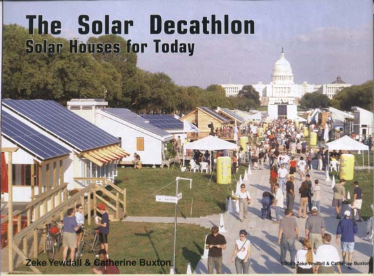
# The Solar Decathlon
## Solar Houses for Today




**Solar homes were shining on the National Mall in Fall 2002. The Solar Decathlon set some new examples for home building and brought fourteen teams together to share knowledge and compete.**

Imagine fourteen solar homes planted on the National Mall in Washington, D.C. Teams of university students display their best energy efficient home designs, competing with each other while learning from each other. Thousands of people cruise the mall, learning about energy efficiency and renewable energy. Even a few Congressional representatives and staff see that solar energy works. Pipe dream? No, it's the Solar Decathlon!

The Solar Decathlon is a new Department of Energy (DOE) event where colleges and universities compete to design and build the best solar powered house. The first competition was held from September 19 to October 9, 2002 on the National Mall, between the Capitol building and the Washington Monument. Fourteen teams competed in this first event. Most teams consisted of a mix of architecture and engineering students.

The houses were limited to 800 square feet (74 $m^2$) maximum footprint, with at least 450 square feet (42 $m^2$) of conditioned space. They could use only the energy of the sunlight falling on them. They were transported to Washington, D.C. from all over the country (including Puerto Rico), set up in a temporary solar village on the mall, and monitored to see which ones performed best. All houses had stand-alone electrical systems. The idea was to create a solar house that could maintain all of the elements of the American lifestyle.

BP Solar, Home Depot, Electronic Data Systems (EDS), the American Institute of Architects (AIA), and the National Renewable Energy Lab (NREL) were national sponsors for this event. Each team was responsible for

## The Ten Contests:

In the original Greek Pentathlon, athletes competed in contests of physical strength and endurance, as they do in its successor, the modern Olympic Decathlon. The Solar Decathlon is a contest of ingenuity and design instead of athleticism, and consists of ten contests. Each contest, with the exception of Design and Livability, was worth 100 points.

1. Design and Livability: This competition had twice the weight of each of the others, and was decided by a panel of architecture judges.
2. Design Presentation and Simulation: The structural drawings and computer simulations of performance were evaluated by a panel of engineers.
3. Graphics and Communication: Each team conducted tours, published a Web site, and wrote and distributed newsletters, which were judged on content and effective presentation.
4. Comfort Zone: NREL staff monitored temperature, humidity, and energy use of each house. A panel of engineering judges considered consumer appeal, innovation, and integration.
5. Refrigeration: NREL staff looked for adequate temperatures in the fridge and freezer, and an engineering panel judged refrigerator innovation.
6. Hot Water: Having an adequate supply of 120°F (49°C) water for showers, dishwashing, and washing machine was the goal here.
7. Energy Balance: The houses had to generate as much electrical energy during the week as they consumed.
8. Lighting: The houses had to be well lit through a combination of electric lights and daylighting.
9. Home Business: Each house was required to run a computer and printer to produce daily newsletters and respond to e-mail.
10. Getting around: Each team used an identical Ford Th!nk Neighbor to drive around town, and the maximum number of miles won.

raising all of the funds needed to compete. The teams had two years from the request for proposals to the time of the competition. Once the teams arrived on the Mall, they had nine days to assemble the homes before the first tours.

### The Turnout

The contest drew an estimated 100,000 people to the National Mall over the two weekends the houses were open for tours. Hundreds of people stood in long lines to get a tour of the most popular houses. Hometown newspapers carried frequent updates on the progress of their towns' teams. Fox, C-Span, and others carried live TV coverage of the event. Architecture and engineering students, not used to being in the limelight, achieved what seemed to them like rock star status. Indeed, the event has been called a solar Woodstock.

The turnout was not limited to the general public. The Secretary of Energy, Spencer Abraham, spoke at the opening ceremonies, and toured several of the houses during the competition. Word has it that he was so impressed during his official tour that he came back the next day with his whole family. Several senators and representatives came down to cheer on their favorite teams. Notably absent was the President, who didn't show, despite two of his home state's schools being represented.

## The Teams & Homes

### Auburn University

Auburn incorporated old and new design ideas into their house. It was an effective synthesis of the traditional southern "dogtrot" design (separate house sections connected by a walkway) and new technologies like solar electricity and passive solar heating. A sundial in front of the house represented one of the oldest and most visual technologies that uses sunlight.

Inside, the team used "solar megaphones" (skylights filled with prisms that amplify sunlight for daylighting), which are the most efficient source of solar daylighting on the market. The house is aesthetically pleasing and functional. Large water-filled cylinders decorate the rooms of the home and also moderate the house's temperature. The water acts as a thermal mass that helps the home stay cooler in the summer and warmer in the winter.

### Carnegie Mellon University

This house was designed to be an urban row house in Pittsburgh, where it would be rebuilt and donated to a needy family after the competition. Because space is at a premium in the city, the team decided that it would not be viable to build a one-story, 800 square foot (74 $m^2$) house, as the competition rules suggest. This team felt that two-story houses are a much more efficient use of space. So even though it resulted in losing 48 points in the competition, they built the house that was best for its final destination. In keeping with the urban design, a large rooftop deck contains a garden under a canopy of evacuated tube hot water collectors.

### Crowder College

Can a two-year technical school in rural Missouri compete against the best schools in the nation? You bet! Crowder's winning solar car team went for bigger goals this year. They constructed their solar powered house using electricity from their portable solar trailer, on their campus and at the mall—the only school that didn't use a gasoline generator for construction on the mall! No diesel powered cranes or forklifts were used in the construction either. They were the only team who off-loaded their house completely with hand cranks and jacks.

The Crowder team was also different in their use of solar energy. They used amorphous thin film, BP Millennia photovoltaic modules, instead of crystalline silicon modules like other teams. The modules were integrated into a standing seam metal roof so you could barely tell they were there.

Crowder's unique water heating system used the waste heat from their PV modules. A system of copper tubes was attached to the back of the modules, and an extra layer of glazing was added above the modules. This effectively turned each module into the absorber plate of a flat plate solar water heating collector.

### University of Colorado at Boulder

Colorado set out to destroy many of the notions of what is "required" for a solar house. The roof is almost 20 degrees flatter than the optimum slope (see *PV Orientation* by Zeke Yewdall, in *HP93*), and part of it faces southwest. Their hot water collectors are flat, but have tilted absorber plates in the evacuated tubes. Another guiding theme was that everything in the house is commercially available and mass produced.

The house is light and pleasant inside, and the main kitchen/living room feels very large. The team had trouble keeping people out, or keeping them from plopping down on the couch during tours and just staying!

### University of Delaware

The University of Delaware's house was the only semicircular house on the mall. Not only was this shape reminiscent of the school's initial, "D," it also allowed the sun to enter the house at all times of the day. The house's inhabitants could sit and watch the sun travel across the sky without moving from their seats.

The Delaware house features a Warmboard panel radiant floor heating system. This system integrates fluid piping into a plywood underlayment, with aluminum sheeting that helps to distribute the heat. Unlike concrete, this system can be implemented on any floor of a house, since it is not much heavier than an average floor.

**The solar home teams that entered the Solar Decathlon in Washington, D.C. had to first build their entries at their campuses or off site, and then ship them to the National Mall where the contest was held.**

**Here are two construction photos of University of Colorado at Boulder putting their entry's structurally insulated panel (SIP) walls together in the parking lot of Home Depot, an event sponsor.**

### University of Maryland

Maryland's key goal was to produce a house that did not appear to be a solar house. Except for the well-integrated PV array on the back roof, their house looks like it would fit right into any housing development. It uses a skylight and bay window for natural lighting, an electric daylight dimming system, and super efficient, off-the-shelf appliances. Maryland also excelled in their hot water system design. The system provided both domestic hot water and hot water for the radiant floor heating system.

Because they only had to transport the house 15 miles (24 km), they were able to use a poured slab concrete floor, which allows high efficiency radiant heating to be used. They also had a large north deck that made the house feel much larger than the actual interior size of 600 square feet (56 $m^2$).

### University of Missouri at Rolla/Rolla Technical Institute

Rolla Missouri's team wanted to build a house that the average consumer would accept as comfortable and familiar. They felt that a futuristic house might scare people away from using solar energy. Their traditional ranch home was transported in three sections that were each mounted on trailer frames.

The house is very cozy and comfortable—anyone would feel right at home when walking in. The Rolla Technical Institute students contributed their skills by building the cabinetry, shelving, and deck. The engineers from UMR designed the house, including the sun room on the south side of the house. This sun room contains all of the controls for the house, and its floor is tiled with the names of the team's sponsors.

### University of North Carolina at Charlotte

A small, but very dedicated, team of architects built this house. It was unique in that it used only 120 volt appliances, and one 4 kilowatt inverter. Most of the appliances are from the yacht industry. They are smaller than normal, and use less energy than their traditional counterparts—perfect for a small solar house.

The house also uses Kalwalls (an insulated translucent fiberglass product that lets in 10 percent of the sun's light) to provide added daylighting. Skylights and creative lighting schemes made the house's interior more interesting.

### University of Puerto Rico

Of all the teams, Puerto Rico had the biggest travel challenge. They had to pack their house up in shipping crates, load it on a barge, and send it off to Washington. For that reason, they had less time to work on their house before bringing it to the mall.

This team was made up of architects from one campus on the island and engineers from another campus. They had never worked together before, and they not only had to tackle the issue of transportation, they also had to build a house for a climate that they had never lived in. Working together with area manufacturers, they researched the weather in Washington, D.C., and built an effective house with the resources they had.

### Texas A&M University

Texas A&M is one of the top construction science schools in the country, so they wanted to focus most of their design's attention on cutting-edge construction techniques in relation to solar energy. The team actually set out to not only show the consumer that using solar energy was possible, they were also targeting contractors and builders.

One interesting technology implemented in this house was the interior wall of water. Based on refrigeration technology, the team used water running through pipes in the wall to moderate the temperature of the house. This team also designed their own refrigeration system for the kitchen. Unfortunately, Texas A&M did not participate in the bulk of the competitions because student representatives were unable to be present during the competition week.

### University of Texas at Austin

Perhaps the most intriguing house at the competition, this house started as an Airstream trailer and hundreds of parts that looked like a giant erector set. Slowly, columns, the roof, and finally the walls, emerged from the seeming chaos and became a house. This team used the trailer as part of the house, so that when the owners want to go on vacation they can take their home with them.

The Airstream trailer housed all the "wet rooms" of the house like the kitchen and bathroom. The land-anchored house sections were the living room, office, and bedroom. Between the trailer and land sections of the house runs a breezy deck area where a Texas homeowner could enjoy the great outdoors.

### Tuskegee University

This house is an adaptation of the traditional southern "dogtrot" design with an open breezeway down the center of the house for natural ventilation. It was the only two-story house in the competition that was under the 18 foot (5.5 m) height limit—quite a feat.

The house is heated by passive solar energy, with an air source heat pump backup. There is an air conditioning system if needed, but the house is also designed for maximum natural ventilation, with a north-facing balcony. Education has been a key portion of Tuskegee's mission in this competition. The house was designed to be a beautiful addition to the campus and will form the core of a new renewable energy center that is being developed.

Warren Gretz—NREL

### University of Virginia

The University of Virginia's goal was to create a house that appealed to the experimental and rebellious nature of today's younger generation. Though the house (dubbed the "Trojan Goat" by the team) may look strange to the more traditionally minded, the team hoped that anyone could feel right at home once inside the house.

One of the unconventional but intriguing aspects of their house was the "Smart(W)all 3000." This large, light-emitting diode wall is art that reflects the home's environmental conditions. When temperature is high, it's one color; when the house is cool, it's another. Another climate control aspect of the house is the south wall. It is almost completely glass, shaded by wooden louvers. These louvers can be opened parallel to the sun's rays in winter to reflect more light into the living room in colder months.

### Virginia Polytechnic Institute

This entry is the epitome of multifunctionality. Every aspect of the house has more than one purpose, including the solar-electric panels. To celebrate solar energy and not hide it, this team conspicuously mounted the panels on angled racks atop the roof. The panels act as a shading device for the house while collecting electrical energy.

Inside the house, the furniture, rooms, and even the appliances serve more than one purpose. The appliances are grouped together on the north wall and serve as a thermal buffer for the rest of the house. The outer walls of the house were made of a translucent aerogel material that insulated while providing daylighting.

### The Solar Village

Though these fourteen teams were competing against each other, by the end of the week, they had realized that their competitors were also their new neighbors in a little community. All of them had the same ultimate goal of advancing the public perception of solar energy. By the end of the competition, team lines had blurred, and people were hanging out in each other's houses, cheering each other on for various competitions, and hitting the local restaurant or party scene together every night.

When it came time to pack up and leave, it was rather sad to disassemble the new little village when everyone was just getting to know each another. Interestingly enough, after two weeks, some team members knew their neighbors on the mall better than people they had lived next door to for years back at home. A future article will cover themes found in many designs, how the competition played out, and what is next. The next Solar Decathlon will be held in 2005. The deadline for college proposals is April 30, 2003. See Access for info.

**Solar Decathlon Systems Information**

| Item | Auburn Univ. | Carnegie Mellon Univ. | Univ. of CO at Boulder | Crowder College | Univ. of Delaware | Univ. of Maryland | Univ. of Puerto Rico |
|---|---|---|---|---|---|---|---|
| PV KW (STC rating) | 5.76 | 7.14 | 7.68 | 3.35 | 4.80 | 5.76 | 4.16 |
| PV modules | 36 BP Solar BP-3160 | 42 BP Solar BP-5170 | 63 Astropower AP-120 | 78 BP Solar MST-43 | 40 Astropower AP-120 | 96 BP Solar MSX-60 | 26 BP Solar BP-160 |
| Charge controllers | 5 Solar Boost 3048 | 4 Trace C40 | Outback MX-60, Solar Boost 3048, Trace C40 | 4 Solar Boost 3048 | 4 Trace C40 | 4 Solar Boost 50 | 2 Trace C40 |
| Inverters | 2 Trace SW5548 | 2 Trace SW5548 | 2 Trace SW5548 | 2 Trace SW4048 | SW5548 Power Panel | 2 Trace SW4048 | 2 Trace SW5548 |
| Battery bank | 800 AH, 48 V | 810 AH, 48 V | 1,400 AH, 48 V | 800 AH, 48 V | 1,086 AH, 48 V | 800 AH, 48 V | 1,800 AH, 48 V |
| Battery type | Concorde PVX-12100 sealed AGM | 16 sealed AGM | 32 Deka L-16 flooded lead-acid | 24 Eagle Picher AGM | 20 Concorde PVX-2580 sealed AGM | 38 Concorde aircraft sealed AGM | 36 Clean Moura CM-200 |
| Water heating | 2 Heliodyne Gobi 4 x 8 ft. flat plate collectors, 80 gal. tank, AC circulation pump | 2 Viessmann Vitosol H-30 evacuated tubes, 3 x 3 m,$^2$ each | 12 Sun Utility evacuated tubes, 80 gal. storage, AC circulator pump | Thermal collectors integrated with 12 of the Millenia PV modules, 250 gal. Tank | 40 Thermomax evacuated tubes, 80 gal. storage tank, AC circulator pump | 40 Thermomax evacuated tubes, 120 gal. storage, PV direct pump | 1 Solatron evacuated tubes, 120 gal. storage tank |
| Construction | SIPs,[1] floors = R-24, outer walls, ceilings, & roof = R-38 | SIPs, walls = R-33, roof = R-50 | Polystyrene SIPs, walls = R-30, ceiling = R-40, floor with icycnene insulation | 2 x 6 stud walls with Fg batt, roof = R-40, E2 Andersen windows | Ecothermal SIPs, walls = R-30, ceiling = R-50, floor = R-18 | Polyurethane SIPs, walls = R-35, ceiling = R-40 | Steel framing 4 in. polystyrene, R-19 & R-21, synthetic wood flooring |
| Space heating | Trane air source heat pump | Water source heat pump | Carrier air source heat pump with energy recovery ventilator | Radiant floor | Ground source heat pump with radiant floor | Radiant slab | 4 evacuated tubes, 300 gal. storage tank |
| Space cooling | Trane two speed DX split system | Water source heat pump | Carrier air source heat pump with energy recovery ventilator | York 1.5 ton split system | Ground source heat pump | Trane XL 1500 split system, energy recovery ventilator | Hybrid: liquid desiccant / 1 ton carrier with Puron refrigerant |
| Web site | www.ausolar .org | www.arc.cmu .edu/carnegie _team | solar .colorado.edu | crowder.edu /solar | me.udel.edu /asme/solar | www.enme .umd.edu /solartech | www.habitat upr.edu |

[1] Structural insulated panels

| Univ. of MO at Rolla & Rolla Tech | Tuskegee Univ. | Texas A & M Univ. | Univ. of TX at Austin | Virginia Tech | Univ. of NC at Charlotte | Univ. of Virginia |
|---|---|---|---|---|---|---|
| 5.12 | 6.08 | 3.60 | 3.60 | 6.00 | 4.80 | 5.28 |
| 32 BP Solar BP-3160 | 39 BP Solar (1 for monitoring) BP-3160 | 12 ASE 300 | 6 ASE 300 & 25 BP Solar BP-275 | 80 BP Solar BP-275 | 16 ASE 300 | 16 ASE 330 |
| 4 Solar Boost 3048 | 2 Trace C40 | 2 Trace C40 | Connect Power Center PSC500 | 4 Solar Boost 3048 | 2 Trace C60 | 4 Trace C60 |
| 2 Trace SW5548 | 2 Trace SW4048 | 2 Trace SW5548 | Trace SW5548 | 2 Trace SW4048 | Trace SW4024 | 2 Trace SW4024 |
| 1,500 AH, 48 V | 3,050 AH, 48 V | 1,156 AH, 48 V | 1,975 AH, 48 V | 1,275 AH, 48 V | 800 AH, 24 V | 2,000 AH, 24 V |
| 32 Trojan L-16H flooded lead-acid | 40 Concorde PVX-2580L sealed AGM | Rolls flooded lead-acid | 20 Trojan L-16H flooded lead-acid | 20 Concorde PVX-6225 sealed AGM | 16 MK BA4D sealed AGM | 16 Concorde PVX-2120 sealed AGM |
| 20 Thermomax evacuated tubes, 40 gal. storage tank | 4 x 10 ft. Solar Direct flat plate collector 80 gal. storage tank | Progressive tube thermal system | 30 Thermomax evacuated tubes | 140 sq. ft. of SunEarth absorber plates in custom built vertical collectors | 3 x 6 ft. flat plate collector, 1.5 ton water source heat pump, 140 gal. storage tank | 5 AET & 1 reclaimed flat plate collectors, 90 gal. storage, heat pump backup |
| Steel studs, 3 in. XPS foam insulation, walls & floor = R-21, ceiling = R-40 | Wood stud walls, batt insulation | SIPs, walls = R-30 floor & roof = R-55 | Steel prefab frame, SIP infill, built around Airstream trailer | South, east & west walls = R-15, north wall = R-23, roof = R-31 | SIPs, walls = R-19 roof = R-40 | Engineered studs, foam insulation, walls = R-50, roof = R-70, ground-coupled floor |
| Thermomax forced air heating unit | High efficiency heat pump | Water source heat pump | BIO-Radiant Hydro-Air, with domestic hot water | Ground source heat pump & solar thermal | Passive solar | Passive solar with auto-control, ground source heat pump, radiant floor |
| Mitsubishi variable speed heat pump | High efficiency heat pump | Water source heat pump | BIO-Radiant Hydro-Air ice battery | Ground source heat pump | Water source heat pump passive ventalation | ground source heat pump, hydronic via natural convecting valance |
| www.umr.edu /~sunhome | tusolar.tusk .edu | archnt2.tamu .edu /solardecathlon | www.ar.utexas .edu/cadlab /decathlon | www.caus.vt .edu/vtsolar | www.uncc.edu /lighting | solarhome.lib. virginia.edu |

## Access

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Fax: 303-384-6490 • cecile_warner@nrel.gov
www.eren.doe.gov/solar_decathlon

The Home Depot, 2455 Paces Ferry Road, Atlanta, GA 30339 • 800-430-3376 or 770-433-8211
www.homedepot.com

The American Institute of Architects (AIA), 1735 New York Ave., NW, Washington, DC 20006 • 800-242-3837
Fax: 202-626-7547 • infocentral@aia.org •www.aia.org

Warmboard, Inc., 8035 Ste. 41-A, Aptos, CA 95003
877-338-5493 or 831-685-9276 • Fax: 831-685-9278
info@warmboard.com • www.warmboard.com

Kalwall Corp., PO Box 237, Manchester, NH 03105 • 800-258-9777 or 603-627-3861
www.kalwall.com

Skywall Translucent Systems, a division of Butler Manuf., PO Box 629, Terrell, TX 75160 • 800-259-7941 or 972-551-6470 • Fax: 972-551-6421
rcoskery@vistawall.com • www.vistawall.com
Aerogel building materials

See "A Race Worth Running" in *HP*89, page 8