

The 2005 Solar D house

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Abstract

The Solar Decathlon provided an international forum for competition among eighteen university student teams, each of which designed, built, and operated a totally solar-powered home with a home office and their transportation needs using a solar-charged vehicle. Organized by the U.S. Department of Energy and the National Renewable Energy Laboratory, the Solar Decathlon competition challenges university teams to design and build an 800 ft² (74.3 m²), totally solar-powered house. The competition took place on the National Mall in Washington D.C., where each house was constructed and operated from September 28 to October 19, 2005. The competition consisted of ten contests focusing on ingenuity, energy production, energy-efficiency, design, thermal comfort, refrigeration, lighting, communication and transportation.

Professor Michael Garrison, Assistant Professor Samantha Randall and Lecturer Elizabeth Alford of the School of Architecture were the faculty advisors for the University of Texas at Austin (UT) Solar Decathlon student team, which included more than 40 graduate and undergraduate architecture, landscape architecture, and engineering students.

The team developed a design that features four pre-fabricated modules that can be snapped together in order for the house to be transported from Austin, Texas to Washington D.C. and constructed in just four days, operated for two weeks, and then deconstructed and sent back to Austin, Texas again. An innovative foundation system of rails and rollers allow each module to be lowered off a truck and rolled onto the rails and the four sections of the house snapped into place.

1 Design

The University of Texas 2005 Solar Decathlon House is limited in size by rules of the competition, which, require that the roof “foot-print” must be less than



800 ft². To provide our modest 1-bedroom/1 bath house with a spacious feel, the team utilized three design techniques. 1) The spaces are multi-use, so the bathroom is also the laundry room; the bedroom has a foldaway bed so it can function as an office/study during the day; and a central main room contains the kitchen, dining and living room in an open plan configuration. 2) The main room connects to a patio deck space along the entire south elevation to expand the interior space to the outdoor deck space. 3) The combination of a cathedral ceiling and generous amounts of daylighting enhance the sense of spaciousness in the modest sized house.



Figure 1: 2005 UT Solar D house on the National Mall in Washington D.C.



Figure 2: UT Solar D house south elevation.

The design of the house stressed four fundamental principles including,

1. Well constructed and tightly sealed thermal envelope with appropriate ventilation.
2. Proper design and installation of heating and cooling systems (properly sized, high-efficiency, good ventilation and sealed ductwork).
3. Energy-efficient doors, windows, and appliances.
4. Home orientation and placement of building elements to maximize natural heating and cooling efficiency.



Figure 3: Interior of the UT Solar D house with Congressman Lamar Smith.

2 Energy systems

The Texas solar decathlon house is solar-powered and utilizes the latest energy efficiency technologies and sustainable building materials. The Energy saving features of the house include, a 7.9 kW photovoltaic solar power system, evacuated tube “heat pipe” solar water collectors, a high efficient HVAC system and an energy conserving design that achieves a ratio of one ton of air conditioning per 933 ft² (86.7 m²) of conditioned space. The HVAC system combines a variable-speed Inverter compressor mini-split heat pump with an energy recovery ventilator, a separate refrigeration whole-home dehumidifier and horizontal direct-drive chilled water DHW/Air Coil heat exchanger. The four components work together to assure a narrow interior comfort zone of between 72°F and 76°F (22°C and 24.4°C) and a humidity range of between 45 and 50% relative humidity. To control the components the team developed a computer controlled smart building technology that allows the building to be controlled on the Mall from Austin, Texas.

2.1 Photovoltaic solar system

The Texas 2005 solar decathlon house is designed to be energy efficient and is a stand-alone system, which does not use electric utility power. PV's provides direct DC power when sunlight is available. If power is needed when sunlight is not available, batteries will be required to store power for the times when the sun is not shining.

The Texas 2005 solar decathlon house has 42-175 W BP polycrystalline panels and 4 Romag-BP custom-translucent thin film panels that comprise the 7.9 kW PV system. For our area, we multiplied the rated wattage by 5.1 to get the average Wh (watt hours) amount produced in one day. The 5.1 factor equals



the viable operating hours per day and accounts for the fact that there will be more sun available in the summer and less in the winter ($7.9 \text{ kW} \times 5.1 = 40.29 \text{ Wh}$).

The 42 BP 4175 modules are mounted on the roof canted at 20 degrees. The 4 BP-Romag custom modules are cantilevered off the roof, shading the southern glazing. Single insulated conductor MC USE-2 cables are used to connect the modules in free air to roof-mounted fuse/combiner boxes. The PV array is divided into three inverter groupings; 4 parallel/8 series BP 4175B modules for the SB6000U inverter and 10 series BP4175B modules for the SB2500U inverter. All series strings first go through fuses in pullout holders before any combing of parallel circuits through a terminal block. After the combiner boxes, conductors are run from the roof to the electrical closet.

The electrical section of the closet contains the disconnect switch and over current devices for the PV array, the inverters, the DC circuit breakers, and the AC distribution panel. A contiguous, but separated section of the closet is used to store the 32-Marathon 12V batteries. The system is dependent on the inverters to perform all necessary ground fault detection and interruption (GFDI) of ungrounded and grounded conductors to prevent fire on the roof mounted system.

Although the solar decathlon competition requires a stand-alone system for the competition on the National Mall, this system will be adapted to a grid connected system upon the redeployment of the house in Austin, Texas after the competition. In the grid connected system PV's can, provide power directly to the user and to the centralized power grid when PV power exceeds the user's requirements. The Austin solar decathlon house will use power from the central utility when needed and supplies surplus home-generated power back to the utility. It is termed a "parallel" system by Austin Energy. The power produced will be metered so that when power is produced by the PVs and sent into the grid the meter will run backwards, thus allowing for a discount in consumption costs.

2.1.1 Evacuated tube solar water heating

The 2005 Texas solar decathlon house utilizes Sunda's Seido evacuated tube solar water collectors, which function as heat pipes. A heat pipe acts like a low-resistance thermal conductor. Due to its thermal-physical properties, its heat transfer rate is a thousand's times greater than that of the best solid heat conductor of the same dimensions. Sunda's Seido heat pipe is a closed system comprised of two meters of copper tubing, an evaporator section, a capillary wick structure, a condenser section and a small amount of vaporizable fluid. The heat pipe employs an evaporating-condensing cycle. Heat pipes are inserted into the aluminum absorbers forming assemblies, which in turn are inserted into the glass tubes. The tubes are made of borosilicate glass, which is strong and has a high transmittance for solar irradiation. In order to reduce the convection heat lost, glass tubes are evacuated to vacuum pressure. By evacuating air out of the glass tube the absorber material and selective coating are protected from corrosion and other environmental influences.



2.1.1.1 Energy conservation The 2005 Texas solar decathlon house utilized a number of energy conservation design standards to improve thermal performance, including site planning and building configuration, thermal capacitance; thermal insulation; glazing type, amount and orientation of windows and air flow.

The UT solar decathlon house is elongated on an east-west axis which is the most efficient shape for most U.S. climates because it captures low-angled solar radiation in winter, which minimizes heating requirements and, with a properly designed shading overhang, minimizes cooling requirements in the summer.

Because the diurnal temperature swing during the summer months in Washington D.C. and Austin, Texas is relatively low, the likelihood of inadequate night time flushing of a high thermal capacitance design led our team to a strategy of light frame construction. Light frame construction also allows the HVAC system to respond more adequately to a rapidly changing exterior climate.

The next consideration is the type of wall, roof, and foundation system to be used and the R-value that will be achieved. R-value represents resistance to heat flow, the higher the R-value, the better a wall's efficiency. High R-values can be achieved with any type of construction: standard "stick-built" or alternative wall construction methods such as structural insulated panels, insulating concrete forms, or straw bale construction. Our team chose to use 6-inch thick structural insulated panels, which are rated at R-30.

Windows, which have a much smaller R-value than walls, can have a large impact on the energy efficiency of a building. For this reason, one step towards efficiency is to minimize window area, which for our building represents less than 13% of our wall area. There are several other factors to consider when choosing windows including, frame material, glass coatings (such as low-e), gas-fill between the panes, overall U-value, solar heat gain coefficient (SHGC), and ultraviolet (UV) and visible light transmittance (VLT). Windows specified for the Texas Solar Decathlon House are Comfort Line fiberglass Low-E, argon filled. These windows have a typical U value of .24 and a SHGC value of .38. The fiberglass frames do not expand and contract with water or differences in temperature, they have a strong strength to weight ratio, do not degrade due to sunlight and contain a recycled glass content.

Keeping air from leaking in and out of a building can dramatically reduce energy needs. Air infiltration, which occurs naturally through small gaps and cracks between a wall and foundation, around windows and doors, and through utility penetrations between conditioned and unconditioned spaces, can be a big source for energy loss. Air infiltration can draw in humidity during the cooling season, and create uncomfortable drafts during the heating season. To improve comfort and reduce energy use created by air infiltration, our team caulked and sealed all the air leaks of the house during the framing and finishing process of construction.

Taken together the energy conservation techniques utilized in the UT solar decathlon house provided an energy efficient design with a ratio of 933 ft² (86.7 m²) of space per ton of air conditioning.



3 Material systems

The UT Solar D Team has chosen to think beyond the competition requirements of solar power and energy efficiency by embracing the full spectrum of sustainable design. This strategy includes resource efficiency and the use of recyclable, recycled, reused, and local underutilized materials. Recyclable materials include the house's exterior zinc siding, the galvalume roofing, the stainless steel trim and the structural steel foundation rails. Building materials made from recycled materials include, the exterior decking, which is made from recycled plastic and wood scrap, the bathroom tile, which is made from recycled glass and granite scrap, the bathroom wall panels made of Ecoresin recycled plastic and the redwood trellis rain screen made from reclaimed redwood. Examples of reused materials include aluminum shingles, which are reused newspaper litho plates from our school newspaper the Daily Texan. Local and underutilized green materials are also used as well. These include the use of mesquite wood flooring, cabinets made from MDF agricultural waste straw fiber and trim made from local reclaimed cypress. In addition to using green materials to construct the house the team recycled all the jobsite construction wastes.

Structural Insulated Panels (SIPs) are an innovative green-engineered material system used to construct the UT Solar D House. SIPs replace conventional stud or "stick frame" construction. They were made in a factory and shipped to our job site where they were connected together to frame the walls, floor and roof of the house.

A SIP consists of an engineered sandwich or laminate with a solid expanded polystyrene foam core 6" thick and structural galvalume facing on each side. The facing is glued to the foam core and the panel is pressed in a vacuum to bond the sheathing and core together. SIPs structural characteristics are similar to a steel I-beam. The skins act like the flanges of an I-beam, and the rigid core provides the web of the I-beam configuration. This composite assembly yields stiffness, strength, and predictable performance



Figure 4: Metals USA SIP wall and floor panels.

The greatest advantage of these panels is that they provide superior and uniform insulation in comparison to more common methods of house construction. SIP walls are superior to conventional walls in a number of ways. SIPs combine a high insulation R-value with speed and ease of construction. The solid foam core eliminates air movement within the walls and minimizes thermal bridges through wood studs. Together, all these reduce air infiltration, and make a tightly sealed/easy to build structure. This makes the building more comfortable, energy-efficient, and quieter.



Figure 5: Metals USA SIP panels.

In regard to Fire safety, SIPs have performed well in combustion tests. When the interior of the SIP is covered with a fire-rated material such as gypsum board, the fire resistance of gypsum board protects the SIP facing and foam long enough to give building occupants a good measure of escape time.

4 Process conclusions

To provide for a pedagogical method to link architectural theory to practice, the hands on experience of the solar decathlon gave architecture students proper grounding in action and immediate experience and argues in favor of experiential knowledge over ungrounded abstract knowledge.

This experience allowed students to develop the knowledge of how to apply and test out their ideas and theories on sustainable design. This kind of knowledge is rooted in the realms of value. And these kinds of values and consequences are acquired through the actual building experience. In this way the students are able to evaluate the performance of design decisions. Hands-on learning seeks to re-establish the continuity and inter-relationship between the processes of conceiving, making, and using buildings. In architect Samuel Mockbee's words, "its the importance of making and thinking at the same time."

The "hands-on" process fosters a pedagogical approach that encourages faculty and students to discover how buildings really work as they are constructed and occupied. Through observation, simulation, and data gained by

designing and then building the design, students discover lessons on the success and failure of different design approaches. Analysis of the material observed in the field, along with comparisons to values derived by model studies, computer simulation and calculations, gives students an opportunity to assess whether the stated design intent has been achieved and to understand and describe the variety of ways occupants actually experience a building.

This level of understanding involves both disciplinary and interdisciplinary learning. It is this area that the solar decathlon experience is especially potent as the forum in which disciplinary knowledge and interdisciplinary understanding take place.

References

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