Building a Solar House

An exercise in safety education & experience

By Jerry Davis and Fazel Hayati

THE FIRST SOLAR HOUSE DECATHLON was hosted by the U.S. Dept. of Energy (DOE) on the National Mall in Washington, DC, from Sept. 25 to Oct. 8, 2002. The competition tested a wide range of categories associated with a solar house, such as design and livability, graphics and communication, hot water, refrigeration, energy balance and lighting. Fourteen universities nationwide participated in the competition, the pinnacle of more than a year's activity on the part of students, staff and faculty. The Auburn (AL) University team consisted of more than 75 students, support staff and faculty from the colleges of architecture and engineering. Members of the team were responsible for design, construction, assembly, simulation, testing, deconstruction and transportation of the solar house.

As part of this effort, graduate students and faculty of the Dept. of Industrial Systems and Engineering's Occupational Safety and Ergonomics Program provided safety coverage for the team during the construction, assembly and deconstruction phases. The project team designed and constructed a 500-square-foot house powered by 36 solar panels and equipped with 36 batteries for energy storage. The project was the largest student designed and constructed project in the history of Auburn. The case study presented in this article demonstrates how the team integrated safety into its project, taking into account unique design and construction requirements, as well as the predominantly inexperienced workforce involved.

Construction Considerations

Statistics show that the construction industry, including residential home building, suffers many injuries and fatalities annually from a myriad of hazardous operations and conditions (BLS). At first glance, the design and construction of a 500-square-foot house powered by solar energy may appear relatively straightforward. However, this process was complicated due to the competition rules and requirements. One requirement stated that the house must be constructed at the participating university site, then transported to the nation's capital overland. To meet this requirement, the house was designed in two sections. Initial construction was performed in a covered bay facility near the university campus, and the sections were moved to an open field for assembly and testing. The house was then disassembled for transport to Washington, DC—a distance of nearly 800 miles—and reassembled at the competition site. At the conclusion of the contest, the house was again disassembled for its final trip back to the university. Therefore, the process required the house to be entirely assembled and disassembled three separate times.

The rules also stated that the house must be designed and constructed exclusively by students, staff and faculty advisors. Of some 75 individuals involved in the project, only five had any significant experience in a construction environment. To keep the project on schedule, a plan was developed with clearly defined milestones. Participants held weekly meetings to discuss progress and other matters that arose, including safety issues.

Safety Considerations

Faculty and graduate students in the Occupational Safety and Ergonomics Program formed a safety committee to integrate safety concepts into the construction process (Stephenson) at the suggestion of the dean of engineering, who considered it vital to incorporate safety during the earliest stages of the project.

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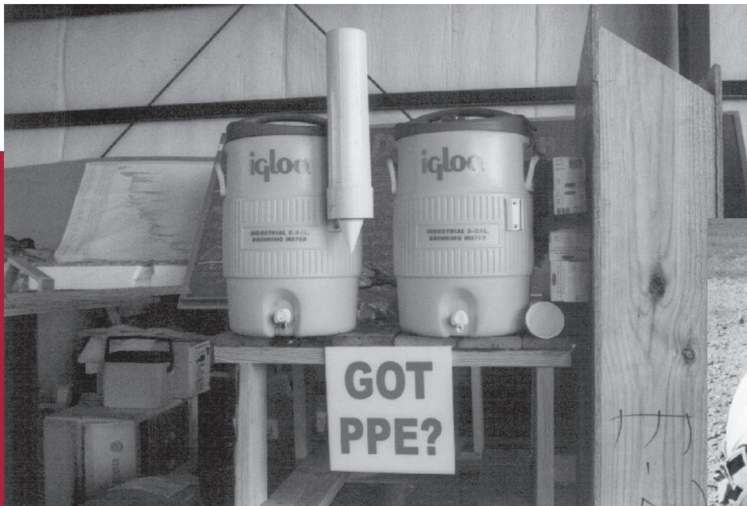

[Clockwise from bottom, left]: Photo 1: Half of Auburn University's solar house during construction.

Photo 2: PPE reminder signs were placed in strategic locations throughout the construction site.

Photo 3: A project participant works on a platform for the solar house.

Photo 4: The solar house at night. The house was powered by 36 solar panels and equipped with 36 batteries for energy storage.

In addition to general construction safety considerations, the committee paid much attention to the multiple assembly and disassembly operations required, as well as to the inexperienced workforce involved. To address these concerns, the team developed a safety program with three major components: 1) hazard identification and injury prevention; 2) education and training in safety principles and operations; and 3) extensive presence of safety team members on the jobsite. The College of Engineering agreed to support a budget for the safety component of the project.

Hazard Identification & Injury Prevention

The committee first considered hazardous conditions that are present on most construction projects, such as operating hand and power tools, crane safety, suspended load operations, noise, heat stress, electric shock, cuts, manual materials handling, slips and falls, elevated work and ladder safety, and hazardous materials. The team then looked at project-specific hazards and identified several special situations.

•Work on the large direct-current battery bank (36 sealed batteries). The battery bank was charged during daylight and discharged at night to provide rectified electrical power to the house.

•Scalding/burning hazards associated with the solar-powered water collectors.

•Handling and attaching the solar panels to the roof. Each panel measured 3 x 5 feet and weighed some 40 pounds. Generation of electrical potential while the collector is exposed to the sunlight posed an additional hazard of panel handling.

•Handling and installing building materials. The solar house was designed using structurally integrated panel system (SIPS) materials for the walls, floors, ceiling and roof. The use of SIPS materials created its own set of unique hazards. The heavy and bulky SIPS had to be mechanically positioned, lifted and attached during both construction and disassembly phases.

•Roof work. The solar house required significant additional roof work due to the installation of the photovoltaic panels, hot water heat collectors and numerous skylight attachments.

•Heat stress concerns. In addition to high regional summer temperatures (mean of 82.6°F and often exceeding 90°F), the heat caused by the reflective metal roofing material created a significant amount of thermal discomfort for the workers.

•Welding on the trailer (frame) that supports the two house sections.

•Hinged roof. The large sections of the roof system had to be hinged to allow removal or folding down of the edged roof sections to accommodate highway transport requirements.

•Moving the house sections to and from an open pasture for testing, over unsteady terrain.

The next step was to develop a plan to create a

Figure 1

Solar Decathlon Construction Safety Audit

Date: ______________________ **Conducted by:** ______________________

Time: ______________________ **Location:** ______________________

1) PPE			
All necessary PPE is being used correctly?	Y	N	N/A
Glasses	Y	N	N/A
Hardhat	Y	N	N/A
Gloves	Y	N	N/A
Boots	Y	N	N/A
Earp plugs	Y	N	N/A
Dust masks	Y	N	N/A
Eyewash station is present, clean and accessible?	Y	N	N/A
First-aid kit is present, clean and accessible?	Y	N	N/A
2) Heat			
On hot days, fans are running?	Y	N	N/A
Water is readily accessible?	Y	N	N/A
When working in the sun, periodic breaks are taken?	Y	N	N/A
3) Tools & Ladders			
Proper tool used for the job?	Y	N	N/A
Power tools operated correctly?	Y	N	N/A
Cords are clear of walkways and work surfaces?	Y	N	N/A
Tools are properly grounded?	Y	N	N/A
Tool users are aware of their surroundings and fellow workers?	Y	N	N/A
Ladder of appropriate length is used?	Y	N	N/A
Ladder is stable and on stable ground?	Y	N	N/A
Overreaching is avoided?	Y	N	N/A
4) Electricity			
All cords are grounded?	Y	N	N/A
Cords are in good condition?	Y	N	N/A
Outlets, power tools, etc., are free of water or puddles?	Y	N	N/A
Electrical hazards are shielded (i.e., no open live wires)?	Y	N	N/A
Only qualified personnel perform wiring or electrical work?	Y	N	N/A
Batteries safely stored and handled?	Y	N	N/A
5) Materials Handling			
Proper lifting procedure followed?	Y	N	N/A
Only qualified operators use heavy equipment?	Y	N	N/A
Awareness of coworkers when lifting long or unwieldy objects?	Y	N	N/A
Proper precautions taken when handling hazardous materials?	Y	N	N/A
6) Site Maintenance			
Walkways unobstructed?	Y	N	N/A
Floor is free of puddles/slip hazards?	Y	N	N/A
Tools put away when not in use?	Y	N	N/A
Potential dangers (electrical, etc.) labeled where appropriate?	Y	N	N/A
Hazardous materials properly stored?	Y	N	N/A
Combustibles properly stored/disposed of?	Y	N	N/A
7) General			
All workers maintain awareness of surroundings and coworkers?	Y	N	N/A
All workers cautious around the site/each other?	Y	N	N/A

Notes & Comments:

safe and productive work environment. It was clear from the start that hazard recognition and PPE would be major components of the safety strategy (NSC). Aided by graduate students in the Dept. of Industrial and Systems Engineering (all master's or doctoral students majoring in occupational safety and ergonomics), a review of the MSDS and a PPE assessment was completed for each of the various processes. All student, staff and faculty team members were equipped with steel-toe shoes, helmets, hearing protection, gloves and safety glasses. Additional PPE for the electrical work and battery bank handling included sleeve-length rubber gloves, aprons, faceshields and rubber matting for electrical isolation. Those working on elevated surfaces also used fall protection equipment, including harnesses.

Training & Education

The safety team considered workforce training and education an integral part of providing a safe work environment. Modules covered safety concepts, safe equipment operation, awareness of coworkers, and health and emergency care topics such as:

•Hazard identification and recognition. Lectures covered both general safety topics and topics relating specifically to solar house construction.

•Proper use of PPE. The construction area was designated a PPE-required site; reminder signs were prominently displayed around the site.

•First-aid care. Training included the correct use of eyewash equipment and proper wound care. An eyewash station and first-aid kit were placed on the construction site.

•CPR and AED use. Since the house was constructed at a remote location—about eight miles from the university campus—with a potentially long response time from emergency medical services, all team members were trained in CPR. Also, due to the presence of electrocution hazards, an automated external defibrillator (AED) was purchased and placed on the construction site. The City of Auburn (AL) Fire Dept. provided training in AED use and CPR.

•Some members of the construction team received indepth training associated with their specific portion of the project, such as proper handling of solar panels and battery banks.

Training and education continued throughout the construction phase and all relevant issues were discussed at the weekly project meetings.

Safety Team Presence on the Jobsite

The third component of the safety program was the extensive presence of the safety team at the construction site. This supervisory approach required active participation of team members throughout the project; during the construction, assembly and disassembly phases, and during the testing and competition phases. Jobsite visits were conducted to 1) identify any new hazardous conditions that arose; 2) inspect and enforce safety rules; and 3) provide support for the student workers, answer questions and explain the purpose of the regulations. The safety team developed and implemented the following guidelines:

•No student was permitted to work on the jobsite alone. Although a faculty member was not required to be present at the jobsite, a minimum of two students were required to be present during any operation (at least one of whom had a cell phone).

Photo 5 (top): The Auburn team consisted of more than 75 students, support staff and faculty from the colleges of architecture and engineering.

Photo 6: Visitors tour the house during the competition in Washington, DC.

Decathlon Results

The University of Colorado at Boulder took first place in DOE's Solar Decathlon. The University of Virginia captured second place, while Auburn University took third—and received an award for "Best Construction Safety." Each house, limited to roughly 500 square feet for purposes of the competition, were judged on 10 criteria to determine which most efficiently employed solar energy for heating, cooling, hot water, lighting, appliances, computers and charging an electric car. For more details, visit www.solardecathlon.org.

•The safety team conducted frequent jobsite inspections and developed a construction safety audit (Figure 1) to facilitate these inspections. Any deviation from the safety rules was discussed with the faculty advisor at the jobsite.

•Safety team members had the authority to address any egregious safety violations on the spot and immediately implement appropriate countermeasures.

•Safety team members had the authority to immediately stop any operations deemed unsafe.

•Safety team members participated in the weekly project meetings. These provided an opportunity for the safety team to debrief the project team on safety issues, discuss new potential hazards and revise the safety plan if deemed necessary.

Safety team members were also present during the assembly and disassembly of the solar house in Washington, DC. The students worked in two shifts and a safety team member was present for each shift. Safety personnel from DOE were also present to oversee the construction and deconstruction phases.

Lessons Learned

The Solar House Decathlon project took more than a year from the beginning of the design phase to the return of the module to its permanent site at the university. The construction and testing phases lasted approximately three months. This project was a tremendous experience in terms of teamwork, coordination and education for all involved. From a safety standpoint, only minor injuries were suffered by project team members. Although the necessity and role of safety in this project was initially unclear to some student workers, the level of understanding and appreciation of safety issues grew considerably as the project progressed. The authors consider the safety portion of the Solar House Decathlon project a success because it provided an opportunity to develop a safety program, and to educate and train inexperienced workers in safe working practices, enabling them to complete the project with no significant injuries. Several lessons were learned from this experience.

•The key factor in the success of the project's safety program was the support of the dean of the School of Engineering. The dean initiated and supported the project's safety program both administratively and financially. All necessary resources, both on and off campus, were readily available to the safety team.

•The project offered students and faculty an opportunity for hands-on experience.

•Faculty from the departments involved in the project were supportive of the safety program as well. They set a good example by following all PPE requirements and safety rules.

•At first, some student workers did not understand the purpose and necessity of following safety procedures, and reluctantly followed PPE requirements and other construction safety rules. However, with education and training during team meetings, the students became more committed to safety as the project progressed.

•The presence of the safety team on the jobsite was crucial to the success of the safety program. Jobsite inspections also provided an educational opportunity for safety team members and demonstrated the team's commitment to the project's success.

•Due to the intensity of the work and approaching deadlines as the project neared completion, students had to work extremely long and irregular hours. Tired and under pressure, student workers sometimes overlooked safety precautions. Emphasis on the safety procedures often created tension between the safety team and workers. After discussion between project leaders, safety team members and student workers, a policy was implemented that consisted of frequent but shorter duration work periods coupled with additional rest breaks.

•On the jobsite, safety team members often felt they should be involved in the actual construction process, particularly as the deadline approached. They were periodically reminded that their participation in construction work could distract them from their primary responsibility at the jobsite—to pay close attention to safety details and watch for new safety hazards that develop over the course of the construction project.

Conclusion

Auburn University finished third in the overall Solar House Decathlon competition. DOE singled out the team for "Best Construction Safety 2002." The project's complex design and construction phases and the inexperienced workforce offered a challenging and unique opportunity for safety students and faculty to develop and integrate an on-the-job safety program. Such opportunities and challenges are rarely available in an academic environment. ■

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