempted from Rule 5-2 if all of the following conditions are met:
    i. The team makes a request to the competition manager for an exemption prior to the start of assembly.
    ii. The team can prove to the competition manager's satisfaction that the component is not significantly restricting a neighbor's right to the sun.
    iii. The competition manager determines that the component is sufficiently unique in function and small in size to warrant an exemption.
c. Moveable or convertible house or site components shall not extend beyond the solar envelope during live demonstrations or in printed or electronic media presented by the team during jury visits, public exhibit hours, or contests.

d. Any vehicle on the competition site shall not extend beyond the solar envelope during live demonstrations or in printed or electronic media presented by the team during jury visits, public exhibit hours, or contests.

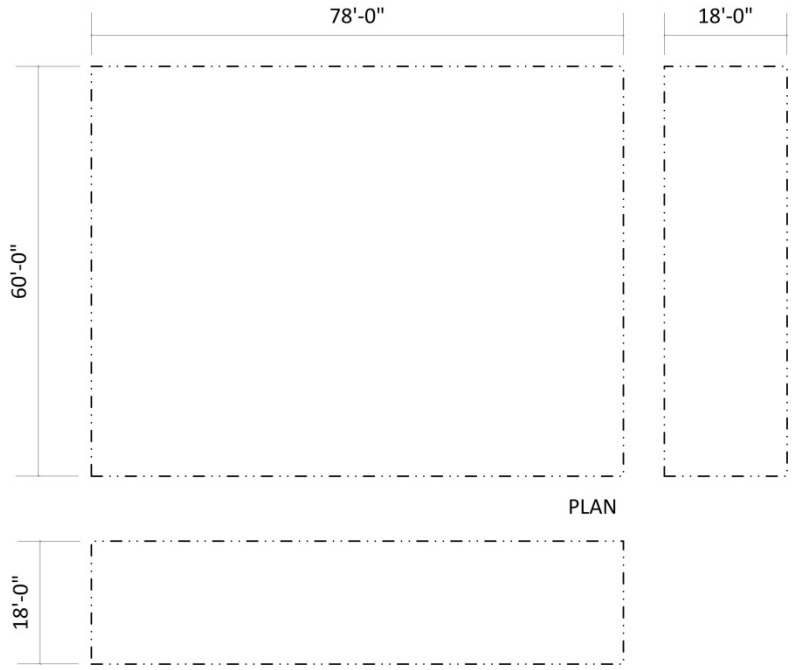


Figure 2: Solar envelope dimensions

Rule 6. The House

6-1. Structural Design Approval

Each team shall submit structural drawings and calculations that have been stamped by a qualified, licensed design professional registered in the State of California or eligible for California registration reciprocity.

a. By stamping the structural drawings and calculations, the licensed professional certifies that the structural provisions of the Solar Decathlon Building Code have been met by the design, and that the structure is safe for the public to enter if it has been built as designed.

b. The licensed professional shall stamp the structural drawings and calculations of the house and all site components that might pose a threat to public safety if they fail.

6-2. Finished Square Footage

The finished square footage, as defined by ANSI Z765-2003, "Square Footage—Method for Calculating," shall be at least 600 ft^2 (55.7 m^2), but shall not exceed 1000 ft^2 (92.9 m^2).

a. If the building has convertible or moveable components, the maximum and minimum square footages observed during live demonstrations or shown in printed or electronic media presented by the team during jury visits, public exhibit hours, or contests count as the maximum and minimum square footages of record, respectively.

b. For the purposes of the Solar Decathlon, all finished square footage built is included in the finished square footage calculation, regardless of whether or not the finished square footage is contiguous (i.e. attached to the main dwelling unit).

6-3. Entrance and Exit Routes

a. The main house entrance may be placed on any side of the house. However, an accessible route leading from the main street of the solar village to the main house entrance shall be provided as part of the competition prototype.

b. The house exit route shall be accessible to the public and lead from the main house exit to one of the publically accessible streets of the solar village adjacent to the solar envelope.

c. Teams shall clearly illustrate and label the entrance and exit routes between solar envelope "property lines" and house entrance/exit in the construction drawings.

6-4. Competition Prototype Alternates

Alternates to the competition prototype shall not be proposed in materials intended for consideration by the Architecture, Market Appeal, and Engineering juries. Team websites and public exhibit communications materials, including signage, handouts, and public display information, are not subject to this rule.

a. Renderings and other graphical representations may only show the competition prototype house and the associated competition prototype site components on a featureless lot equal in size and orientation to the solar envelope. The featureless lot has a flat, uniform ground covering to be specified by the team.

b. Natural and man-made features, including adjacent competition prototypes, located near the target client's site may be depicted, providing the depicted features are located outside of the solar envelope.

c. Teams shall not propose alternates to address local building code provisions and site restrictions at the target client's site. The juries will be instructed to assume that the Solar Decathlon Rules and Building Code also apply at the target client's site.

d. Public exhibit communications materials are not considered part of the competition prototype and, therefore, shall not be shown in renderings and other graphical representations.

Exception:

The cost estimator and juries will disregard all containers and associated equipment, such as pressure pumps, that would be unnecessary if city water and sewer services were available on the competition site. Therefore, these components shall be noted as "Temporary for Competition Purposes" in drawings and other graphical representations. Note that all structures and surfaces that surround the containers will be evaluated by the cost estimator and juries.

The cost estimator and juries will disregard any element included in a competition prototype house that is not used during the competition, does not impact the performance of the house, and is not presented or visible to the juries in any way.

The cost estimator and juries will disregard the electric vehicle used as part of Contest 9. All required charging equipment and vehicle-associated structures, however, shall be included in their evaluations.

Rule 7. Vegetation

The use of potted vegetation is permitted. All potted vegetation shall comply with Rules 4-4 and 4-6.

7-1. Placement

Vegetation may be moved around the solar envelope until the beginning of contest week, after which it shall remain stationary until the conclusion of contest week unless the drawings clearly show how some or all vegetation is designed to be moved as part of an integrated system.

7-2. Watering Restrictions

Greywater that may possibly contain organisms that could go septic shall not be used to water vegetation.

Rule 8. Energy

8-1. PV Technology Limitations

a. Bare photovoltaic cells and encapsulated photovoltaic modules must be commercially available to all teams by the beginning of the event.

b. Substantial modification of the crystal structure, junction, or metallization constitutes the manufacture of a new cell and is not allowed.

8-2. Energy Sources

After the conclusion of stand-alone assembly (see Rule 8-5c for details) and until the conclusion of the Energy Balance Contest (see Appendix A for the detailed event schedule), global solar radiation incident upon the lot and the energy in small primary batteries (see Rule 8-3 for limitations) are the only sources of energy that may be consumed in the operation of the house without the requirement of subsequent energy offsets.

Exception: Teams may use organizer-supplied village grid power that is exempt from the Energy Balance Contest during grid-tie assembly for construction equipment, site lighting, and task lighting located outside the finished square footage only. Teams may use generators during grid-tie assembly for nighttime construction lighting only.

a. All other energy sources, such as AC grid energy, consumed in the operation of the house must be offset by an equal or greater amount of energy produced, or "regenerated," by the house.
b. Fireplaces, fire pits, candles, and other devices using non-solar fuels are not permitted in the designs.

   Exception: The limited use of batteries is permitted by Rule 8-3.

8-3. Batteries

Hardwired battery banks and large plug-in uninterruptable power supplies (UPS) are not permitted. Batteries include most commercially available energy storage devices, such as electrochemical batteries and capacitors.

a. The use of primary (non-rechargeable) batteries (no larger than "9V" size) is limited to smoke detectors, remote controls, thermostats, alarm clock backups, and other small devices that typically use small primary batteries.
b. The use of the factory-installed battery within the team's electric vehicle is permitted for the operation of the electric vehicle only. Vehicle-to-grid power flow is not permitted.
c. "Plug-in" (non-hardwired) devices with small secondary (rechargeable) batteries that are designed to be recharged by the house's electrical system (e.g., a laptop computer), shall be connected, or "plugged into," the house's electrical system whenever the devices are located in the house or within the solar envelope.

   Exception: If not used in the operation of the house at any time during contest week, portable electronic devices used for mobile communications, such as cell phones and tablets, are permitted within the solar envelope without having to be plugged into the house's electrical system.
d. Stand-alone, PV-powered devices with small secondary batteries are permitted, but the aggregate battery capacity of these devices may not exceed 100 Wh.

8-4. Desiccant Systems

If a desiccant system is used, it must be regenerative.

a. To ensure that the desiccant has been fully regenerated by the conclusion of the Energy Balance Contest, the desiccant material or device must be easily measurable.
b. In most cases, the material or device will be measured prior to and at the conclusion of the Energy Balance Contest. In some cases, a measurement at the conclusion of the Energy Balance Contest may not be necessary.
c. At the conclusion of the Energy Balance Contest, the weight of the desiccant material or device shall be less than or equal to its initial weight.
d. Some desiccant systems with very low moisture storage capacities may be exempt from this requirement. Exemptions will be granted on a case-by-case basis by the competition manager.

8-5. Village Grid

The organizers shall provide the village with an electric power grid that provides AC power to and accepts AC power from the houses.

a. The organizers shall provide the necessary service conductors and connect the conductors at the utility intertie point.
b. All houses shall operate with an AC service of 60 Hz, 120/240V split-phase with neutral.
c. At a date and time specified in Appendix A, teams have the option to switch from stand-alone assembly to grid-tie assembly if all relevant inspections have been passed and the village grid is available. Teams shall not switch back to stand-alone assembly after switching to grid-tie assembly. At a later date and time specified in Appendix A, all teams shall have switched to grid-tie assembly. Failure to have switched by this time will be considered a rule violation subject to Rule 2-7.

8-6. Net Metering Rules

a. When a team switches from stand-alone assembly to grid-tie assembly, its bidirectional meter resets to zero.
b. If the meter reading indicates net energy production at the start of the Energy Balance Contest, the meter is reset to zero. If the meter reading indicates net energy consumption at the start of the Energy Balance Contest, the meter is not reset and the team begins the Energy Balance Contest with an energy deficit.
c. The team's electric vehicle shall begin and end the contest week with a fully charged battery. Failure to do so will be considered a rules violation and any difference measured will be considered as energy consumption within Contest 10.

Rule 9. Liquids

9-1. Container Locations

a. Primary supply water and greywater containers shall be located outside of the finished square footage as defined by Rule 6-2. These containers may not be located beneath the finished square footage.

   Exception: Teams may utilize one or more small tanks up to a maximum aggregate volume of 20 gal (75.7 L) to accept wastewater discharge in preparation for delivery to the main wastewater tank(s).
b. Solar storage, hot water, or other thermal storage containers may be located within the finished square footage.
c. The primary supply water tank(s) shall be fully shaded from direct solar radiation between 9 a.m. and 5 p.m. Pacific Daylight Time (PDT) on October 1.

9-2. Team-Provided Liquids

A team may provide its own liquids for the following purposes:

a. Personal hydration
b. Irrigation [one-time delivery before water delivery day, 50 gal (189.2 L) limit, water only]
c. Thermal mass (quantity limited by bearing pressure limit and Rule 4-4; see Rule 9-6 for restrictions)
d. Food preparation
e. Hydronic system pressure testing[3]
f. Assembly (e.g., hydraulic fluid), finishing (e.g., paint), and cleaning (e.g., mineral spirits).
g. Teams may provide glycol, deionized water, or other working fluids for thermodynamic systems using working fluids other than non-potable water if approved by the organizers prior to arrival at the competition site.

9-3. Greywater Reuse

A team may reuse greywater for irrigation only.

[3] The water may only fill isolated loops; it shall not enter tanks.

Exception: Greywater reuse for other purposes may be approved by the Solar Decathlon Building Official on a case-by-case basis. Alternative purposes must be approved by the Solar Decathlon Building Official before the start of assembly on the competition site to be permitted.

a. Greywater reuse systems shall comply with Rule 7-2.

9-4. Rainwater Collection

A team may collect rainwater that falls on its site and use it in, or as, any of the following:

a. Irrigation source
b. Water feature
c. Heat sink or heat source.

Exception: Rainwater reuse for other purposes may be approved by the Solar Decathlon Building Official on a case-by-case basis. Alternative uses must be approved by the Solar Decathlon Building Official before the start of assembly on the competition site.

9-5. Evaporation

Water may be used for evaporation purposes.

9-6. Thermal Mass

Teams may use liquids as thermal mass.

a. The thermal storage containers shall be filled and sealed before their arrival on the competition site and shall remain sealed until they are removed from the competition site by the teams.
b. The thermal storage containers shall be isolated, i.e., the contained liquid shall not circulate to other containers or systems.

9-7. Greywater Heat Recovery

Heat may be recovered from greywater as it flows from the drain to the waste tank.

a. "Batch"-type greywater heat recovery is prohibited.

9-8. Water Delivery

A team may request up to 1500 gal (5678.1 L) of water from the organizers in its detailed water budget.[4]

The procedure and associated requirements for water delivery follow.

a. On water delivery day, two water trucks begin at the north ends of Decathlete Way in the morning and proceed to service each house. Each truck will be equipped with a pump to aid in water delivery.
b. Teams shall provide a minimum of six people, on command, to help move the water hose to their house from the previously serviced house.
c. After the two trucks have serviced all houses once, they will visit the village again to service any house needing additional water.
d. Teams that delay the water supply process or request additional water after the trucks complete their second circle around the village are subject to a penalty and a delay in receiving their water. Instead of or in addition to a penalty, these teams may be required to pay for their own water. Teams required to pay for their own water supply shall use a company approved by the organizers.
e. Team design deliverables shall clearly indicate the fill location(s), quantity of water requested at each fill location, container dimensions, diameter of the opening(s) (minimum 4 in., or 10 cm), and clearance above the container(s) fill location(s) (minimum 12 in., or 30.48 cm). All openings shall be easily accessible.
f. Teams are responsible for distributing water within their houses. This includes all necessary pumps, containers, lines, valves, etc. All pumping power to distribute water must be delivered by an AC circuit.

[4] The detailed water budget shall be included in the Project Manual (see *Content Requirements* in Appendix D-5).

9-9. Water Removal

The procedure and associated requirements for water removal follow.

a. On water removal day, two water trucks begin at the north Ends of Decathlete Way to service each house. Each truck will be equipped with a pump to aid in water removal.

b. Teams shall supply a minimum of six people, on command, to help move the water hose to their house from the previously serviced house.

c. After the two trucks have serviced all houses once, they will visit the village again to service any house needing remaining water removed.

d. Teams that delay the water removal process may be required to pay for their own water removal. Teams required to pay for their own water removal shall use a company approved by the organizers.

e. Team design deliverables shall clearly indicate the removal location(s), quantity of water to be removed from each removal location, container dimensions, diameter of the opening(s) (minimum 4 in., or 10 cm), and clearance above the container(s) fill location(s) (minimum 12 in., or 30.48 cm). All openings shall be easily accessible.

f. Teams are responsible for either removing remaining water from the site or moving remaining water to the designated removal locations.

Rule 10. The Event

10-1. Registration

All Solar Decathlon event participants must register either through the online registration site, which will be available closer to the event, or on the competition site.

a. The following rules apply to **all participants**:

   i. Each event participant must register individually. Group registrations are not allowed.

   ii. Online registration is encouraged for all event participants, because on-site registration could cause delays in gaining access to the competition site.

   iii. When registering, event participants must complete all required information and forms before access to the competition site is allowed.

b. **Organizers, team members, and staff** are required to provide a photo that will be kept on file and used for security purposes. Participants should use the online registration site to submit completed forms, information, and photos prior to the event. Once all information, forms, and photos are received, the organizers will issue an event security ID that must be visible at all times while on the competition site.

   Exception: team crew are not required to provide a photo.

c. **Visiting media** are not considered participants and will not be required to register, but must check in at registration headquarters. Due to safety concerns, site access for visiting media may be restricted.

10-2. Event Sponsor Recognition

All communications materials produced by the teams concerning or referring to the project (including team websites) shall refer prominently to the project as the "U.S. Department of Energy Solar Decathlon."

a. Teams are required to use the Solar Decathlon logo, the DOE wordmark, and the NREL logo on all communications materials visible at the Orange County Great Park. The DOE wordmark and NREL logo shall be a maximum of one-third the size of the Solar Decathlon logo as outlined in the Solar Decathlon identity guidelines[5].

b. The Solar Decathlon logo, the DOE wordmark, and NREL logo are the only required graphic elements teams must use.

c. Team websites shall comply with Rule 10-2 with the exception of the one-third size rule for team sponsor text and logos.

[5] Solar Decathlon identity guidelines are available at: http://www.solardecathlon.gov/commstandards.

d. Team uniforms are exempt from Rule 10-2. See Rule 11-5 for specifics.

10-3. Team Sponsor Recognition

Team sponsors may be recognized with text, logos, or both, but the text and logos must appear in conjunction with the Solar Decathlon text and logo and be a maximum of one-third of the size of the Solar Decathlon text and logo, as outlined in the Solar Decathlon identity guidelines.

a. Team websites shall comply with Rules 10-2 and 10-3, with the exception of the one-third size rule for team sponsor text and logos.

b. Rule 10-3 applies but is not limited to all communications materials that will be on display or distributed on the competition site.

c. Communications materials or other products that exist largely for the recognition of sponsors are limited to 10 square feet (0.93 square meters), in aggregate within the solar envelope. "Other products" include but are not limited to signs, exhibits, posters, plaques, photos, wall art, and furnishings.

d. For multimedia or audio presentations shown on the competition site, no more than 20% of the total time, 1 minute, or whichever is less may be dedicated to recognition of team sponsors.

e. Off-the-shelf components that feature a built-in manufacturer's logo are acceptable and need not be accompanied by the Solar Decathlon text and logo.

f. Team uniforms are exempt from Rule 10-3. See Rule 11-5 for specifics.

10-4. Logistics

a. Each team is responsible for the transport of its house, the house's contents, and all necessary tools and equipment, and shall be responsible for any damage to or loss of such items.

b. Each team is responsible for procuring all necessary equipment, tools, and supplies.

c. Each team is responsible for transportation, accommodations, lodging, food, and beverages.

   i. The organizers will make drinking water available on the competition site to all team members for the duration of the event.

d. Each team is responsible for making its own reservations and arrangements and for covering all necessary costs.

10-5. Inspections

Each project shall be inspected for compliance with the Solar Decathlon Rules and the Solar Decathlon Building Code.

a. Inspections will occur only between the hours of 7 a.m. and 7 p.m. during the assembly period, but may be restricted further due to environmental constraints.

b. A team shall notify the appropriate inspector when it is ready for an inspection. When two or more teams request an inspection simultaneously, the order of inspections shall be determined in a drawing.

c. Additional random inspections for compliance shall take place throughout contest week.

d. The competition manager shall check each team's inspection status, as indicated on the team's official inspection card, to determine which houses are eligible to participate in the contests. All final inspections shall be passed by the conclusion of last-chance final inspections. Failure to pass inspections by the required deadline may disqualify a team for participation in the event and will be considered a rules violation subject to Rule 2-7. A team must have passed inspections by the conclusion of the inspector's work day for a team to be eligible to participate in the following day's contests, which officially start at midnight.

   Exception: Jury visits will proceed as scheduled regardless of a team's inspection status. However, jurors will be made aware of the team's inspection status and may consider it in their evaluations.

e. Because open, partially functioning houses are preferable to closed, fully functioning houses, the organizers will direct the inspectors to require that an unsafe condition be corrected so that public visits can occur—even if, as a consequence, the house is ineligible for participation in one or more contests.

10-6. Communications Materials

All communications materials shall support the goal of Contest 4: Communications, which is to educate consumers about the project and topics relevant to the project.

Rule 11. Contest Week

11-1. House Occupancy

Under normal circumstances, no more than six people may be located in the house at any one time.

a. Rule 11-1 is automatically suspended whenever the Comfort Zone Contest measurements are suspended. See Appendix A-3 for the Comfort Zone Contest schedule.
b. Jurors, observers, official organizer-provided competition photographers, media, writers, and others with authority to enter a house as an organizer are not counted toward the number of house occupants.
c. Up to 10 people may be located in the house during dinner parties. At least six of the people in the house during dinner parties shall be the two decathletes from each of the three guest teams. No more than two of the remaining people in the house may be VIP guests.

11-2. House Operators

Only decathletes are permitted to operate the house and participate in the contests during contest week.

a. All competition-related communications on the competition site shall be between the organizers and decathletes. Non-decathlete team members and team crew are not permitted to participate in or listen to competition-related communications.
b. Non-decathlete team members are permitted to give tours to the public and be present on the competition site.

11-3. Late Design Changes

The final project assembled on the competition site shall be consistent with the design and specifications presented in the as-built drawings and project manual.

a. If there are known inconsistencies between the final project and the as-built drawings and project manual, the team shall document these inconsistencies and submit the documentation to the competition manager as soon as possible after the inconsistency is known. The competition manager will then submit this documentation or a summary of the documented inconsistencies to the respective juries and inspectors.
b. The competition manager will compile a summary of all undocumented inconsistencies discovered during the inspections process and submit the summary to the respective juries.

11-4. Public Exhibit

a. Teams are required to provide an accessible route to all areas of the house and site that is available to the public during exhibit hours.
b. Teams are permitted to produce and distribute only one informational brochure or handout on the competition site.
c. Teams are encouraged to provide visitors a means to return the handout at the end of the tour for reuse.
d. Teams shall develop signage that complements public exhibit tours by informing visitors about the team project and engaging visitors waiting in line.
e. Teams are prohibited from selling items to the general public on the competition site.
f. Only organizer-approved vendors may provide food and beverage to the general public on the competition site.

11-5. Team Uniforms

a. During contest week and special events specified by the organizers, all team members present on the competition site or the site of a special event shall wear uniforms representing their team.

b. Team uniforms are exempt from Rules 10-2 and 10-3.

c. Team sponsor logos are approved to be visible only on the back of the team uniform (jacket, shirt, hat, or other wearable item).

d. The only information or graphics that are approved to be visible from the front of the team uniform (jacket, shirt, hat, or other wearable item) shall be the institution and its logo, the team name and logo, the Solar Decathlon logo, and event sponsor logos.

e. A built-in clothing manufacturer logo may be visible on the front or back of the team uniform, or both.

11-6. Impound

Each house shall be impounded on specified nights as indicated in Appendix A under the direct supervision of the organizers or staff. Team members shall not occupy the competition site during impound hours. There is a 10-minute impound grace period for teams to leave the competition site.

SECTION III: CONTEST CRITERIA

The Solar Decathlon competition consists of 10 separately scored contests, and some contests contain one or more subcontests. For example, Contest 7: Appliances consists of six separately scored subcontests. The team with the highest total points at the end of the competition wins. Table 2 shows the competition structure.

Table 2: Competition structure

Contest Number	Subcontest Number	Contest Name	Available Points	Subcontest Name	Available Points	Contest or Subcontest Type	Brief Description
1	n/a	Architecture[6]	100	n/a	n/a	Juried	Architecture Jury reviews and evaluates the drawings, construction specifications, audiovisual presentation, architecture narrative, and final constructed project
2	n/a	Market Appeal	100	n/a	n/a	Juried	Market Appeal Jury reviews and evaluates the drawings, construction specifications, audiovisual presentation, market appeal narrative, and final constructed project
3	n/a	Engineering	100	n/a	n/a	Juried	Engineering Jury reviews and evaluates the drawings, construction specs, energy analysis results and discussion, audiovisual presentation, engineering narrative and final constructed project
4	n/a	Communications	100	n/a	n/a	Juried	Communications Jury reviews and evaluates the team website, audiovisual presentation, communications narrative, onsite public exhibit, and public exhibit materials
5	n/a	Affordability	100	n/a	n/a	Juried	Cost estimator reviews the drawings, construction specifications, and final constructed project to estimate construction costs
6	6-1	Comfort Zone	100	Temperature	75	Measured | Monitored	Keep zone temperature in 71°F – 76°F (22°C – 24°C) range
	6-2			Humidity	25	Measured | Monitored	Keep zone relative humidity below 60%
7	7-1	Appliances	100	Refrigerator	10	Measured | Monitored	Keep refrigerator temperature in 34°F – 40°F (1°C – 4°C) range
	7-2			Freezer	10	Measured | Monitored	Keep freezer temperature in -20°F – 5°F (-29°C to -15°C) range
	7-3			Clothes Washer	16	Measured | Task	Successfully wash eight loads of laundry (one load = six bath towels) during contest week
	7-4			Clothes Drying	32	Measured | Task	Return eight loads of laundry to their original weight (one load = six bath towels) during contest week
	7-5			Dishwasher	17	Measured | Task	Successfully wash five loads of dishes (one load = eight place settings) during contest week
	7-6			Cooking	15	Measured | Task	Successfully perform five cooking tasks (one task = vaporize 5 lb or 2 kg of water in less than 2 hours) during contest week
8	8-1	Home Life	100	Lighting	25	Measured | Task	All interior and exterior lights on at full levels at night
	8-2			Hot Water	50	Measured | Task	Successfully conduct 16 water draws during contest week [one water draw = deliver 15 gal (56.8 L) of water at average 110°F (43°C) temperature within 10 minutes]
	8-3			Home Electronics	10	Measured | Task	Operate a TV and computer during specified hours
	8-4			Dinner Party	10	Measured | Task	Host two dinner parties for up to eight guests
	8-5			Movie Night	5	Measured | Task	Host neighbors to watch a movie on the home theater system
9	n/a	Commuting	100	n/a	n/a	Measured | Task	Drive an electric vehicle at least 25 miles, eight times during contest week
10	10-1	Energy Balance	100	Energy Production	50	Measured | Monitored	Produce at least as much electrical energy (kWh) as is consumed during contest week
	10-2			Energy Consumption	50	Measured | Monitored	Consume less than 175 kWh of electrical energy during contest week
TOTALS			**1,000**	**500 total juried points and 500 total measured points from 21 individually scored contest elements**			

[6] Lighting quality and lighting control evaluations are conducted by the Architecture, Market Appeal, and Engineering juries.

There are three ways to earn points:

- Jury evaluation
- Task completion
- Monitored performance.

Subcontests based on task completion or monitored performance are called measured subcontests.

Points for task completion, or measured performance, are awarded as a function of "closeness to completion." Points for measured performance are either awarded at the end of each scored period throughout contest week or at the conclusion of contest week when performance requirements are met or partially met.

The scoring of the juried contests is more flexible than the scoring of the measured subcontests described above. However, for the sake of fairness, consistency is important. To increase the consistency of the scoring in juried contests, the jurors shall use the evaluation method described in Appendix B-1.

Contest 1. Architecture

A jury of architects shall assign an overall score for the design's architectural conceptual coherence, merit, integration and implementation by reviewing the team's drawings, construction specifications, audiovisual presentation, and architecture narrative (see Appendix D), and by performing an on-site evaluation of the competition prototype (see Appendix B).

The jury shall consider the following specific criteria in its evaluation:

Architectural Concept and Design Approach

- How well did the team utilize an overall clear concept, idea or ideas to guide the development of the whole design process?
- How well does the competition prototype house demonstrate overall coherence among architectural, structural, mechanical, electrical, plumbing, landscaping, and other related disciplines?
- How effectively will the overall architectural design offer a sense of inspiration and delight to Solar Decathlon visitors?

Architectural Implementation and Innovation

- To what degree was the team effective in its use of architectural elements including, but not limited to: scale and proportion, indoor/outdoor connections, composition, and linking of various house elements?
- How effectively did the team create a holistic and integrated design, inclusive of space, structure and building envelope; that will be comfortable for occupants and compatible with the surrounding environment in the target market climate?
- How well does the team integrate both natural and electric lighting into the competition prototype? For instance, are the lighted spaces rich and varied? Do they have adequate light for tasks? Do they have good color rendition? Do the luminaires properly distribute light? Is the admission of direct and diffuse sunlight effectively controlled?
- How well does the competition prototype demonstrate quality design through material selection, well-conceived details, and architectural implementation?[7]
- To what extent does the competition prototype take an innovative approach to addressing residential architecture?

Documentation

- How effectively did the drawings, construction specifications, audiovisual presentation, and architecture narrative enable the jury to conduct a preliminary evaluation of the design prior to its arrival at the competition site?

[7] The jury should consider the design, detailing and implementation from the perspective of a professionally constructed house. Student-built or installed elements should be evaluated as if they were professionally built and installed.

- How well do the drawings, construction specifications, and audiovisual presentation accurately reflect the constructed project as assembled on the competition site?

Contest 2. Market Appeal

A jury of professionals from the homebuilding industry shall assign an overall score for the house's market appeal by reviewing the team's drawings, construction specifications, audiovisual presentation, and market appeal narrative (see Appendix D), and by performing an on-site evaluation of the competition prototype (see Appendix B).

The jury shall consider the following specific criteria in its evaluation of the responsiveness of the design to the characteristics and requirements of a team-defined target client (see Table 3 for examples of target client characteristics and requirements, which shall be included in the Market Appeal jury narrative and project summary).

Teams shall define their target client with a minimum level of specificity as indicated in Table 3. The target market defined for the competition prototype house must be a primary residence intended for year-round occupancy.

Livability

- How well does the design offer the intended occupant(s) a safe, functional, convenient, comfortable, and enjoyable place to live?
- How appropriate is the operation of the house's lighting, entertainment, and other controls for the target client?
- How successfully does the design meet the unique needs and desires of the target client?

Marketability

- How successfully does the house demonstrate exterior and interior appeal for the target client?
- How appropriate are the material, equipment, and detailing choices to the desires of the target client?
- How effectively does the team use sustainability features and strategies to make a positive contribution to the house's marketability to the target client?
- To what extent does the house offer a good value to the target client?

Buildability

- How effectively do the drawings and construction specifications enable, through sufficient quality and detail, a contractor to generate an accurate, detailed construction cost estimate?
- How effectively do the drawings and construction specifications enable, through sufficient quality and detail, a contractor to construct the building as the design team intended it to be built?

Table 3: Examples of target client characteristics and requirements

Characteristic or Requirement	Example #1	Example #2	Example #3
Location of permanent site	Minot, ND	Folsom, CA	Boston, MA
Housing type	Remote worker housing	Single family	Single family
# of occupants	2	3	1
Client demographic	Working professionals	Mid-30s married couple with infant	Retired individual
Client annual income	$85,000	$100,000	$65,000
# of bedrooms	2	3	1

Notes:

1. These examples show the *minimum* required level of detail for the target client characteristics and requirements.
2. The target client characteristics and requirements shall be included in the project manual and project summary (see Appendix D).

Contest 3. Engineering

A jury of engineers shall assign an overall score for the design's engineering merit and implementation by reviewing the team's drawings, construction specifications, energy analysis, audiovisual presentation, and engineering narrative (see Appendix D), and by performing an on-site evaluation of the competition prototype (see Appendix B).

The jury shall consider the following specific criteria in its evaluation:

Innovation

- To what extent were unique approaches used to solve engineering design challenges?
- To what extent do the proposed innovations have true market potential?
- How well does the design demonstrate market-leading technologies and engineering integration?

Functionality

- How well do the house systems function to enhance occupant comfort and house performance?
- How well will the HVAC system as designed maintain uniform thermal comfort conditions via temperature control, humidity control, air movement, and a successful distribution system design?
- How effective is the design of the HVAC system and thermal envelope in minimizing energy use while ensuring occupant comfort, including indoor air quality?

Efficiency

- To what extent does the team consider energy efficiency and overall system performance as part of the competition prototype design? Relative to conventional systems, how much energy is the design expected to save over the course of an entire year?
- How effectively will house controls facilitate a reduction in energy consumption during an entire year of operation?
- How effective, efficient and practical is the design in its engineering approach?

Reliability

- How well does the design address maintenance and owner operation of house systems?
- How long are the systems expected to operate at a high level of performance?

Documentation

- How effectively did the drawings, construction specifications, energy analysis results and discussion, and audiovisual presentation enable the jury to conduct a preliminary evaluation of the design prior to its arrival at the competition site?
- How well do the drawings, construction specifications, energy analysis results and discussion, and audiovisual presentation accurately reflect the constructed project as assembled on the competition site?

Contest 4. Communications

A jury of communications professionals will evaluate and assign an overall score for the team's communications efforts by reviewing the quality, delivery, and innovation of each team's final electronic communications, communications narrative, and audiovisual presentation (see Appendix D), and by evaluating the public exhibit materials, public exhibit, and communications summary presentation onsite (see Appendix B). The Communications Contest is designed to ensure that each team's communications materials educate the public about its project.

The jury will consider the following specific criteria:

Communications Strategy

- How well did the team's communications deliverables work together to convey a comprehensive, consistent, and integrated communications strategy?
- How effective are the team's educational and outreach messages about the Solar Decathlon, the team, and the competition prototype house?

Electronic Communications (team website and social media)

- How well does the team communicate its messages to online audiences?
- How well do the website's graphical elements and information architecture support a logical, consistent, enjoyable and successful user experience?
- How well does the team employ social media to achieve comprehensive and successful communications outreach?

Public Exhibit Materials (on-site signage and handout)

- How well do the signage and handout communicate the team's messages to visitors?
- How creative, original and informative are the team's public exhibit materials?
- How well does the team's handout align with its communications objectives as stated in the narrative?

Public Exhibit Presentation

- How informative, interesting, engaging, and audience-appropriate was the team's comprehensive tour?
- How effective was the team at describing their approach for an informative, interesting, engaging and audience-appropriate fast tour designed to accommodate large crowds and long lines?

Audiovisual Presentation

- How interesting and informative was the audiovisual presentation of the team's house?
- How well does the audiovisual presentation explain to viewers what they're seeing and the philosophy behind the house design?
- How effectively does the audiovisual presentation showcase the completed, constructed as-built house as presented on the competition site?

Contest 5. Affordability

A professional cost estimator shall assign an estimated construction cost to each project. All available points are earned for achieving an estimated construction cost of $250,000 or less.

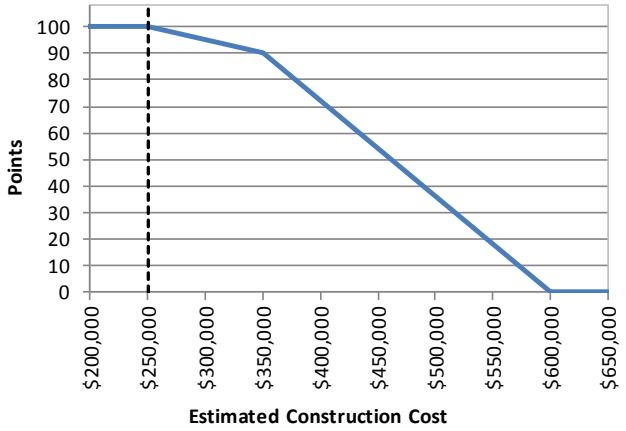
a. Reduced points are earned for an estimated construction cost between $250,000 and $600,000. No points are earned for an estimated construction cost at or above $600,000. Reduced points are scaled linearly, as shown in Figure 3.

b. When information necessary for completing a thorough, accurate estimate is missing, the estimators will err on the high side to accommodate for uncertainty.

c. Each team is required to declare the target construction cost of its design by a specified deadline. The team's target construction cost shall be within ±20% of the professional cost estimator's final estimated construction cost.

d. Teams may submit a request to competition management to have the cost of a particular innovative technology included in their competition prototype considered equal to a market-ready equivalent. The procedures for submission of this request and approval are described in the Affordability Contest methodology document (see item "e" below).

e. A file describing the estimating methodology is posted in the "/Files/Rules/Rules Reference Documents/" folder on the Yahoo Group.



Full points:		Cost ≤ $250,000
Reduced points (shallow):	$250,000 <	Cost ≤ $350,000
Reduced points (steep):	$350,000 <	Cost < $600,000
No points:		Cost ≥ $600,000

Figure 3: Scoring function for the Affordability Contest

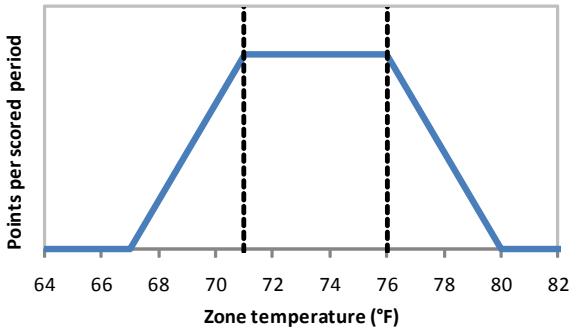
Contest 6. Comfort Zone

6-1. Temperature

All available points are earned at the conclusion of each scored period by keeping the time-averaged interior dry-bulb temperature between 71.0°F (21.7°C) and 76.0°F (24.4°C) during the scored period. See Appendix A-3 for the schedule of scored periods and for the number of available points per scored period.

a. Reduced points are earned if the time-averaged interior dry-bulb temperature is between 67.0°F (19.4°C) and 71.0°F (21.7°C) or between 76.0°F (24.4°C) and 80.0°F (26.7°C). Reduced point values are scaled linearly, as shown in Figure 4.

b. The zone temperature deviating farthest from the target temperature range is the zone temperature of record. The organizers will identify at least two thermal zones in each house and measure the temperature of each zone.



Full points:	71 °F	(22 °C) ≤	Temperature	≤ 76 °F	(24 °C)
Reduced points:	67 °F	(19 °C) <	Temperature	< 71 °F	(22 °C)
or	76 °F	(24 °C) <	Temperature	< 80 °F	(27 °C)
No points:			Temperature	≤ 67 °F	(19 °C)
or			Temperature	≥ 80 °F	(27 °C)

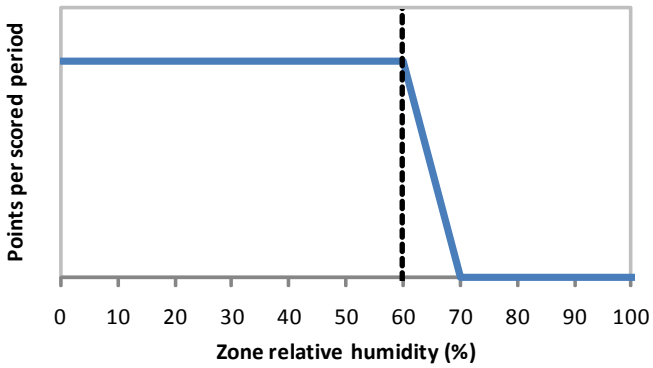
Figure 4: Scoring function for the Temperature Subcontest

6-2. Humidity

All available points are earned at the conclusion of each scored period by keeping the time-averaged interior relative humidity below 60.0% during the scored period. See Appendix A-3 for the schedule of scored periods and for the number of available points per scored period.

a. Reduced points are earned if the time-averaged interior relative humidity is between 60.0% and 70.0%. Reduced point values are scaled linearly, as shown in Figure 5.

b. In multi-zone houses, the zone humidity deviating farthest from the target humidity range is the zone humidity of record.



Full points:		Relative humidity ≤ 60 %
Reduced points:	60 % <	Relative humidity < 70 %
No points:		Relative humidity ≥ 70 %

Figure 5: Scoring function for the Temperature Subcontest

Contest 7. Appliances

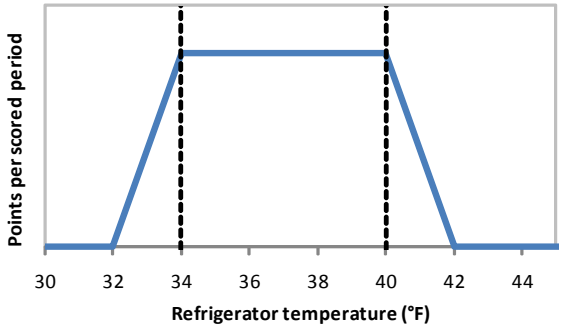
7-1. Refrigerator

All available points are earned at the conclusion of each scored period by keeping the time-averaged interior temperature of a refrigerator between 34.0°F (1.11°C) and 40.0°F (4.44°C) during the scored period. See Appendix A-3 for the schedule of scored periods and for the number of available points per scored period.

a. Reduced points are earned if the time-averaged interior refrigerator temperature is between 32.0°F (0.00°C) and 34.0°F (1.11°C) or between 40.0°F (4.44°C) and 42.0°F (5.56°C). Reduced point values are scaled linearly, as shown in Figure 6.

b. The refrigerator volume published in the manufacturer's specifications shall be a minimum of 6.0 ft^3 (170 L).

c. The refrigerator may be used to store food and beverages.



Full points:	34 °F	(1.1 °C)	≤	Temperature	≤	40 °F	(4.4 °C)
Reduced points:	32 °F	(0 °C)	<	Temperature	<	34 °F	(1.1 °C)
or	40 °F	(4.4 °C)	<	Temperature	<	42 °F	(5.6 °C)
No points:				Temperature	≤	32 °F	(0 °C)
or				Temperature	≥	42 °F	(5.6 °C)

Figure 5: Scoring function for the Refrigerator Subcontest

7-2. Freezer

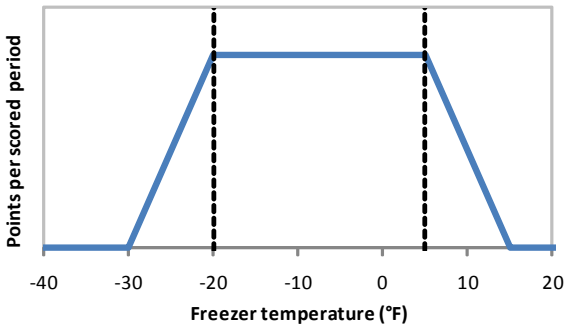
All available points are earned at the conclusion of each scored period by keeping the time-averaged interior temperature of a freezer between -20.0°F (-28.9°C) and 5.0°F (-15.0°C) during the scored period. See Appendix A-3 for the schedule of scored periods and for the number of available points per scored period.

a. Reduced points are earned if the time-averaged interior freezer temperature is between -30.0°F (-34.4°C) and -20.0°F (-28.9°C) or between 5.0°F (-15.0°C) and 15.0°F (-9.44°C). Reduced points are scaled linearly, as shown in Figure 7.

b. The freezer volume published in the manufacturer's specifications shall be a minimum of 2.0 ft^3 (57 L).

c. The automatic defrost function may be disabled.

d. The freezer may be used to store food and only enough ice to fill the freezer's ice bin (or equivalent).



Full points:	-20 °F	(-29 °C)	≤	Temperature	≤	5 °F	(-15 °C)
Reduced points:	-30 °F	(-34 °C)	<	Temperature	<	-20 °F	(-29 °C)
or	5 °F	(-15 °C)	<	Temperature	<	15 °F	(-9.4 °C)
No points:				Temperature	≤	-30 °F	(-34 °C)
or				Temperature	≥	15 °F	(-9.4 °C)

Figure 6: Scoring function for the Freezer Subcontest

7-3. Clothes Washer

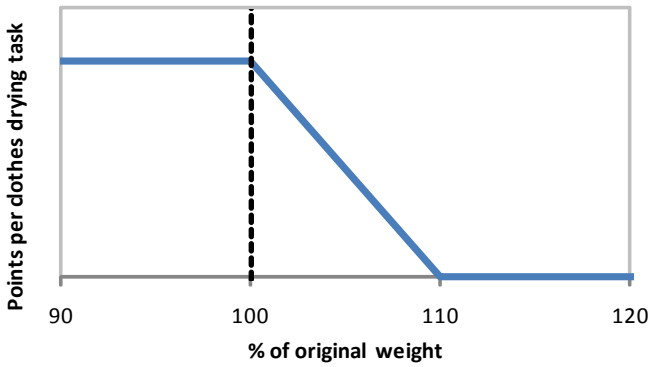
All available points are earned for washing laundry by running a clothes washer through one or more complete, uninterrupted, "normal" (or equivalent) cycles within a specified period of time. See Appendix A-3 for specific details regarding the number of points per clothes-washing task and the time periods designated for clothes-washing tasks.

a. A load of laundry is defined as six organizer-supplied bath towels.
b. The clothes washer shall operate automatically and have at least one wash and rinse cycle.
c. One or more complete, uninterrupted, "normal" (or equivalent) cycles in an automatic clothes washer shall be used to wash the laundry.
d. On several days during contest week, two loads of laundry are required to be washed. Teams have the option to combine double loads and wash them in one clothes washer cycle.
e. The drying function in a combination washer/dryer shall be disabled until the observer can verify that the laundry is wet after the completion of the wash and rinse cycle.
f. Cycle "interruption" includes the adjustment of supply temperature or flow in a manner not anticipated by the manufacturer or addressed in its operation manual.
g. Cycle completion shall be confirmed by the observance of an audible or visible signal.
h. The organizers will consult the operation manual to identify appropriate cycle settings. "Normal" or "regular" settings shall be selected, if available. Otherwise, settings most closely resembling typical "normal" or "regular" settings shall be selected.

7-4. Clothes Drying

All available points are earned by returning a load of laundry (defined as six organizer-supplied bath towels) to a total weight less than or equal to the towels' total weight before washing. Clothes drying shall be completed within a specified period of time. See Appendix A-3 for specific details regarding the number of points per clothes drying task and the time periods designated for laundry tasks.

a. Reduced points are earned if the "dry" towel weight is between 100.0% and 110.0% of the original towel weight. Reduced point values are scaled linearly, as shown in Figure 8.
b. A load of laundry is eligible for clothes-drying points only if the load experienced a complete, uninterrupted cycle (see Contest 7-3h for required cycle settings) in an automatic clothes washer.
c. The drying method may include active drying (e.g., machine drying), passive drying, (e.g., on a clothesline), or any combination of active and passive drying. All drying methods that require the towels to be visible (such as on a clothesline) must be demonstrated to the Architecture and Market Appeal juries as they visit the houses.
d. On several days during contest week, two loads of laundry are required to be dried. Teams have the option to combine double loads and dry them in one clothes-drying cycle, but each load will be scored separately.



Full points:		% of original weight	≤ 100
Reduced points:	100 <	% of original weight	< 110
No points:		% of original weight	≥ 110

Figure 7: Scoring function for the Clothes Drying Subcontest

7-5. Dishwasher

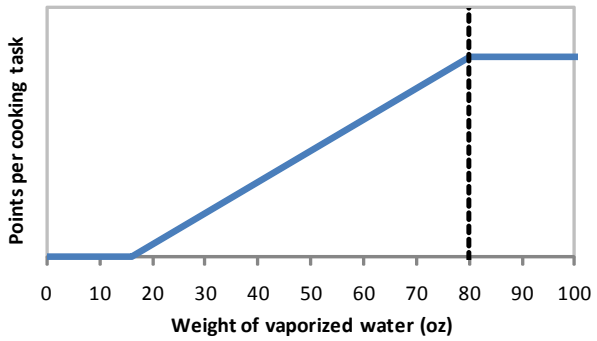
All available points are earned by running a dishwasher through a complete, uninterrupted, "normal" (or equivalent) cleaning cycle within a specified period of time, during which a temperature sensor placed in the dishwasher must reach 120°F (48.9°C) at some point during the cycle. See Appendix A-3 for specific details regarding the number of points per dishwashing task and the time periods designated for dishwashing tasks.

a. Half of the available points are earned if the temperature sensor reaches 115°F (46.1°C), but does not reach 120°F (48.9°C).
b. For redundancy, two temperature sensors shall be placed in the dishwasher for each test. The higher of the two readings is the temperature of record, unless it is determined that the sensor with the higher reading is defective, in which case the lower of the two readings is the temperature of record.
c. The dishwasher shall operate automatically, have at least one wash and rinse cycle, and have a minimum capacity of eight place settings according to the manufacturer's specifications.
d. If the dishwasher has a heated drying option, this option shall be disabled.
e. Cycle "interruption" includes the adjustment of supply temperature or flow in a manner not anticipated by the manufacturer or addressed in its operation manual, including the disruption of an ordinary cycle due to user interaction.
f. Cycle completion shall be confirmed by the observance of an audible or visible signal.
g. The teams shall consult the operation manual to identify appropriate cycle settings. The setting chosen shall be a complete wash cycle. "Normal" or "regular" settings shall be selected, if available. Otherwise, settings most closely resembling typical "normal" or "regular" settings shall be selected.
h. The dishwasher may be run empty, partially loaded, or fully loaded; the load may be soiled or clean.

7-6. Cooking

All available points are earned by using a kitchen appliance to vaporize 5.000 lb (80.00 oz or 2.268 kg) of water within a specified period of time. See Appendix A-3 for specific details regarding the number of points per cooking task and the time periods designated for cooking tasks.

a. Reduced points are earned if between 1.000 lb (16.00 oz or 0.454 kg) and 5.000 lb (80.00 oz or 2.268 kg) are vaporized. Reduced point values are scaled linearly, as shown in Figure 9.
b. Any kitchen appliance may be used, but it must operate in its normal configuration as it is vaporizing the water.
c. The water shall be vaporized in a single container and the starting water weight shall be at least 96.00 oz (2.721 kg).



Full points:	Weight ≥ 80 oz (2300 g)
Reduced points:	16 oz (450 g) < Weight < 80 oz (2300 g)
No points:	Weight ≤ 16 oz (450 g)

Figure 8: Scoring function for the Cooking Subcontest

Contest 8. Home Life

8-1. Lighting

All available points are earned for keeping all interior and exterior house lights on during specified periods of time. See Appendix A-3 for specific details regarding the number of points per lighting task and the time periods designated for lighting tasks.

Exception: Lights located within manufactured residential appliances such as a refrigerator, clothes dryer, microwave, and oven that are intended to illuminate the interior of the appliance are not required to be illuminated. Lights that are not designed to be connected to the house electrical system are not required to be illuminated.

a. All dimmers shall be adjusted to their highest positions and all other lighting control equipment shall be disabled or overridden so that the controlled lamps are fully and continuously on during the specified periods.

b. Partial credit will be awarded for partial compliance.

8-2. Hot Water

Hot water draws will occur at the approximate times specified in Appendix A-3. For each draw, at least 15 gal (56.8 L) of hot water shall be delivered in no more than 10 minutes to qualify for points. All available points are earned by delivering an average temperature of at least 110°F (43.3°C). An average temperature below 100°F (37.8°C) earns no points. For temperatures between 100°F (37.8°C) and 110°F (43.3°C), points are scaled linearly, as shown in Figure 10.

a. These hot water draws are designed to simulate most of the washing and bathing tasks that would take place in a typical day. *Note: The dishwashing task is not simulated by these hot water draws because it occurs in a different contest.*

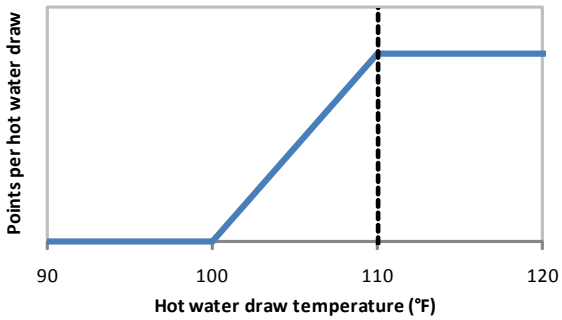
b. The schedule for hot water draws will vary from one day to the next, just as it does in a typical home.

c. The maximum number of hot water draws for one day will not exceed three, but they may occur consecutively.

d. For fairness, all teams will be drawing hot water on nearly identical schedules.

e. Hot water will be drawn from the shower. Teams shall replace their showerhead with an organizer-supplied fitting prior to the start of the contest. If a house has multiple showers, the shower expected to be used most frequently by the occupants will be used for the hot water draws.

f. Teams shall provide a male, 0.5 in. (1.27 cm) National Pipe Thread Tapered Thread (NPT) to accept the organizer equipment.



Full points:	Temperature ≥ 110 °F (43.3 °C)
Reduced points:	100 °F (37.8 °C) < Temperature < 110 °F (43.3 °C)
No points:	Temperature ≤ 100 °F (37.8 °C)

Figure 9: Scoring function for the Hot Water Contest

8-3. Home Electronics

All available points are earned for operating a television (TV) and computer during specified periods of time. See Appendix A-3 for specific details regarding the number of points per home electronics task and the time periods designated for home electronics tasks.

a. The TV display shall be a minimum of 27 in. (68.6 cm) according to the manufacturer's stated display size. The computer display shall be a minimum of 15 in. (38.1 cm) according to the manufacturer's stated display size. The computer may be a laptop or desktop computer. The TV and computer displays shall be able to be operated simultaneously and controlled independently of each other.

b. The organizers will supply content that must be shown on the TV display during the home electronics tasks. There is no required volume setting, but the brightness of the display shall be set to at least 75% of maximum. Observers will conduct spot checks to verify that the TV is showing the supplied content and that the brightness is at the required level.

c. The organizers will supply content that must be shown on the computer display during the scored periods. A decathlete may temporarily suspend the supplied content to use the computer for other practical purposes, but the display of supplied content shall be resumed whenever the computer is not being used for other practical purposes. The brightness of the display shall be set to at least 75% of maximum. Observers will conduct spot checks to verify that the computer is either showing the supplied content or is being used by a decathlete, and that the brightness is at the required level.

8-4. Dinner Party

Each team shall host two dinner parties for its neighbors during contest week. See Appendix A-3 for the dinner party schedule and the number of available points per dinner party. Dinner parties will feature a pair of guest decathletes from each of three competing teams. To earn full points for the dinner party, teams shall:

a. Host at least eight individuals for the dinner party—two decathletes from each of three other teams and up to two VIP guests. VIP guests may include organizers, media, government employees, family members, or other individuals approved by the organizers to attend the dinner parties. If VIP guests do not participate, at least two host team decathletes shall participate in the dinner party.

b. Meet all house occupancy rules described in Rule 11-1c for the dinner party.

c. Have two decathletes attend each of the assigned houses for the duration of the dinner party period as indicated in Appendix A-3. While in attendance, decathletes shall participate in the meal and act respectfully.

d. Serve a complete meal with an adequate amount of food for all guests, at appropriate serving temperatures, and in a timely manner within the dinner party period as indicated in Appendix A-3.

e. Serve a unique meal at each dinner party.

f. Ensure that team decathletes in the house during the dinner party are performing one or more of the following three functions: 1) eating the meal; 2) cooking/preparing the food; or 3) operating the house during scheduled Contest 6, 7, or 8 activities.

g. Prepare and cook all food and beverages in the house during the period of time indicated in Appendix A-3. A file describing eligible and ineligible ingredients is posted in the "/Files/Rules/Rules Reference Documents" folder on the Yahoo Group.

h. Serve and have guests eat the meal in the finished square footage at the eating area designated in the drawings.
i. Submit to the organizers detailed dinner party menus, recipes, and ingredient lists that accurately reflect the meal served for each dinner party.
j. Shall comply with the following safety requirements:
    i. The use of flames, including candle flames, is prohibited during contest week (see Rule 8-2b).
    ii. No alcoholic beverages may be stored in the house, used in meal preparation, served, or part of a meal in any way.
    iii. All water used for cooking and drinking shall be drinking water purchased in sealed containers.
    iv. Prior to use for the Dinner Party, all dishes and cookware shall be washed with hot water and soap and rinsed prior to use.
    v. Normal domestic wastewater may go into the wastewater tank.
    vi. All beverages and food must be stored properly and according to the instructions on the packaging, e.g., beverages and foods marked "refrigerate after opening" must be refrigerated appropriately after opening.
    vii. To help prevent allergic reactions among dinner party guests, teams shall create a list of ingredients for each of the items being served at each meal. Common food allergies include milk/dairy products, eggs, peanuts, tree nuts (walnuts, cashews, pecans), fish, shellfish, soy, wheat, and gluten.
    viii. Outdoor cooking and grilling equipment may be incorporated into the competition prototype, but the use of such equipment is prohibited on the competition site.
    ix. The use of coolers to store food, beverages, or ice associated with the dinner party on site is not permitted. Coolers may be used for transporting food to the competition site only.

8-5. Movie Night

Each team shall host a movie night for its neighbors during contest week. See Appendix A-3 for the movie night schedule and the number of available points for movie night. To earn full points for the movie night, teams shall:

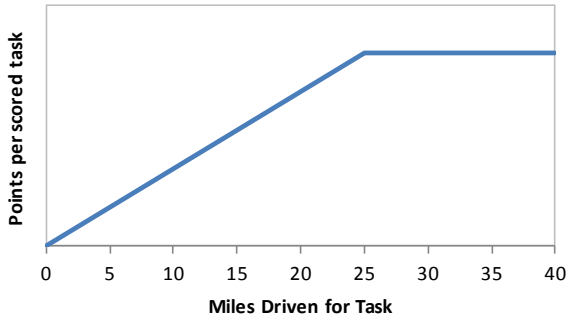
a. Host at least eight individuals for the movie night—two decathletes from each of three other teams and up to two VIP guests. VIP guests may include organizers, media, government employees, family members, or other individuals approved by the organizers to attend the dinner parties.
b. Have two decathletes attend each assigned house for the duration of the movie night period as indicated in Appendix A-3. While in attendance, decathletes shall participate and act respectfully.
c. Vote for one of three movies selected by the organizers via the poll posted to the Yahoo Group prior to the event. The movie receiving the most votes shall be provided by the organizers on the day of movie night and shall be the movie shown in all houses on movie night. The selected movie shall be available in several of the most popular video formats, so that each team may request the format most suitable for its home theater system.
d. Maintain normal audiovisual equipment settings throughout the duration of the subcontest. Observers or a small team of organizers, or both, will verify that these settings are maintained on movie night.

Contest 9. Commuting

Electric vehicle driving tasks will occur at the approximate times specified in Appendix A-3. Teams shall complete each task in no more than 120 minutes to qualify for points. All available points are earned by driving at least 25 miles (40.23 kilometers). For driving between 0 miles and 25 miles (40.23 kilometers), points for each task are scaled linearly, as shown in Figure 11.

a. These driving tasks are designed to simulate most of the transportation requirements that would take place for a household.
b. The schedule for the commuting tasks varies from one day to the next.

c. The vehicle must meet the requirements of Rule 4-8.
d. The vehicle must be driven by a decathlete who is licensed to operate a motor vehicle and accompanied by at least one passenger, who shall also be a decathlete.
e. Both the driver and the passenger must wear a seat belt and follow all applicable driving laws.
f. The electric vehicle may only be charged from the house electrical system. Any charging from alternate locations is considered a rules violation.



Full Points:		Miles Driven ≥ 25 miles
Reduced Points:	0 miles	< Miles Driven < 25 Miles
No Points:		Miles Driven = 0 Miles

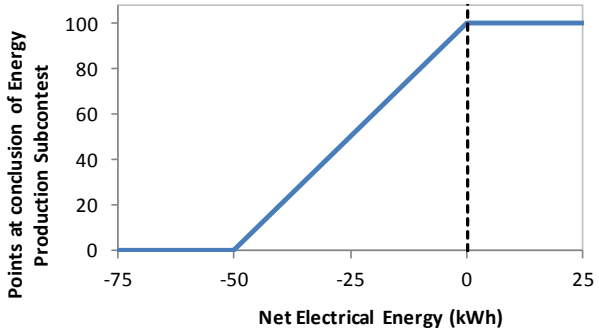
Figure 10: Scoring function for the Commuting Contest

Contest 10. Energy Balance

10-1. Energy Production

All available points are earned at the conclusion of the specified energy balance period (see Appendix A-3 for the energy balance schedule) for a net electrical energy balance of at least 0 kWh. A positive net electrical energy balance indicates net production; a negative net electrical energy balance indicates net consumption.

a. Reduced points are earned for a net electrical energy balance between -50 kWh and 0 kWh. Reduced points are scaled linearly, as shown in Figure 12.



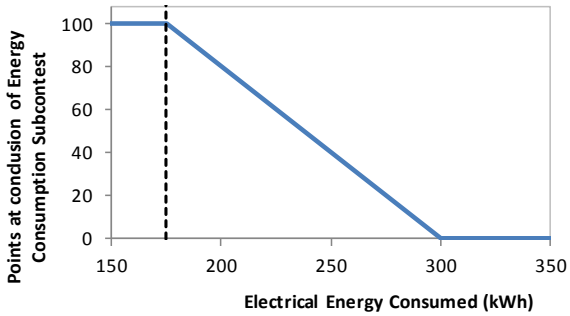
Full points:		Net electrical energy	≥	0 kWh
Reduced points:	-50 kWh <	Net electrical energy	<	0 kWh
No points:		Net electrical energy	≤	-50 kWh

Figure 11: Scoring function for the Energy Production Subcontest

10-2. Energy Consumption

All available points are earned at the conclusion of the specified energy balance period (see Appendix A-3 for the energy balance schedule) for a measured consumption of 175 kWh or less.

a. Reduced points are earned for measured electrical energy consumption between 175 kWh and 300 kWh. Reduced points are scaled linearly, as shown in Figure 13.



Full points:		Electrical Energy Consumed	≤ 175 kWh
Reduced points:	175 kWh <	Electrical Energy Consumed	< 300 kWh
No points:		Electrical Energy Consumed	≥ 300 kWh

Figure 12: Scoring function for the Energy Consumption Subcontest

Appendix A Event Schedules

A-1. Overview Event Calendar

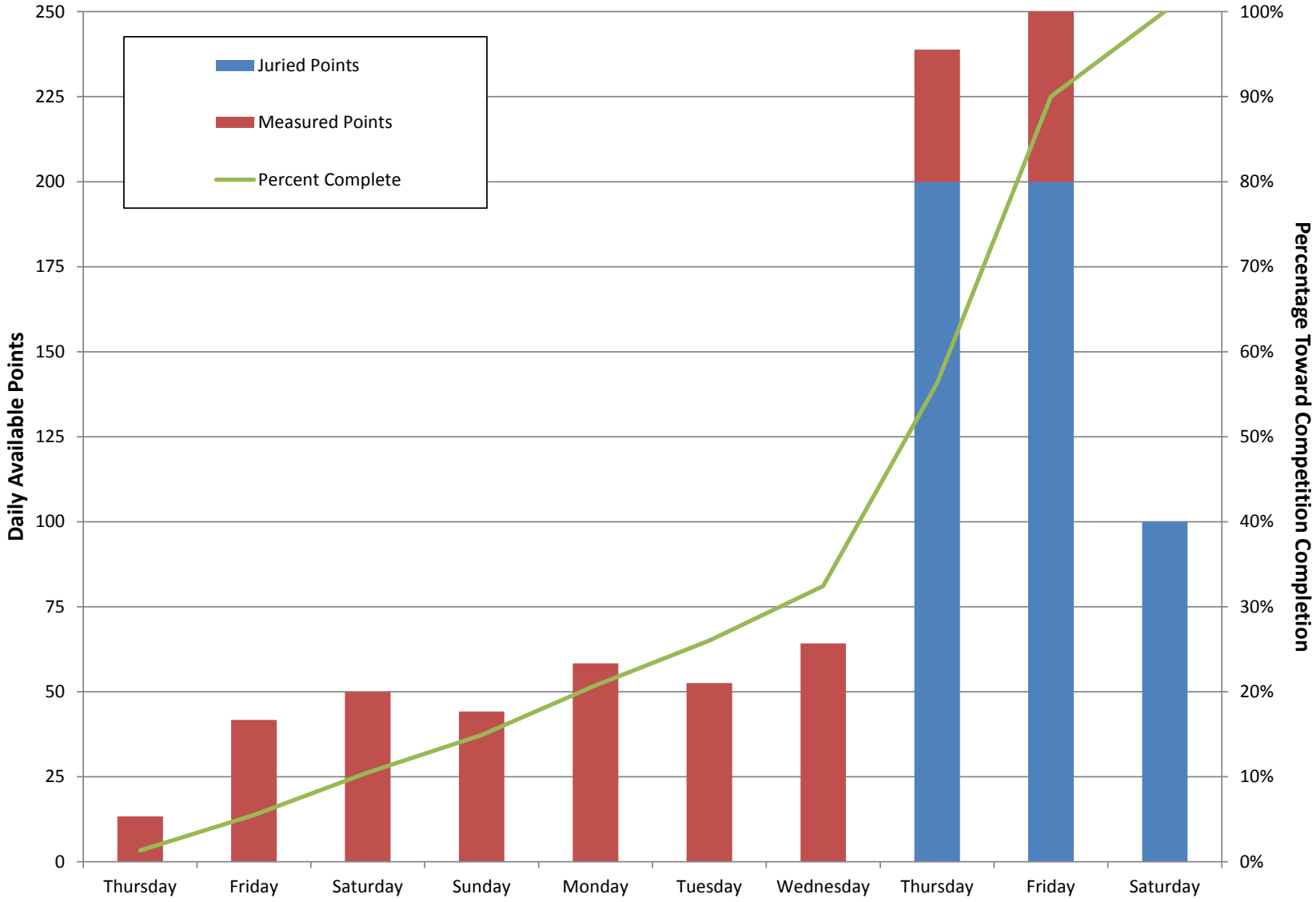
This calendar provides an overview of daily activities. Refer to the Detailed Event Schedule (Appendix A-3) for a complete list and schedule of daily activities.

SUNDAY	MONDAY	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY	SATURDAY
DAY 0 - SEPT 27	DAY 1 - SEPT 28	DAY 2 - SEPT 29	DAY 3 - SEPT 30	DAY 4 - OCT 1	DAY 5 - OCT 2	DAY 6 - OCT 3
REGISTRATION (12 p.m. - 2 p.m.; 4 p.m.-7 pm)	**REGISTRATION** (6:30 a.m. - 6:30 p.m. Daily)	IMPOUND (2 a.m. - 7 a.m.)	IMPOUND (2 a.m. - 7 a.m.)	IMPOUND (2 a.m. - 7 a.m.)	IMPOUND (2 a.m. - 7 a.m.)	IMPOUND (2 a.m. - 7 a.m.)
ALL-TEAM MEETING (2 p.m. - 4 p.m.)	**STAND-ALONE ASSEMBLY** (Begins at 7 a.m.)	**STAND-ALONE ASSEMBLY**	**STAND-ALONE ASSEMBLY**	**STAND-ALONE ASSEMBLY**	**STAND-ALONE or GRID-TIE ASSEMBLY** (Grid avaliable at 12:00 pm)	**STAND-ALONE or GRID-TIE ASSEMBLY**
VEHICLE STAGING (Permitted Sat. and Sun. from 8 a.m. to 6 p.m..)					**GRID-TIE ASSEMBLY AVAILABLE** (Grid avaliable at 12:00 pm)	
DAY 7 - OCT 4	DAY 8 - OCT 5	DAY 9 - OCT 6	DAY 10 - OCT 7	DAY 11 - OCT 8	DAY 12 - OCT 9	DAY 13 - OCT 10
IMPOUND (2 a.m. - 7 a.m.)	IMPOUND (2 a.m. - 7 a.m.)	IMPOUND (2 a.m. - 7 a.m.)	IMPOUND (12 a.m. - 7 a.m. & 11 p.m. - 12 a.m.)	IMPOUND (12 a.m. - 7 a.m. & 11 p.m. - 12 a.m.)	IMPOUND (12 a.m. - 7 a.m. & 11 p.m. - 12 a.m.)	IMPOUND (12 a.m. - 7 a.m. & 11 p.m. - 12 a.m.)
STAND-ALONE or GRID-TIE ASSEMBLY	**STAND-ALONE or GRID-TIE ASSEMBLY** (Until 12 p.m.)	**GRID-TIE ASSEMBLY** (Until 8 a.m.)	**REST DAY**	**CONTESTS** (11:00 a.m. - Midnight)	**CONTESTS** (24 hours)	**CONTESTS** (24 hours)
		FINAL SITE CLEANUP, STAGING AND SIGNAGE (8 a.m. - 12 p.m.)	**MEDIA PREVIEW** (10:30 a.m. - 2 p.m.)	**ALL TEAM PHOTO** (8:30 a.m. - 9 a.m.)		
WATER DELIVERY (8 a.m. - 5 p.m.)	**GRID-TIE ASSEMBLY** (After 12 p.m.)	**STOP WORK FOR LAST-CHANCE FINAL INSPECTIONS*** (No work to take place while teams wait for final inspections) (12 p.m.)	**OPENING REHEARSAL** (3 p.m. - 3:30 p.m.)	**OPENING CEREMONY** (9:30 a.m. - 11 a.m.)		
			OPENING RECEPTION (6 p.m. - 8:30 p.m.)	**PUBLIC EXHIBIT** (11 a.m. - 7 p.m.)	**PUBLIC EXHIBIT** (11 a.m. - 7 p.m.)	**PUBLIC EXHIBIT** (11 a.m. - 7 p.m.)
			TEAM OPEN HOUSE (8:30 p.m. - 11 p.m.)			
DAY 14 - OCT 11	DAY 15 - OCT 12	DAY 16 - OCT 13	DAY 17 - OCT 14	DAY 18 - OCT 15	DAY 19 - OCT 16	DAY 20 - OCT 17
IMPOUND (12 a.m. - 7 a.m. & 11 p.m. - 12 a.m.)	IMPOUND (12 a.m. - 7 a.m. & 11 p.m. - 12 a.m.)	IMPOUND (12 a.m. - 7 a.m. & 11 p.m. - 12 a.m.)	IMPOUND (12 a.m. - 7 a.m. & 11 p.m. - 12 a.m.)	IMPOUND (12 a.m. - 7 a.m. & 11 p.m. - 12 a.m.)	IMPOUND (12 a.m. - 7 a.m. & 11 p.m. - 12 a.m.)	IMPOUND (12 a.m. - 7 a.m. & 11 p.m. - 12 a.m.)
CONTESTS (24 hours)	**CONTESTS** (24 hours)	**CONTESTS** (24 hours)	**CONTESTS** (24 hours)	**CONTESTS** (24 hours)	**CONTESTS** (Midnight - 11a.m.)	**ENGINEERING RESULTS & AWARDS CEREMONY** (10:00 a.m. - 10:45 a.m.)
	JURY WALKTHROUGHS (7:30 a.m. - 12:30 p.m) and (7:30 p.m. to 9:30 p.m)	**JURY WALKTHROUGHS** (7:30 a.m. - 12:30 p.m) and (7:30 p.m. to 9:30 p.m)	**JURY WALKTHROUGHS** (7:30 a.m. - 10:00 a.m) and (7:30 p.m. - 8:30 p.m.)	**AFFORDABILITY & MARKET APPEAL RESULTS** (10:00 a.m. - 11 a.m.)	**COMMUNICATIONS & ARCHITECTURE RESULTS** (10:00 a.m. - 11 a.m.)	
PUBLIC EXHIBIT (11 a.m. - 7 p.m.)				**PUBLIC EXHIBIT** (11 a.m. - 7 p.m.)	**PUBLIC EXHIBIT** (11 a.m. - 7 p.m.)	**PUBLIC EXHIBIT** (11 a.m. - 7 p.m.)
					TEAM OPEN HOUSE (7:30 p.m. - 11 p.m.)	VICTORY CELEBRATION (7:30 p.m. - 10:30 p.m.)
DAY 21 - OCT 18	DAY 22 - OCT 19	DAY 23 - OCT 20	DAY 24 - OCT 21	DAY 25 - OCT 22	DAY 26 - OCT 23	
IMPOUND (12 a.m. - 7 a.m.)	IMPOUND (2 a.m. - 7 a.m.)	IMPOUND (2 a.m. - 7 a.m.)	IMPOUND (2 a.m. - 7 a.m.)	IMPOUND (2 a.m. - 7 a.m.)	IMPOUND (2 a.m. - 7 a.m.)	
PUBLIC EXHIBIT (11 a.m. - 7 p.m.)	**DISASSEMBLY**	**DISASSEMBLY**	**DISASSEMBLY**	**DISASSEMBLY**	**DISASSEMBLY**	
DISASSEMBLY (Begins at 7 p.m.)					**FINAL DISASSEMBLY INSPECTIONS** (7 p.m.)	
					ALL TEAMS OFF SITE (9 p.m.)	

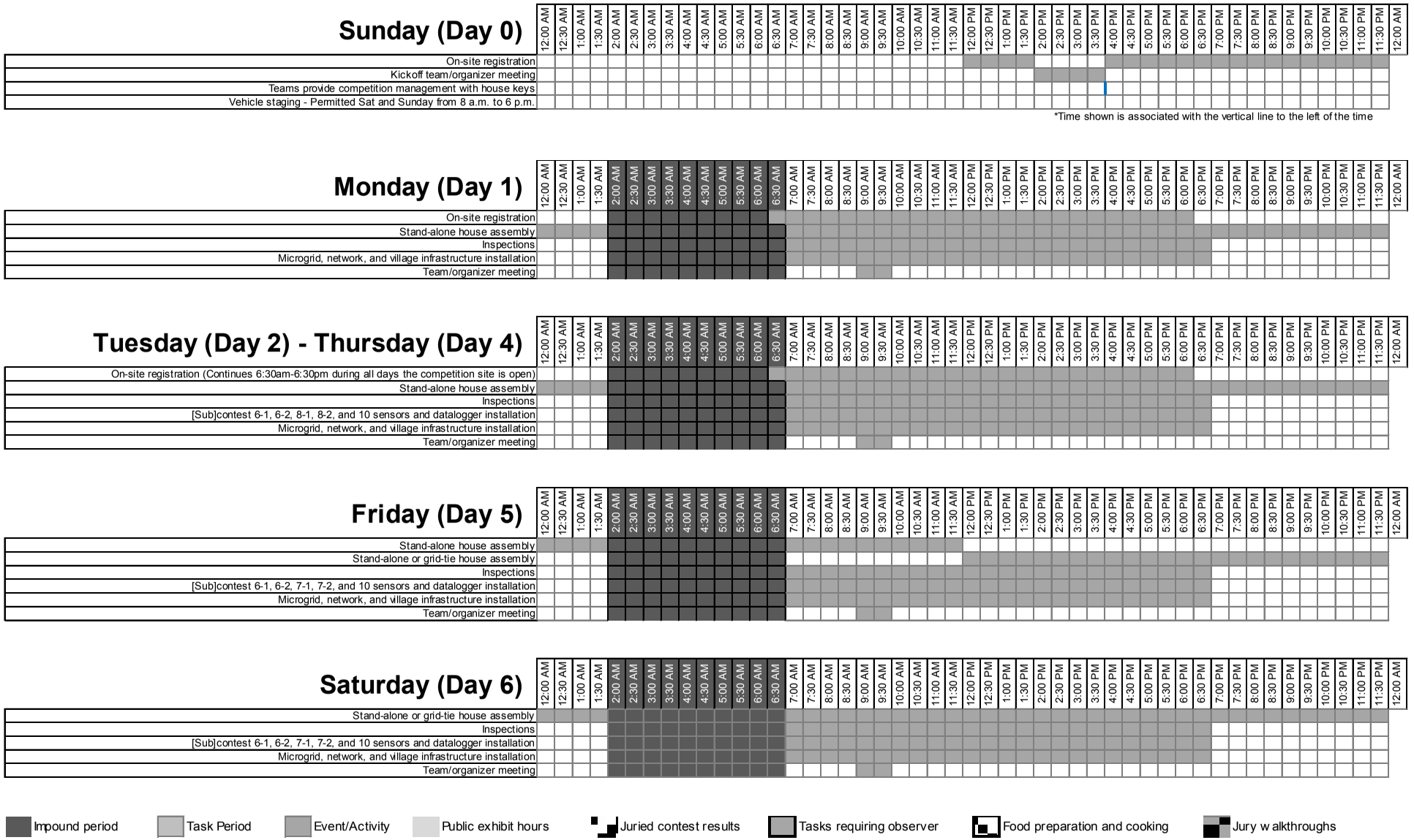
Last Updated On: 2014-06-09

* Significant precipitaiton or the occurrence of an unforeseen circumstance that equally affects all teams' progress during the assembly phase may result in a postponement of the last-chance final inspections. The remainder of the schedule will remain unchanged.

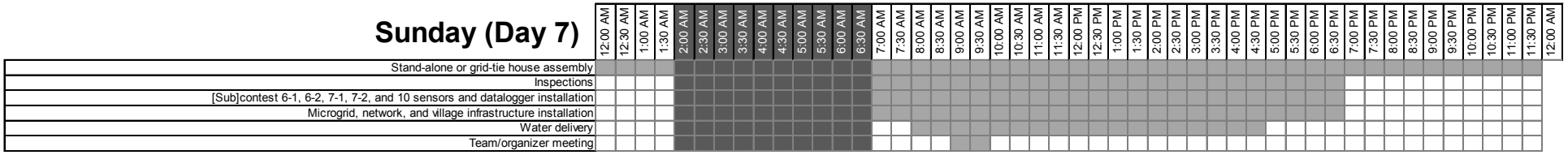
A-2. Scoring Chronology



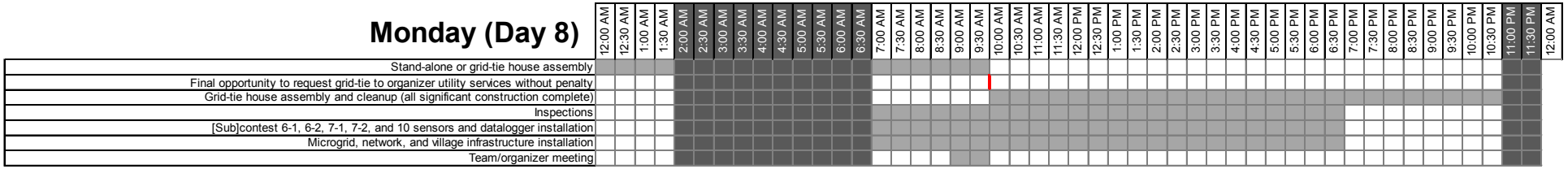
A-3. Detailed Event Schedule



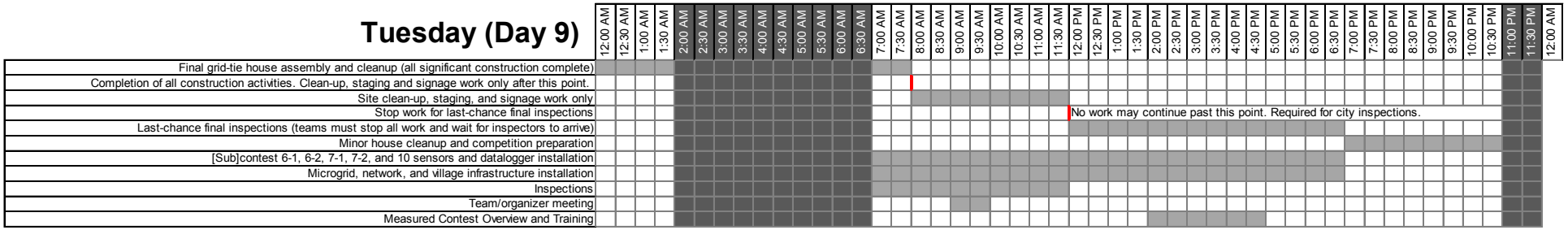
Sunday (Day 7)



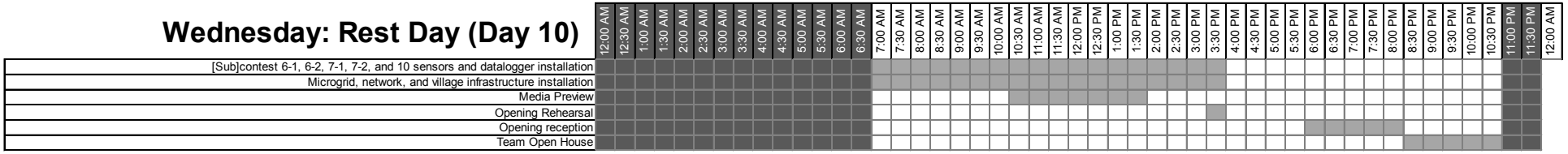
Monday (Day 8)



Tuesday (Day 9)



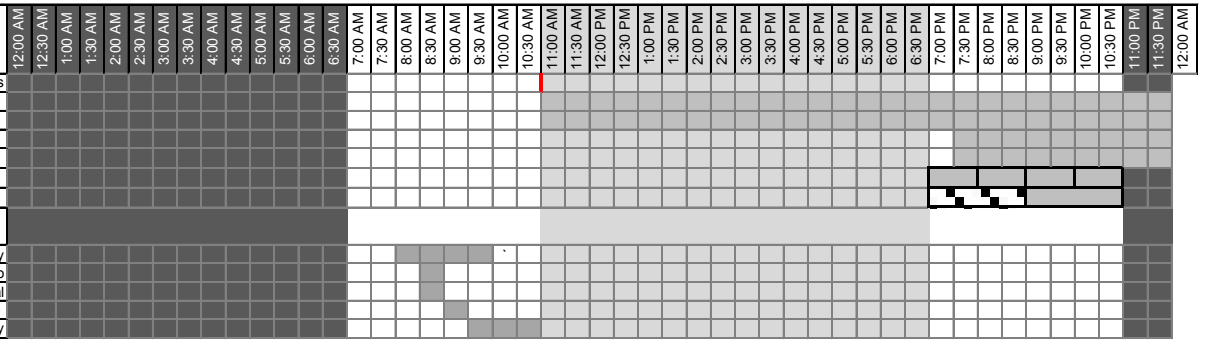
Wednesday: Rest Day (Day 10)



Impound period | Task Period | Event/Activity | Public exhibit hours | Juried contest results | Tasks requiring observer | Food preparation and cooking | Jury w alkthroughs

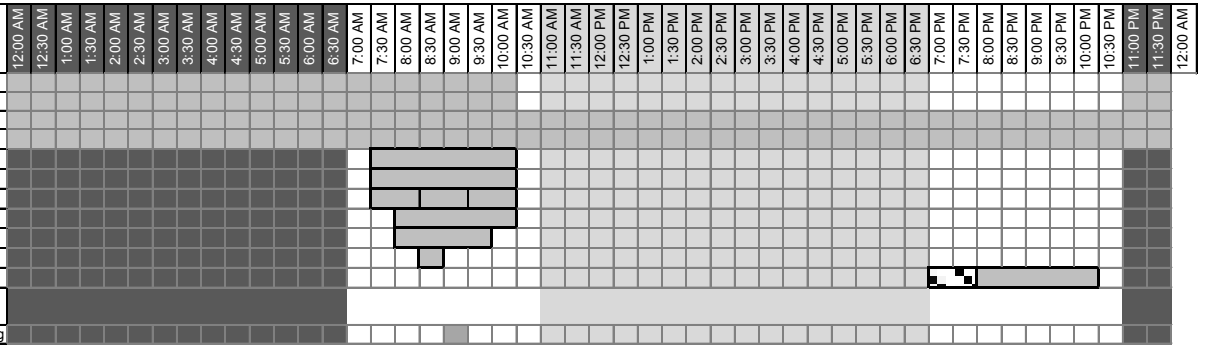
Thurs (Day 11)

	Rules Section	Contest Type	Total Pts Available	Total # of tasks or periods	Daily # of tasks or periods	Daily Points Available
Energy Balance Contest begins						
Refrigerator	C7-1	MEAS	10.000	766	52	0.679
Freezer	C7-2	MEAS	10.000	766	52	0.679
Temperature	C6-1	MEAS	75.000	574	18	2.352
Humidity	C6-2	MEAS	25.000	574	18	0.784
Lighting	C8-1	TASK	25.000	52	8	3.846
Dinner Parties	C8-4	SUBJ	10.000	2	1	5.000
DAILY AVAILABLE POINTS						**13.340**
CUMULATIVE AVAILABLE POINTS						**13.340**
House Photography						
All Team Photo						
Opening Ceremony Dress Rehearsal						
Opening ceremony line-up						
Opening ceremony						



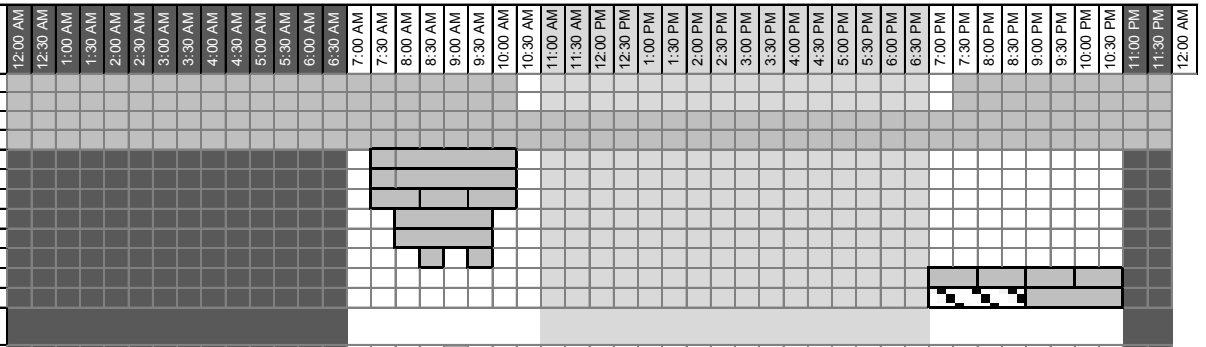
Fri (Day 12)

	Rules Section	Contest Type	Total Pts Available	Total # of tasks or periods	Daily # of tasks or periods	Daily Points Available
Temperature	C6-1	MEAS	75.000	574	46	6.010
Humidity	C6-2	MEAS	25.000	574	46	2.003
Refrigerator	C7-1	MEAS	10.000	766	96	1.253
Freezer	C7-2	MEAS	10.000	766	96	1.253
Clothes Washer	C7-3	TASK	16.000	8	1	2.000
Clothes Dryer	C7-4	TASK	32.000	8	1	4.000
Home Electronics	C8-3	TASK	10.000	34	3	0.882
Dishwasher	C7-5	TASK	17.000	5	1	3.400
Commuting	C9	TASK	100.000	8	1	12.500
Hot Water	C8-2	TASK	50.000	16	1	3.125
Movie Night	C8-5	SUBJ	5.000	1	1	5.000
DAILY AVAILABLE POINTS						**41.428**
CUMULATIVE AVAILABLE POINTS						**54.768**
Team/organizer meeting						



Sat (Day 13)

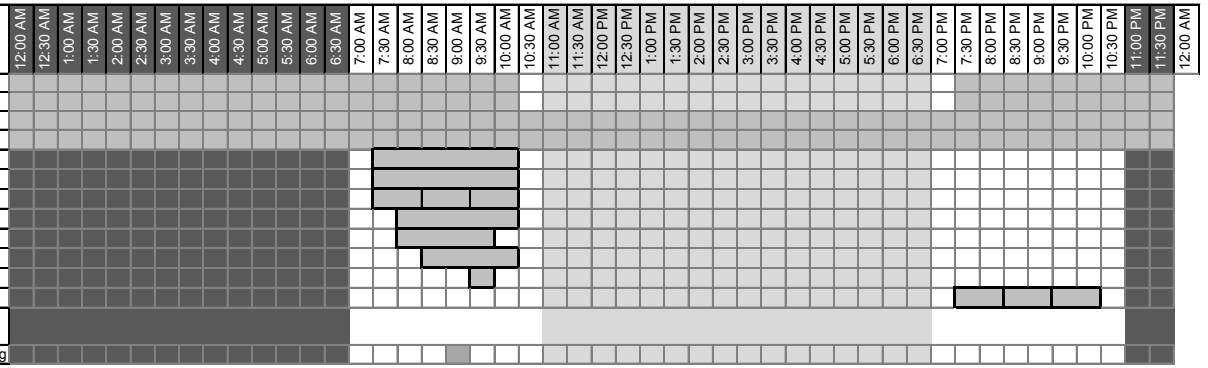
	Rules Section	Contest Type	Total Pts Available	Total # of tasks or periods	Daily # of tasks or periods	Daily Points Available
Temperature	C6-1	MEAS	75.000	574	60	7.840
Humidity	C6-2	MEAS	25.000	574	60	2.613
Refrigerator	C7-1	MEAS	10.000	766	96	1.253
Freezer	C7-2	MEAS	10.000	766	96	1.253
Clothes Washer	C7-3	TASK	16.000	8	1	2.000
Clothes Dryer	C7-4	TASK	32.000	8	1	4.000
Home Electronics	C8-3	TASK	10.000	34	3	0.882
Cooking	C7-6	TASK	15.000	6	1	2.500
Commuting	C9	TASK	100.000	8	1	12.500
Hot Water	C8-2	TASK	50.000	16	2	6.250
Lighting	C8-1	TASK	25.000	52	8	3.846
Dinner Parties	C8-4	SUBJ	10.000	2	1	5.000
DAILY AVAILABLE POINTS						**49.938**
CUMULATIVE AVAILABLE POINTS						**104.706**
Team/organizer meeting						



Impound period | Task Period | Event/Activity | Public exhibit hours | Juried contest results | Tasks requiring observer | Food preparation and cooking | Jury w alkthroughs

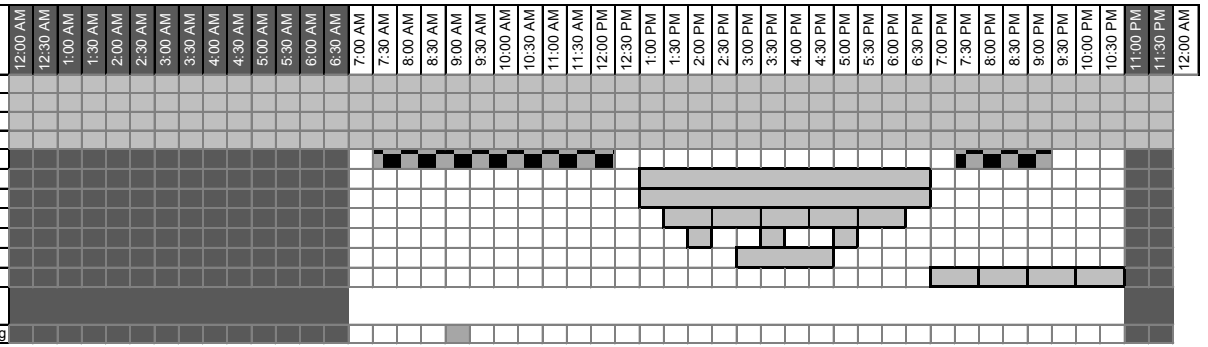
Sun (Day 14)

	Rules Section	Contest Type	Total Pts Available	Total # of tasks or periods	Daily # of tasks or periods	Daily Points Available
Temperature	C6-1	MEAS	75.000	574	60	7.840
Humidity	C6-2	MEAS	25.000	574	60	2.613
Refrigerator	C7-1	MEAS	10.000	766	96	1.253
Freezer	C7-2	MEAS	10.000	766	96	1.253
Clothes Washer	C7-3	TASK	16.000	8	1	2.000
Clothes Dryer	C7-4	TASK	32.000	8	1	4.000
Home Electronics	C8-3	TASK	10.000	34	3	0.882
Dishwasher	C7-5	TASK	17.000	5	1	3.400
Cooking	C7-6	TASK	15.000	6	1	2.500
Commuting	C9	TASK	100.000	8	1	12.500
Hot Water	C8-2	TASK	50.000	16	1	3.125
Lighting	C8-1	TASK	25.000	52	6	2.885
DAILY AVAILABLE POINTS						**44.251**
CUMULATIVE AVAILABLE POINTS						**148.957**
					Team/organizer meeting	



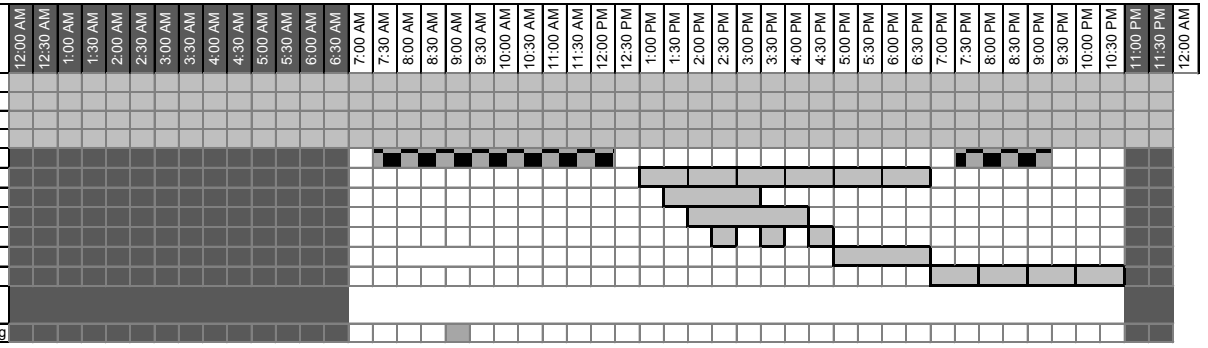
Mon (Day 15)

	Rules Section	Contest Type	Total Pts Available	Total # of tasks or periods	Daily # of tasks or periods	Daily Points Available
Temperature	C6-1	MEAS	75.000	574	96	12.544
Humidity	C6-2	MEAS	25.000	574	96	4.181
Refrigerator	C7-1	MEAS	10.000	766	96	1.253
Freezer	C7-2	MEAS	10.000	766	96	1.253
Jury Walkthroughs	C1,2,3,4	JURIED	-	-	-	-
Clothes Washer	C7-3	TASK	16.000	8	2	4.000
Clothes Dryer	C7-4	TASK	32.000	8	2	8.000
Home Electronics	C8-3	TASK	10.000	34	5	1.471
Hot Water	C8-2	TASK	50.000	16	3	9.375
Commuting	C9	TASK	100.000	8	1	12.500
Lighting	C8-1	TASK	25.000	52	8	3.846
DAILY AVAILABLE POINTS						**58.423**
CUMULATIVE AVAILABLE POINTS						**207.380**
					Team/organizer meeting	



Tues (Day 16)

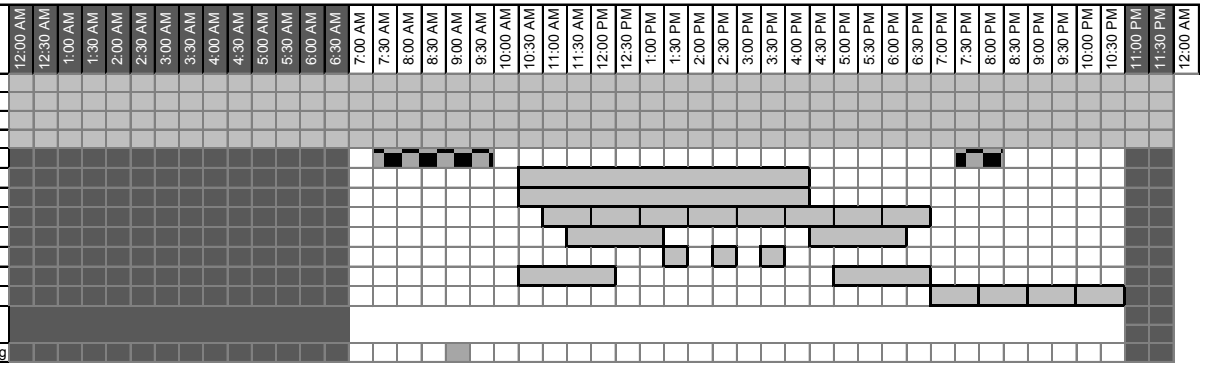
	Rules Section	Contest Type	Total Pts Available	Total # of tasks or periods	Daily # of tasks or periods	Daily Points Available
Temperature	C6-1	MEAS	75.000	574	96	12.544
Humidity	C6-2	MEAS	25.000	574	96	4.181
Refrigerator	C7-1	MEAS	10.000	766	96	1.253
Freezer	C7-2	MEAS	10.000	766	96	1.253
Jury Walkthroughs	C1,2,3,4	JURIED	-	-	-	-
Home Electronics	C8-3	TASK	10.000	34	6	1.765
Commuting	C9	TASK	100.000	8	1	12.500
Dishwasher	C7-5	TASK	17.000	5	1	3.400
Hot Water	C8-2	TASK	50.000	16	3	9.375
Cooking	C7-6	TASK	15.000	6	1	2.500
Lighting	C8-1	TASK	25.000	52	8	3.846
DAILY AVAILABLE POINTS						**52.617**
CUMULATIVE AVAILABLE POINTS						**259.997**
					Team/organizer meeting	



Impound period | Task Period | Event/Activity | Public exhibit hours | Juried contest results | Tasks requiring observer | Food preparation and cooking | Jury w alkthroughs

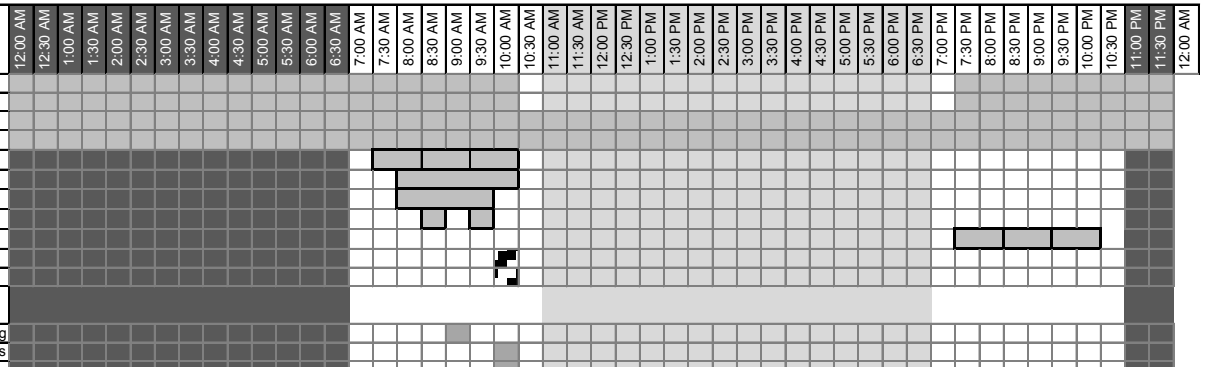
Weds (Day 17)

	Rules Section	Contest Type	Total Pts Available	Total # of tasks or periods	Daily # of tasks or periods	Daily Points Available
Temperature	C6-1	MEAS	75.000	574	96	12.544
Humidity	C6-2	MEAS	25.000	574	96	4.181
Refrigerator	C7-1	MEAS	10.000	766	96	1.253
Freezer	C7-2	MEAS	10.000	766	96	1.253
Jury Walkthroughs	C1,2,3,4	JURIED	-	-	-	-
Clothes Washer	C7-3	TASK	16.000	8	2	4.000
Clothes Dryer	C7-4	TASK	32.000	8	2	8.000
Home Electronics	C8-3	TASK	10.000	34	8	2.353
Cooking	C7-6	TASK	15.000	6	2	5.000
Hot Water	C8-2	TASK	50.000	16	3	9.375
Commuting	C9	TASK	100.000	8	2	25.000
Lighting	C8-1	TASK	25.000	52	8	3.846
DAILY AVAILABLE POINTS						**76.805**
CUMULATIVE AVAILABLE POINTS						**336.803**
Team/organizer meeting						



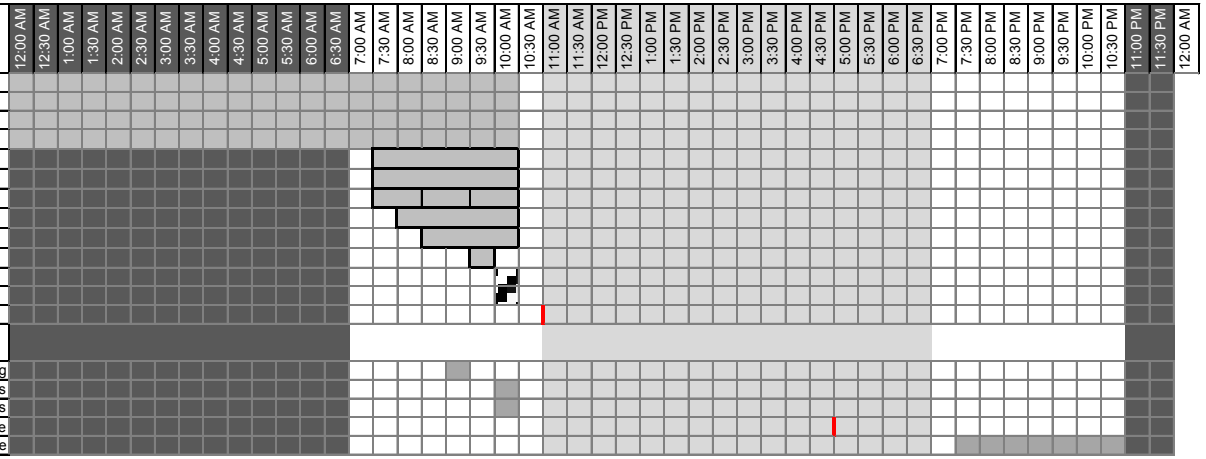
Thurs (Day 18)

	Rules Section	Contest Type	Total Pts Available	Total # of tasks or periods	Daily # of tasks or periods	Daily Points Available
Temperature	C6-1	MEAS	75.000	574	60	7.840
Humidity	C6-2	MEAS	25.000	574	60	2.613
Refrigerator	C7-1	MEAS	10.000	766	96	1.253
Freezer	C7-2	MEAS	10.000	766	96	1.253
Home Electronics	C8-3	TASK	10.000	34	3	0.882
Dishwasher	C7-5	TASK	17.000	5	1	3.400
Commuting	C9	TASK	100.000	8	1	12.500
Hot Water	C8-2	TASK	50.000	16	2	6.250
Lighting	C8-1	TASK	25.000	52	6	2.885
Market Appeal	C2	SUBJ	100.000	n/a	n/a	100.000
Affordability	C5	SUBJ	100.000	n/a	n/a	100.000
DAILY AVAILABLE POINTS						**238.876**
CUMULATIVE AVAILABLE POINTS						**575.679**
Team/organizer meeting						
Market Appeal contest awards						
Affordability contest awards						



Fri (Day 19)

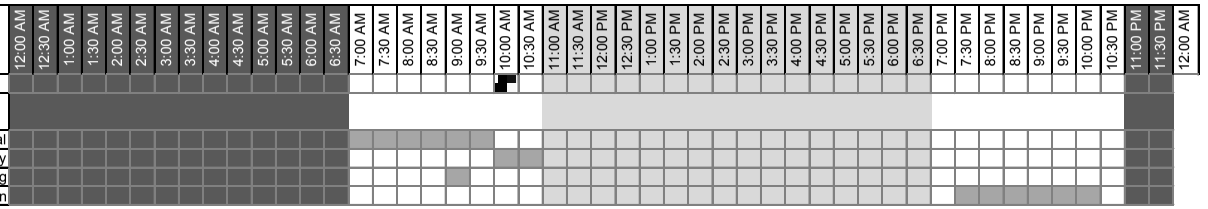
	Rules Section	Contest Type	Total Pts Available	Total # of tasks or periods	Daily # of tasks or periods	Daily Points Available
Temperature	C6-1	MEAS	75.000	574	42	5.488
Humidity	C6-2	MEAS	25.000	574	42	1.829
Refrigerator	C7-1	MEAS	10.000	766	42	0.548
Freezer	C7-2	MEAS	10.000	766	42	0.548
Clothes Washer	C7-3	TASK	16.000	8	1	2.000
Clothes Dryer	C7-4	TASK	32.000	8	1	4.000
Home Electronics	C8-3	TASK	10.000	34	3	0.882
Dishwasher	C7-5	TASK	17.000	5	1	3.400
Cooking	C7-6	TASK	15.000	6	1	2.500
Hot Water	C8-2	TASK	50.000	16	1	3.125
Architecture	C1	SUBJ	100.000	n/a	n/a	100.000
Communications	C4	SUBJ	100.000	n/a	n/a	100.000
Energy Balance	C10	MEAS	100.000	n/a	n/a	100.000
DAILY AVAILABLE POINTS						**324.321**
CUMULATIVE AVAILABLE POINTS						**900.000**
Team/organizer meeting						
Architecture contest awards						
Communications contest awards						
Final Protest Submission Deadline						
Team Open House						



Impound period | Task Period | Event/Activity | Public exhibit hours | Juried contest results | Tasks requiring observer | Food preparation and cooking | Jury w alkthroughs

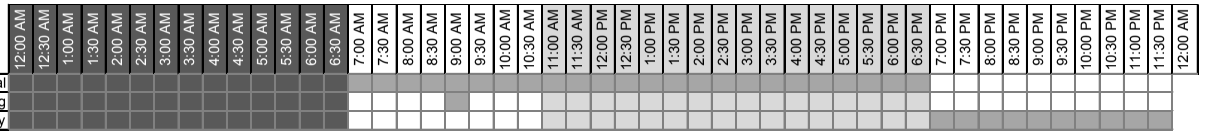
Sat (Day 20)

	Rules Section	Contest Type	Total Pts Available	Total # of tasks or periods	Daily # of tasks or periods	Daily Points Available
Engineering Contest Awards	C3	SUBJ	100.000	n/a	n/a	100.000
DAILY AVAILABLE POINTS						**100.000**
CUMULATIVE AVAILABLE POINTS						**1000.000**
Contest instrumentation removal						
Engineering contest and overall competition awards ceremony						
Team/organizer meeting						
Victory Celebration						



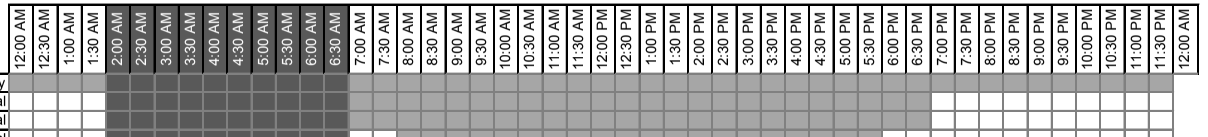
Sunday (Day 21)

- [Sub]contest 6-1, 6-2, 8-1, 8-2, and 10 sensors and datalogger removal
- Team/organizer meeting
- Stand-alone house disassembly



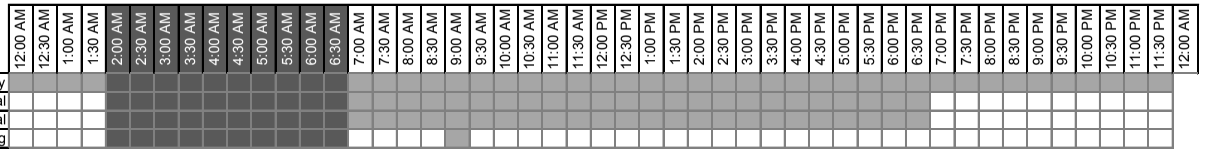
Monday (Day 22)

- Stand-alone house disassembly
- [Sub]contest 6-1, 6-2, 8-1, 8-2, and 10 sensors and datalogger removal
- Microgrid, network, and village infrastructure removal
- Water removal
- Team/organizer meeting



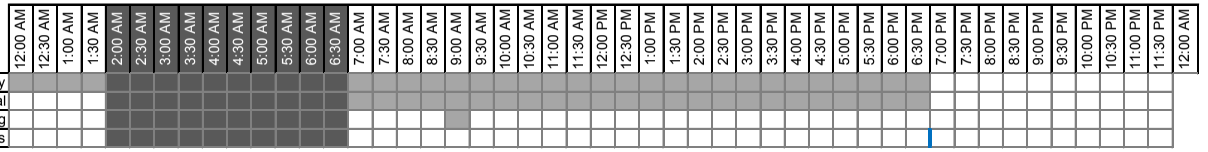
Tuesday (Day 23) - Thursday (Day 25)

- Stand-alone house disassembly
- [Sub]contest 6-1, 6-2, 8-1, 8-2, and 10 sensors and datalogger removal
- Microgrid, network, and village infrastructure removal
- Team/organizer meeting



Friday (Day 26)

- Stand-alone house disassembly
- Microgrid, network, and village infrastructure removal
- Team/organizer meeting
- Final disassembly inspections



Impound period | Task Period | Event/Activity | Public exhibit hours | Juried contest results | Tasks requiring observer | Food preparation and cooking | Jury w alkthroughs

Appendix B Juried Contest Guidelines

B-1. Juror Guidelines

A jury's evaluation of each team's project consists of the following three phases:

1. Deliverables review
2. On-site walkthroughs
3. Deliberation

Table 4: Juror time commitments for deliverables review and on-site walkthroughs

Jury	Time Commitment for Deliverables Review (per team)	Relevant Deliverables for Review	Time Commitment for On-Site Walkthrough (per team)
Architecture	1-2 hours	1. Drawings[8] 2. Construction specifications[9] 3. Audiovisual presentation[10] 4. Architecture narrative[11]	30 minutes (daytime) 10 minutes (nighttime)
Market Appeal	1 to 2 hours	1. Drawings[8] 2. Construction specifications[9] 3. Audiovisual presentation[10] 4. Market appeal narrative[11]	30 minutes
Engineering	1 to 2 hours	1. Drawings[8] 2. Construction specifications[9] 3. Energy analysis results and discussion[12] 4. Audiovisual presentation[10] 5. Engineering narrative[11]	30 minutes
Communications	1 to 2 hours	1. Website[13] 2. Audiovisual presentation[10] 3. Public exhibit presentation and materials[14] 4. Communications narrative[11]	30 minutes

Phase 1: Deliverables Review

Each juror will review the deliverables outlined in Table 4 to explore the relevant details of each team's project. If questions arise during the deliverables review phase, jurors may address those questions to the appropriate contest official before or during the event.

Phase 2: On-Site Walkthroughs

The on-site walkthroughs take place on the competition site and offer the jurors an opportunity to make visual verifications of information presented in the deliverables and to ask the decathletes for clarification of questions that may have arisen during the deliverables review. The logistical details of the on-site walkthroughs will be provided to each juror by the contest official prior to the juror's arrival on the competition site.

[8] See Appendix D-4 for drawings requirements.
[9] The construction specifications are located in the project manual. See Appendix D-5 for project manual requirements.
[10] See Appendix D-7 for audiovisual presentation requirements.
[11] See Appendix D-6 for jury narrative requirements.
[12] The energy analysis results and discussion is located in the engineering jury narrative.
[13] See Appendix D-8 for website requirements.
[14] See Appendix B-3 for public exhibit presentation requirements and Appendix D-10 for public exhibit materials requirements.

Phase 3: Deliberation

STEP #1

During the deliberation phase, which takes place after the completion of on-site walkthroughs, the jury is encouraged to place each team into one of four classes based on each team's performance relative to the contest criteria. The four classes are:

Class #1: ECLIPSES contest criteria 91% – 100% of available points

Class #2: EXCEEDS contest criteria 81% – 90% of available points

Class #3: EQUALS contest criteria 61% – 80% of available points

Class #4: APPROACHES contest criteria 0% – 60% of available points

Juries are not required to place a uniform number of teams in all classes or to place at least one team in every class. For example, if a jury determines that no teams are worthy of Class #1, there would be no teams with scores greater than 90%.

If it is possible to further separate teams within a particular class, assigning different percentage integers within the allowed range of the particular class is encouraged. The assigned percentage integer may fall anywhere within the range associated with the class. If it is not possible to further separate teams within a particular class, it may be appropriate to assign each team in a particular class the same percentage integer.

STEP #2

After assigning each team a percentage integer from 0% to 100%, the jury shall submit its percentage integers to the contest official. The contest official will then submit the percentages to the competition manager, who will convert them into a score based on the total number of available points for the contest being judged. The competition manager will round off any noninteger percentage scores to the nearest integer. Prior to posting scores in the scoring server, the scorekeeper will apply any applicable penalties that may have been incurred.

STEP #3

The three highest-scoring teams (plus ties) will be given awards during a scheduled announcement during contest week (see Appendix A for announcement schedule). Pending the jurors' availability, the organizers will invite the jurors to make the announcement. The scores for all of the teams will be posted immediately following the announcement.

STEP #4

The jury shall submit written or recorded scoring justifications for each team to the contest official. The jury's scoring justifications will be provided as feedback to each team so it might better understand the jury's evaluation. The justifications may be posted on the Solar Decathlon website.

B-2. Team Guidelines

a. It is ultimately the team's responsibility to be ready for the arrival of juries at the times indicated in the jury walkthrough schedule, which is available in the "/Files/Rules/Rules Reference Documents" folder on the Yahoo Group.

b. Teams shall show all possible configurations of the house during the walkthroughs of the Architecture, Market Appeal, and Engineering juries. House configurations that could affect the outcome of contests and that were not demonstrated to the juries are prohibited during contest week. Some examples of reconfigurable features include:

- A significant moveable component, such as a room, wall, or bed (safety plan must also be in place)
- Significant shading devices, such as retractable awnings or operable shutters
- Towel-drying locations
- Window coverings that may obstruct views or reduce light levels.

If a team does not have time to do a live reconfiguration during the jury walkthroughs, the team must use some other method, such as photographs or video, to show all reconfigurable features in their various configurations. If a team is not planning to actually reconfigure qualifying features at any time during

contest week and has not shown or described the reconfiguration in the drawings, project manual, audiovisual presentation, or video walkthrough, that team does not have to show the reconfiguration to the juries.

All plug-in or portable appliances that may be used during contest week must be in their fully deployed locations and configurations during the Architecture, Engineering, and Market Appeal jury walkthroughs. Also be aware that the Architecture, Engineering and Market Appeal juries may request plug-in, portable, or hardwired appliances to be turned on so they can evaluate noise levels or other characteristics of the appliances that may not be apparent when the appliances are off.

c. Rule 11-1, "House Occupancy," applies during jury walkthroughs. Non-decathlete team members and team crew shall not be present during the walkthroughs.

d. The jury walkthroughs will be held to a very strict schedule for each of the houses. The importance of following this schedule is twofold: 1) To ensure each team receives equal visitation time by the juries to maintain a sense of fairness among all the teams; and 2) Any deviation from the schedule will have an immediate effect on other events planned during the days the juries will be evaluating houses. A small deviation in the defined schedule for the juries could result in a very difficult situation to resolve in another component of the competition. If a team is not ready for a jury to begin its evaluation at the scheduled time, then the total time the jury spends in that team's house will be reduced.

e. During daytime jury walkthroughs, the jury will have 30 minutes to visit each house, followed by a 5-minute period to travel to the next house. During the 30-minute walkthrough, 20 minutes will be allocated for the team to lead the jury through the house and answer any questions the jury may have. After 20 minutes, the team shall leave the house so that the jury can hold a private, 10-minute discussion about the house it has just visited.

f. The Architecture Jury will visit each house a second time at night. During the nighttime walkthrough, the Architecture Jury will have 10 minutes to visit each house followed by a 5-minute period to travel to the next house. During the 10-minute walkthrough, 5 minutes will be allocated for the team to answer any questions the jury may have. Teams are permitted to adjust the house lighting during the Architecture Jury visit without consequence on the score for the Lighting Subcontest. After 5 minutes, the team shall leave the house so that the jury can hold a private, 5-minute discussion about the house it has just visited.

g. Presentation boards or other visual media summarizing information in the "Relevant Deliverables" (see the third column in Table 4) are permitted to be on display during jury walkthroughs. The team website, public exhibit handout, and public exhibit materials may only be viewed by the Communications Jury.

h. One or more of the eligible house occupants (see Rule 11-1 and item c above) may audiotape or videotape the jury walkthrough as it is happening, but taping of the private jury discussion period is prohibited.

i. Areas of the house excluded from the accessible exhibit route may be accessed by the juries and considered in their evaluations.

j. The organizers will provide all juries with summaries of important rule and code violations for each team so that juries are aware of violations before giving credit for aspects of the project that are not in compliance.

k. The organizers may provide juries with contents of the organizers' reviews of relevant deliverables.

B-3. Public Exhibit Requirements

The team shall prepare two versions of its public tour. Both versions will be evaluated by the Communications Jury.

Version #1: 10-Minute Personalized Tour

- The personalized tour is a comprehensive tour that addresses individual visitors' needs and questions and is appropriate for times when wait lines are short or nonexistent.
- Each team will be allowed 10 minutes to present the personalized tour to the Communications Jury.
- The version of the personalized tour given to the Communications Jury must represent the personalized tour presented to the public throughout the competition week.

Version #2: 5-Minute Fast Tour

- The 5-minute fast tour is a fast-yet-informative tour that allows visitors to move through the house on their own and accommodates large crowds and long lines.
- Each team will be allowed up to 5 minutes to describe the fast-yet-informative tour to the Communications Jury.
- The version of the fast tour described to the Communications Jury must represent the fast tour presented to the public throughout the competition week.

Common Requirements

- Both versions of the public tours shall be informative, interesting, and accessible by people of all abilities.
- In addition to the two tours described above, teams will be expected to present the team communications strategy, including brand management and outreach off the competition site to the Communications Jury.
- Teams are encouraged to employ effective and creative methods to control wait times and engage visitors waiting in line during public hours.
- The use of power-consuming devices, such as LCD displays, house lighting, mobile electronics, etc., shall not be included as part of the fast tour described the Communication Jury. Any power-consuming devices used during the personalized tour must be plugged into the house at all times when not in use.
- For additional information, see Rule 11-4.

Appendix C Measured Subcontest Guidelines

C-1. Monitored Performance Subcontests

Table 5 lists sensors used[15] in the "monitored performance" subcontests for which points are automatically awarded based on measurements made by each home's datalogger. Purchasing information is provided for teams intending to practice the contests before the competition using the same equipment that will be used by the organizers.

Table 5: Sensors used in "monitored performance" subcontests

Subcontest(s)	Sensor Type	Vendor	Model Number	Approx. Price
6-1. Temperature 6-2. Humidity	Wireless temperature/humidity probe	Point Six	3009-02-V5	$327
7-1. Refrigerator	Wireless RTD sensor	Point Six	3009-20-V4 and 1000-21	$408
7-2. Freezer	Wireless RTD sensor	Point Six	3009-20-V4 and 1000-21	$408
10-1. Energy Balance	Revenue wattnode	Continental Controls	TBD	$250
10-2. Energy Consumption	Revenue wattnode	Continental Controls	TBD	$250
10-1. Energy Production	Current transformers	TBD	TBD	$50
10-2. Energy Consumption	Current transformers	TBD	TBD	$50

Table 6 lists the central data acquisition equipment and associated accessories that collect sensor readings and transmit the data to the scoring server. Please refer to the documents[16] in the "/Files/Rules/Rules Reference Documents" folder on the Yahoo Group for detailed policies and procedures for accommodating competition instruments.

Table 6: Central data acquisition equipment

Equipment Description	Vendor	Model Number	Approx. Price
Datalogger enclosure	Hubbell-Wiegmann	ENC12/14-DC-NM	$235
Datalogger	Campbell Scientific	CR1000	$1,400
Power supply	Campbell Scientific	PS100	$225
Transformer	Campbell Scientific	9591	$50
Ethernet interface	Campbell Scientific	NL120	$220
Transceiver for wireless sensors	Point Six	4010-01	$636
Sensor wire and miscellaneous parts	Various	Various	$125

[15] The sensors and equipment listed here represent the expected solution, but may change as procedures are further developed. All sensors listed as TBD are expected to be determined by spring 2015.
[16] These documents are expected to be posted to the Yahoo Group in spring 2015.

C-2. Task Completion Subcontests

The "task completion" subcontests listed in Table 7 are classified as such because teams earn points by successfully completing a task that is observed by, and the results of which are recorded by, an observer in the "observer logs":

Table 7: Instruments and sensors used in "task completion" subcontests

Subcontest(s)	Instrument or Sensor Type	Vendor	Model Number	Approx. Price
7-3. Clothes Washer	Visual/audible inspection	n/a	n/a	n/a
7-4. Clothes Drying	Scale	Acculab	SVI-50C	$350
7-5. Dishwasher	Nonreversible temperature label	Omega	TL-5-105-10	$10 (pkg of 10)
7-6. Cooking	Kitchen scale	Salton	1008	$50
8-1. Lighting	Visual inspection	n/a	n/a	n/a
8-2. Hot Water	Multiple Components[17]	Constructed	None	$600
8-3. Home Electronics	Visual inspection	n/a	n/a	n/a
8-4. Dinner Party	Visual inspection	n/a	n/a	n/a
8-5. Movie Night	Visual inspection	n/a	n/a	n/a

Please refer to the "Measured Contest Procedures" slideshow[18] in the "/Files/Rules/Rules Reference Documents" folder on the Yahoo Group for detailed task completion subcontest policies and procedures as well as examples of observer logs.

[17] A detailed component list is expected to be posted to the Yahoo Group in spring 2015.
[18] This slideshow is expected to be posted in spring 2015.

Appendix D Competition Deliverables

The design deliverables consist of the schematic design summary, building information model, drawings, project manual, and audiovisual presentations. These design deliverables serve the following important functions:

- In its **schematic design summary**, the team shall disclose to the organizers all non-standard design features, communications strategies, site operations plans, and health and safety considerations that require further review prior to the continuation of the project into the design development phase.
- All the drawings shall be generated in an Autodesk Revit **building information model** compatible format.
- The **drawings and project manual** shall demonstrate compliance with the Solar Decathlon Building Code and the Solar Decathlon Rules so that the inspectors will be able to grant final on-site approval by verifying that the constructed project on the competition site was accurately represented by the approved drawings and project manual.
- The **drawings and project manual** shall clearly describe a team's proposed assembly and disassembly procedures. The site operations manager will review the teams' procedures to identify and address potential conflicts among the teams. Each team is encouraged to consult with the site operations manager as the relevant sections of the drawings and project manual are being developed.
- The **drawings and project manual** shall provide a residential contractor with all the information needed to generate an accurate, detailed cost estimate and to efficiently construct the building as the design team intended it to be built. The drawings and project manual must be comprehensive because the design team shall assume that the contractor has had no prior communication with the design team, has no prior knowledge of the design, and has little or no experience building high-performance residences.
- Because the juries have a very limited opportunity to evaluate the constructed projects on the competition site, the **drawings, project manual, audiovisual presentation, and jury narratives** provide the only means for a team to provide a detailed presentation of its project to the juries. In the weeks leading up to contest week, each juror shall evaluate the audiovisual presentation and sections of the teams' drawings and project manual relevant to the juror's respective area of expertise. The primary purpose of the juries' walkthroughs on the competition site is twofold: 1) to verify that the project, as assembled on the competition site, was accurately represented in the drawings, project manual, audiovisual presentations and narratives; and 2) to ask the decathletes any clarifying questions that arose during the evaluation of the design via the drawings, project manual, and audiovisual presentations.

Additional competition deliverables provided the information required to allow the organizers, juries, and public to develop a comprehensive understanding of each team's competition prototype.

D-1. Schematic Design Summary

The schematic design proposal will be reviewed by the organizers and discussed in detail during the schematic design review. It will not be reviewed by any juries and will not be made publicly available until after the completion of the competition.

Format Requirements

☐	Packaged into a single, bookmarked PDF file (see Appendix F for PDF formatting and file-naming requirements)
☐	Intent of figures shouldn't be lost if printed in black and white
☐	ANSI "A" (8.5 in. X 11 in.) sheet size and/or ANSI "D" (22 in. X 34 in.) sheet size
☐	20 to 30 pages, including figures and tables; cover sheet, table of contents, and appendices do not count toward page limit
☐	11-point body text
☐	Maximum 14-point heading text
☐	One-inch margins on top, bottom, left, and right
☐	Include page numbers and numbered captions for figures and tables for easy navigation through document.

Content Requirements

☐	Team mission statement (1 paragraph)
☐	Detailed strategy for winning the competition including a realistic contest-by-contest breakdown of points the team expects to earn (2 to 3 pages)
☐	Narrative describing the architectural and engineering design approaches (1 to 2 pages)
☐	Design drawings and written description of the following systems and components, with a focus on unique systems and components that may not be addressed by model building codes (12 to 17 pages): • Temporary foundations and anchors • Complete floor plans, including interior and exterior accessible tour route • Building sections • Exterior building structures, such as decks, outbuildings, and overhead structures • Ramps, railings, and guards • Glazing types and locations • Interior finishes • Fire protection • DC electrical • AC electrical • Water storage/service • Plumbing • Mechanical (includes HVAC) • Solar mechanical
☐	Description of public exhibit, communications, and outreach strategy (1 to 2 pages)
☐	Computer-generated renderings of competition prototype (5-6 images; images to be minimum 3000 px by 2400 px
☐	Health and Safety Plan outline including approach to meeting OSHA training requirement (1 to 2 pages)
☐	Identification and summary of qualifications for the licensed design professional who will be stamping the structural drawings and calculations (1 page).

D-2. Computer-Animated Walkthrough and Computer-Generated Renderings

Computer-Animated Walkthrough

Each team shall provide a computer-animated walkthrough of its house for the following purposes:

1. To be included in a compilation video of all Solar Decathlon 2015 walkthroughs that will be presented to the public and used in marketing materials associated with the project.
2. To be posted on the Solar Decathlon website as an introduction to each house.

Format Requirements

☐	Packaged into a single Quicktime .MOV or H.264 compressed MP4 (MPEG-4) file type using 720 x 480 resolution and 16:9 aspect ratio
☐	Runtime between 1 and 1.5 minutes
☐	Shall be accompanied by a verbatim transcript in a Microsoft Word-compatible format to meet Section 508 Accessibility standards.

Content Requirements

☐	Comprises animated computer renderings that demonstrate all aspects of the house
☐	Includes an audio narrative that explains to viewers what they're seeing and describes the philosophy behind the design
☐	Does not include elements that are inherently inaccessible to those with visual disabilities
☐	Does not contain background music that violates U.S. copyright laws; all incorporated music must be an original or royalty-free composition; proof of licensing shall be submitted with the final file and transcript.

Computer-Generated Renderings

The computer-generated renderings will be posted to the Solar Decathlon website and used in various communications materials to introduce the public to each competition prototype.

Format Requirements

☐	Minimum resolution of each image shall be 3000 px wide by 2400 px
☐	Composed of image files (JPEG, TIFF, etc.) packaged as one Zip (.zip) file.

Content Requirements

☐	Includes, at a minimum: • Two (2) elevation views of the competition prototype • One (1) birds-eye perspective view of the competition prototype • Two (2) interior views of the competition prototype.

D-3. Building Information Model (BIM)

The BIM is a deliverable that is due at the conclusion of the design development phase, at the conclusion of the construction documentation phase, and again just prior to the competition. Each iteration of the BIM shall include an increasing level of detail and refinement as the project progresses. Each will be used by the organizers for several purposes outlined in the Appendix D introduction above. The BIM will not be reviewed by any juries and may be made publicly available following each submission.

Format Requirements

☐	One (1) Autodesk Revit (.rvt)-compatible file or one (1) Autodesk Revit Architecture -compatible file with relative references to additional Revit (.rvt)-compatible files as required; if multiple Autodesk Revit-compatible files are submitted, they should be packaged as one Zip (.zip) file

☐	Should feature extensive use of the Revit template (.rte) file[19] available for download in the "/Files/Rules/Resources" folder on the Yahoo Group; limited minor modifications to the template are allowed, but must be approved by competition management.

Content Requirements

☐	House model
☐	Site model including all exterior site components
☐	Drawing set sheet views matching submitted drawings Notes: 1) Shop drawings submitted by subcontractors need not be recreated from scratch in the BIM unless they contain information that is required to make the BIM complete 2) Even if shop drawings aren't recreated in the BIM, they shall be imported into the BIM file and included in sheet views for inclusion in the drawing set.

D-4. Drawings

The drawings shall be generated from sheet views in the BIM file. Each iteration of the drawings shall include an increasing level of detail and refinement as the project progresses. The drawings may be made publicly available after each submission.

Format Requirements

☐	Packaged into a single, bookmarked PDF file (see Appendix F for PDF formatting and file-naming requirements) using NCSv5-compliant order and formatting
☐	Compliant with United States National CAD Standard® – Version 5.0; EXCEPTION: The use of keynotes is not expected
☐	ANSI "D" (22 in. X 34 in.) sheet size
☐	Graphic scales included to allow users to reduce or enlarge printed sheets
☐	Very similar formatting as the sample drawings[20] generated from the sample BIM.

Content Requirements

☐	Sufficient detail to enable the organizers to develop detailed cost estimates and a product directory using only the information included in the drawings and project manual; sample drawings posted[20] for download in the "/Files/Rules/Resources" folder on the Yahoo Group include the minimum required level of detail.

D-5. Project Manual

The project manual is a competition deliverable that is due at the conclusion of the design development phase, at the conclusion of the construction documentation phase, and again just prior to the competition. Each iteration of the project manual shall include an increasing level of detail and refinement as the project progresses. The project manual may be made publicly available following each submission.

Format Requirements

☐	ANSI "A" (8.5 in. X 11 in.) sheet size
☐	Organization and formatting of construction specifications in compliance with the Construction Specifications Institute's MasterFormat 2014 Edition, SectionFormat, and PageFormat standards
☐	Packaged into a single, bookmarked PDF file (see Appendix F for PDF formatting and file-naming requirements)

[19] The Revit template was posted in summer 2014
[20] A first version of the sample drawings was posted for download in summer 2014

☐	Should feature extensive use of the Word template (.dotx) file[21] available for download in the "/Files/Rules/Resources" folder on the Yahoo Group.

Content Requirements

☐	Rules compliance checklist[22] (see content requirements below)
☐	Structural calculations
☐	Detailed water budget
☐	Summary of unlisted electrical components
☐	Summary of reconfigurable features (see Appendix B-2b)
☐	Interconnection application form
☐	Complete quantity take-offs of entire competition prototype
☐	Complete set of construction specifications (including links to manufacturers' data sheets).

Content Requirements for Rules Compliance Checklist

	Rule #	Rule Description	Content Requirement(s)
☐	4-2	Construction Equipment	Drawing(s) showing the assembly and disassembly sequences and the movement of vehicles and equipment on the competition site
☐	4-2	Construction Equipment	Specifications for equipment
☐	4-3	Ground Penetration	Drawing(s) showing the locations and depths of all ground penetrations on the competition site, if any
☐	4-4	Impact Within the Solar Envelope	Drawing(s) showing the location, contact area, and bearing pressure of every component resting directly within the solar envelope
☐	4-5	Generators	Specifications for generators (including sound rating), if any
☐	4-6	Spill Containment	Drawing(s) showing the locations of all equipment, containers, and pipes that will contain liquids at any point during the event
☐	4-6	Spill Containment	Specifications for all equipment, containers, and pipes that will contain liquids at any point during the event
☐	4-7	Lot Conditions	Calculations showing that the structural design remains compliant given site specific vertical elevation change
☐	4-7	Lot Conditions	Drawing(s) showing shimming methods and materials to be used if vertical elevation change varies
☐	5-2	Solar Envelope Dimensions	Drawing(s) showing the location of all house and site components relative to the solar envelope
☐	6-1	Structural Design Approval	List of, or marking on, all drawing and project manual sheets that have been or will be stamped by the qualified, licensed design professional in the stamped structural submission; the stamped submission shall consist entirely of sheets that also appear in the drawings and project manual
☐	6-2	Finished Square Footage	Drawing(s) showing all information needed by the rules officials to measure the finished square footage electronically
☐	6-3	Entrance and Exit Routes	Drawing(s) showing the accessible public tour route
☐	7-1	Placement	Drawing(s) showing the location of all vegetation and, if applicable, the movement of vegetation designed as part of an integrated mobile system
☐	7-2	Watering Restrictions	Drawing(s) showing the layout and operation of greywater irrigation systems, if any
☐	8-1	PV Technology Limitations	Specifications for photovoltaic components

[21] A project manual template was posted in summer 2014.
[22] A template version of the rules compliance checklist was included in the project manual template.

	Rule #	Rule Description	Content Requirement(s)
☐	8-3	Batteries	Drawing(s) showing the location(s) and quantity of all primary and secondary batteries and stand-alone, PV-powered devices
☐	8-3	Batteries	Specifications for all primary and secondary batteries and stand-alone, PV-powered devices
☐	8-4	Desiccant Systems	Drawing(s) describing the operation of the desiccant system, if any
☐	8-4	Desiccant Systems	Specifications for desiccant system components, if any
☐	8-5	Village Grid	Completed interconnection application form
☐	8-5	Village Grid	Drawing(s) showing the locations of the photovoltaics, inverter(s), terminal box, meter housing, service equipment, and grounding means
☐	8-5	Village Grid	Specifications for the photovoltaics, inverter(s), terminal box, meter housing, service equipment, and grounding means
☐	8-5	Village Grid	One-line electrical diagram
☐	8-5	Village Grid	Calculation of service/feeder net computed load per NEC 220
☐	8-5	Village Grid	Site plan showing the house, decks, ramps, tour paths, and terminal box
☐	8-5	Village Grid	Elevation(s) showing the meter housing, main utility disconnect, and other service equipment
☐	9-1	Container Locations	Drawing(s) showing the location of all liquid containers relative to the finished square footage
☐	9-1	Container Locations	Drawing(s) demonstrating that the primary supply water tank(s) is fully shaded from direct solar radiation between 9 a.m. and 5 p.m. PDT or between 8 a.m. and 4 p.m. solar time on October 1
☐	9-2	Team-Provided Liquids	Quantity, characteristics, and delivery date(s) of all team-provided liquids for irrigation, thermal mass, hydronic system pressure testing, and thermodynamic system operation
☐	9-3	Greywater Reuse	Drawing(s) showing the layout and operation of greywater reuse systems, if any
☐	9-4	Rainwater Collection	Drawing(s) showing the layout and operation of rainwater collection systems, if any
☐	9-6	Thermal Mass	Drawing(s) showing the locations of liquid-based thermal mass systems, if any
☐	9-6	Thermal Mass	Specifications for components of liquid-based thermal mass systems, if any
☐	9-7	Greywater Heat Recovery	Drawing(s) showing the layout and operation of greywater heat recovery systems, if any
☐	9-8	Water Delivery	Drawing(s) showing the complete sequence of water delivery and distribution events
☐	9-8	Water Delivery	Specifications for the containers to which water will be delivered
☐	9-9	Water Removal	Drawing(s) showing the complete sequence of water consolidation and removal events
☐	9-9	Water Removal	Specifications for the containers from which water will be removed
☐	11-4	Public Exhibit	Interior and exterior plans showing entire accessible tour route.

D-6. Jury Narratives

The jury narratives are written documents that provide a summary of each team's approach to meeting the contest requirements for the Architecture, Market Appeal, Engineering, and Communications contests. The narratives will be reviewed by the respective jury prior to the competition in accordance with Table 4: Juror time commitments for deliverables review and on-site walkthroughs. The narratives may include any combination of text and graphics. The narratives will not be made public prior to the release of the respective contest results.

Format Requirements

☐ ANSI "A" (8.5 in. X 11 in.) sheet size

☐	Packaged into a single, bookmarked PDF file (see Appendix F for PDF formatting and file-naming requirements).

Content Requirements

☐	Architecture Narrative (5 pages, maximum)
☐	Market Appeal Narrative (5 pages, maximum)
☐	Engineering Narrative (10 pages, maximum + appendices) In addition to the summary of each team's approach to meeting the contest requirements (5 pages), the engineering jury narrative should include an "energy analysis and discussion" (5 pages + appendices) which clearly outlines team climate analysis, energy balance analysis, system sizing analysis, design and testing of any unique technologies, and expected house performance discussion.
☐	Communications Narrative (2 pages, maximum) The narrative should present the team's communications goals, objectives, 2-3 high-level strategies/tactics for meeting these goals and objectives, target audiences, key messages, and metrics for success (e.g., how the team will know if its communications succeeded).

D-7. Audiovisual Presentation

The audiovisual presentation is a competition deliverable that is due just prior to the competition. The juries will review the audiovisual presentation prior to the competition in accordance with Table 4: Juror time commitments for deliverables review and on-site walkthroughs. The presentation will be made publicly available soon after the submission as an update to the Computer-Animated Walkthrough.

Format Requirements

The format requirements for the audiovisual presentation are outlined below.

- .MOV or H.264 compressed.MP4 (MPEG-4) file type
- 3–3.5 minute runtime
- 16:9 aspect ratio
- 720 x 480 resolution
- Accompanied by a verbatim transcript of the audio narrative to meet Section 508 Accessibility standards. Transcript should be submitted in a Microsoft Word-compatible format. For an example of a text version script, see the Wind Power Animation (Text Version). Closed captioning does not need to be included within the video file.

Content Requirements

☐	Must primarily include video footage of the actual constructed house as built prior to the competition
☐	May contain still photos and graphics
☐	Gives the jurors a realistic preview of what they will experience during the on-site walkthroughs
☐	Includes an audio narrative that explains to viewers what they're seeing and describes the underlying philosophy behind the design and team approach to the competition
☐	Contains only originally created or properly credited work that does not violate U.S. copyright laws
☐	Does not contain background music that violates U.S. copyright laws; all incorporated music must be an original or royalty-free composition; proof of licensing shall be submitted with the final file and transcript
☐	Follows guidelines for logos as described in Rules 10-2 and 10-3
☐	Does not contain interactive elements that are inherently inaccessible to those with visual disabilities.

D-8. Website

The website is a deliverable that is due near the beginning of the project as a preliminary website and again just prior to the competition. The website serves as part of each team's communications strategy and will be reviewed

by the communications jury in accordance with Table 4: Juror time commitments for deliverables review and on-site walkthroughs.

Preliminary Website

A preliminary website consisting of at least three pages shall be evaluated by communications professionals at NREL to ensure compliance with the Minimum Website Coding Standards document available on the Yahoo Group[23].

Final Website

The final website shall be evaluated by the Communications Jury. The final website shall consist of considerably more content than the preliminary website.

Each team may request up to one courtesy review of the final website prior to submission. Teams shall request a courtesy review by contacting sdrules@nrel.gov. After each courtesy review, each team shall be notified of required changes it should make to achieve compliance.

The Communications Jury shall begin evaluations of team websites at the same time as the as-built deliverable submission. Communications professionals at NREL will also evaluate each final website for compliance with the Minimum Website Coding Standards document posted in the Yahoo Group. The organizers will provide the Communications Jury with a summary of aspects that are not in compliance for each team so that the jury is aware of any violations.

The Communications Jury will re-evaluate the website following the on-site walkthrough to determine effective use of project updates, photographs, social media, and other communications efforts.

D-9. Project Summary

Important to many communications-related aspects of the Solar Decathlon, project summaries:

- Provide essential content for the organizers to use while developing various event materials (e.g., the website, event program, media kit, and village signage)
- Prepare teams to answer questions from visitors to their construction sites and to the competition site at Orange County Great Park
- Help organizers and teams respond effectively to media inquiries.

All project summary materials (narrative, photograph, computer-generated house rendering, and logos) shall be saved in the formats indicated and submitted to organizers packaged as a single .zip file.

Overview

Format Requirements

☐	Packaged into a single, bookmarked PDF file (see Appendix F for PDF formatting and file-naming requirements)
☐	10 pages maximum
☐	11-pt. type, double spaced, 1-in. (or metric equivalent) margins.

Content Requirements

☐	A 100-word or less description of your team house. (1 paragraph)
☐	Design philosophy and house design. What is the team trying to portray or accomplish with this design? What will the house look like? What are some of the key features? (1 page)
☐	Unique house features. What makes the house unlike any other? (1 page)
☐	Technological innovations. Summarize the unique or unusual technologies incorporated into your house. (1-2 pages)
☐	Define the target client for the team house. How does the design accommodate the needs and desires of this client? (1 paragraph)

[23] The Minimum Website Coding Standards document was posted for download in spring 2014

☐	Team organization and contacts. How is your team organized and approximately how many students, faculty, and others (e.g., sponsors, volunteers, family members) are involved in the project? (1 page)
☐	Future plans for your house, if known. Where will it go after the competition? (1 paragraph).

Team Photograph

For use in the event program, media kit, and Solar Decathlon website, the team photo is an important conveyance of your team's personality.

Format Requirements

☐	Native format of the camera, such as JPEG or RAW, if available
☐	2048 × 1080 minimum pixel dimensions
☐	RGB, 8-bit color, not black and white.

Content Requirements

☐	Include all team members (if possible) and strive for creativity; for examples of past team photos, visit the History section of the Solar Decathlon website
☐	For a photograph to be properly credited, the following information shall be included in a Microsoft Word-compatible text file accompanying the photograph file: • Name, phone number, and email of person submitting the photograph • Photograph date and location • Photographer's name and affiliation.

Team Logo

The team logo is used by organizers in village signage, the event program, media kit, and Solar Decathlon website.

Format Requirements

☐	Submit two versions of your logo: • One for Web (GIF or JPG, at least 200 px wide); GIF is preferred for simple flat-color logos and JPG is preferred for complex logos • One for print (high-resolution or vector format; EPS preferred).

Content Requirements

☐	Include a text file containing the following additional information: • Name, phone number, and email of person submitting the logo • A list of all Pantone (PMS) or CMYK numbers used in the logo (please consult the graphic designer of your logo if you need help providing these specific color requirements).

Computer-Generated Renderings

The computer-generated renderings will be posted to the Solar Decathlon website and used in various communications materials to introduce the public to each competition prototype.

Format Requirements

☐	Minimum resolution of each image shall be 3000 px wide by 2400 px
☐	Composed of image files (JPEG, TIFF, etc.) packaged as one Zip (.zip) file.

Content Requirements

☐	Includes, at a minimum: • North elevation view of the competition prototype

- South elevation view of the competition prototype
- East elevation view of the competition prototype
- West elevation view of the competition prototype
- Two (2) birds-eye perspective views of the competition prototype
- Four (4) interior views of the competition prototype.

Competition Prototype Graphic Floor Plan

The graphic floor plan will be posted to the Solar Decathlon website and used in various communications materials to introduce the public to each competition prototype. The single plan should be presented in a way to demonstrate the layout of the house, interior furnishings, and all site elements.

Format Requirements

☐	Natively-generated vector PDF file (see Appendix F for PDF formatting and file-naming requirements)
☐	Scale of drawing: ¼" = 1'-0".

Content Requirements

☐	Complete plan showing all exterior elements, including landscaping, ramps, decks, and solar envelope
☐	Complete floor plan showing all interior elements, including furniture and fixtures.

Dinner Party Menus and Recipes

The dinner party information will be provided to visiting teams for review prior to participation in the dinner party subcontest and will be posted to the Solar Decathlon website.

Format Requirements

☐	Packaged into a single, bookmarked PDF file (see Appendix F for PDF formatting and file-naming requirements).

Content Requirements

☐	Restaurant-style dinner party menu for each dinner party
☐	Cookbook-style recipes for all components of dinner party
☐	Comprehensive ingredient list for each dinner party.

D-10. Public Exhibit Materials

All team communications materials on the competition site shall support the goal of Contest 4: Communications, which is to educate consumers about the project and topics relevant to the project.

- Teams shall submit all public exhibit materials to organizers for review. Organizers will determine whether materials meet competition guidelines.
- Public exhibit materials shall be evaluated by Communications Jury members.

Format Requirements

☐	Packaged into a single, bookmarked PDF file (see Appendix F for PDF formatting and file-naming requirements)
☐	Each public exhibit material shall be represented at its full scale within the PDF; therefore, it is expected that the PDF may contain sheets at several different scales.

Content Requirements

☐	Team handout (shall abide by Rules 10-2, 10-3, and 11-4b)
☐	Signage (shall abide by Rules 10-2, 10-3, and 11-4d)

☐	Team uniform design (shall abide by Rule 11-5)
☐	Plan drawing of team site depicting public exhibit material locations and tour route at 1:48 scale.

D-11. Final Report

The Final Report shall reflect the results of the team's Solar Decathlon project.

Format Requirements

☐	Packaged into a single PDF file (see Appendix F for PDF formatting and file-naming requirements)
☐	Intent of figures shouldn't be lost if printed in black and white
☐	ANSI "A" (8.5 in. X 11 in.) sheet size
☐	20 pages maximum, including figures, tables, and appendices; cover sheet and table of contents do not count toward page limit
☐	11-point body text minimum, maximum 14-point heading text
☐	One-inch margins on top, bottom, left, and right
☐	Include page numbers and numbered captions for figures and tables for easy navigation through document.

Content Requirements

☐	Discussion of fundraising activities— final project budget and lessons learned—what went well, what didn't, and what you would do differently
☐	Results of media-outreach activities—include statistics
☐	Results of on-site exhibition activities—estimates of the number of visitors to the house (justify estimates); assessment of visitor experiences (include qualitative data); and lessons learned—what went well, what didn't, and what you would do differently
☐	Evaluation of the team's website—number of hits, unique visits, and any other user statistics; lessons learned—what went well, what didn't, and what you would do differently
☐	Team perspective on the effectiveness of the organizers' communications efforts with both the teams and the public
☐	Description of future plans for the house, including a statement indicating whether the participating institution(s) would be interested in partnering with NREL to use the house for follow-up collaborative research and outreach projects.
☐	Short description of each team officer's future plans for employment, continued study, or other endeavors; NREL requests this information for possible inclusion in publications and presentations describing how the Solar Decathlon serves as an effective workforce development and university research project
☐	Suggested competition improvements
☐	Any other information you feel would be helpful to the organizers or future teams.

Appendix E Health and Safety Plan

The overall success of the Solar Decathlon competition is dependent on the health and safety of all team members, volunteers, organizers, and the public. To achieve this objective, each team is required to submit a Health and Safety Plan that identifies the following elements:

- How you will be minimizing risk
- How you will address major hazards that may be encountered during assembly and disassembly activities on the competition site
- How you will control these hazards to prevent injury to team members, volunteers, organizers and the public
- Areas of high risk—such as electrical safety, working at elevated heights/fall protection, hoisting and rigging activities and safe equipment operations—shall include the necessary level of detail to ensure the health and safety of all site personnel
- How you will ensure that you are in compliance with applicable regulations
- The roles and responsibilities for the health and safety officer(s) throughout the event.

E-1. Plan Development

A Health and Safety Plan template is available in the "/Files/Site Ops and Safety" [24] folder of the Yahoo Group. The template identifies major topics to address, the level of detail required, performance expectations, and requirements such as minimum levels of training needed for various team positions. The format of each team's submitted plan can deviate slightly from the recommended template as long as the information and level of detail are equivalent. Each plan shall be developed in consideration of the unique needs and requirements of each team's competition prototype alternate and construction methodologies on the competition site.

Teams are expected to work or consult with their school's environment, safety and health department during the development process. They can be an excellent resource when developing your Health and Safety Plans, while also ensuring that school-specific requirements are addressed.

E-2. Required Training

To ensure a minimum knowledge base regarding health and safety issues during construction activities, the team's project manager, construction manager, and health and safety officer (each role must be filled by a different individual) are required to complete the OSHA 30-hour Construction Safety Training course. Proof of course completion for the OSHA 30-hour Construction Safety Training shall be included in the final Health and Safety Plan.

E-3. Submission and Approval

Teams are required to submit their Health and Safety Plan to NREL for acceptance. Teams are responsible for updating the Health and Safety Plan, both before and after acceptance, to reflect changes in construction parameters. For example, if a team did not plan to use a crane to place its house when the plan was submitted but later decided that a crane would be necessary, then the team is required to update the plan accordingly.

During the event, a current copy of each team's Health and Safety Plan shall be posted on their site in a prominent location. Individuals working on your site shall be briefed on the final, approved plan and should know the expectations regarding safety, hazards, and controls.

[24] The template was posted to the Yahoo Group in spring 2014

Appendix F Deliverable Submission Instructions

Deliverables are considered to be on time if they are received by the competition manager by 5 p.m. Mountain Time on the respective due date. Refer to the "Deliverable Status Sheet" in the "/Files/Deliverable status sheets" folder on the Yahoo Group for deliverable due dates and required file formats for each of the respective deliverables.

F-1. Website URL

Website URLs shall be emailed to the competition manager at sdrules@nrel.gov.

F-2. PDF Requirements

a. Files submitted as a PDF shall meet the following criteria:
   i. Embed all fonts.
   ii. Maintain a minimum resolution of 300 dpi.
b. If an application does not support a direct-to-PDF function, create a postscript file by printing to a postscript printer with the "print to file" option selected. Use this postscript (.ps or .prn) file to create a PDF using Acrobat Distiller's high-resolution job settings.
   i. Creating a PDF from scans, or by outputting the content into a raster image format (.jpg, .tiff, .png, .gif, etc.) and then creating a PDF from the images, is not acceptable.
   ii. All-raster PDFs are large files at 300 dpi, are of unacceptable quality at lower resolutions and are not scalable without degradation.

F-3. Electronic File-Naming Instructions

The required file-naming convention for all electronic files follows:

[TEAM ABBREVIATION]_[DELIVERABLE ABBREVIATION]_[SUBMISSION DATE (YYYY-MM-DD)].[EXTENSION]

See Table 8 for a list of team name and deliverable abbreviations.

Example: A building information model submitted by West Virginia on April 5, 2014, would have the following file name:
WVU_BIM_2014-04-05.rvt

Table 8: Team and deliverable abbreviations

Team Name	TEAM ABBREVIATION	Deliverable Name	DELIVERABLE ABBREVIATION[25]
Team NY Alfred	ALFRED	Schematic Design Summary	SCHEMATIC
Team Orange County	CAIRV	Building Information Model	BIM
Cal Poly	CALPOLY	Constructions Drawings	DRAW
Sacramento State	CASAC	Project Manual	MANUAL
Clemson	CLEM	Health and Safety Plan	SAFETY
Crowder/Drury	CROWD	Computer-Animated Walkthrough	ANIMATION
Florida/Singapore	FLOR	Stamped Structural Drawings	STRUCT
Missouri S&T	MST	Stamped Structural Calculations	CALCS
U at Buffalo	NYBUFF	Project Summary ZIP file	SUMMARY
NY City Tech	NYCCT	Jury Narratives	NARRATIVE
Stevens	SIT	Audiovisual Presentation	AV
Stanford	STAN	Overview	OVERVIEW
Team Tennessee	TENN	Team Photograph	PHOTO
Texas/Germany	TEX	Team logo	LOGO
UC Davis	UCDAV	Computer-Generated Renderings	RENDER
Mass/Central America	WNE	Dinner Party Menus and Recipes	DINNER
West Virginia/Rome	WVU	Public Exhibit Materials	EXHIBIT
Yale	YALE	Final Report	FINALREPORT
		Construction Drawings	CD

F-4. Electronic File Submission Options

All electronic files shall be uploaded to the Solar Decathlon uplink. Teams wishing to reduce file upload times may submit electronic files as ZIP files.

[25] Accompanying files, such as text transcripts for videos and metadata files for photos and logos, should also use the appropriate abbreviation from this list.