AC 2012-3534: COMPETING IN THE 2011 SOLAR DECATHLON

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Kevin Rodgers is a second year graduate student in the College of Technology at Purdue University. He also holds a B.S. degree in mechanical engineering Technology from Purdue. While at Purdue, Rodgers narrowed his focus and interests toward sustainability in residential and commercial buildings with a specific research interest in passive design. Most recently, Rodgers held the Project Manager position for Purdue's entry in the U.S. Department of Energy Solar Decathlon 2011, where he was responsible for guiding the efforts of close to 200 students on designing and constructing a net-zero solar powered residential home. One innovative feature of the home is a biofiltration system that Rodgers designed, which is incorporated into the home's HVAC system and helps filter contaminants and improve indoor air quality, while potentially offering energy savings.

Competing in the 2011 Solar Decathlon

Abstract

This paper explains the benefits and challenges for Engineering Technology programs that take leadership roles in multidisciplinary design competitions that are increasingly popular on university campuses. The context for this analysis is the 2011 Solar Decathlon, a high-profile international competition sponsored by the U.S. Department of Energy where university students design, build, and demonstrate solar powered homes that are fully operational and cost effective. This event is held every other year on the National Mall in Washington, DC and draws in excess of 300,000 spectators plus significant national and international media coverage. This paper will discuss one team's strategy for competing successfully and provide insight about what that other Engineering Technology programs can expect by participating in future Solar Decathlons or similar events.

What is the Solar Decathlon?

Over the past 20 years, design competitions sponsored by professional societies or federal agencies have become increasing popular. From solar powered cars to autonomous vehicles, thousands of university students participate annually in contests that apply classroom knowledge to real world projects. It's easy to see why these problem based learning opportunities are so appealing to students. The work is hands-on, collaborative, and creative, features that likely attracted them to their technical major in the first place.[1]

Among all the popular student competitions, the U.S. Department of Energy Solar Decathlon might be the biggest overall event. Twenty teams of university students are selected to design, build, and demonstrate their own version of a solar powered home. Although the homes are limited to 1,000 ft^2 in size; they are fully operational in every respect. Since its inception in 2002, this event has been held every other year in September on the National Mall in Washington, DC where it draws in excess of 300,000 spectators plus significant national and international media coverage.[2]

The Solar Decathlon is part of DOE's strategy for gradually moving the market for residential buildings closer to net zero energy. In other words, the goal is that homes in the not too distant future will use renewable energy, typically solar and wind, to generate as much on-site energy as they consume on an annual basis. The final year of the Solar Decathlon is planned for 2020; by that time it is hoped that the technologies for net zero energy homes will have become commercially viable and cost effective.

Figure 1 gives an idea of the scale of the event. It was taken during the final phases of construction for the most recent 2011 competition that was held in West Potomac Park, which is located between the Lincoln and Jefferson Memorials and adjacent to the new Martin Luther King Memorial in Washington, DC. Student teams had one week to assemble their houses and have them fully inspected before the competition started. The house in the foreground is the entry from the University of Maryland that ultimately won the competition, but international entries from Belgium, China, and Canada are also prominent in the picture.

Figure 1. The 2011 Solar Decathlon took place in West Potomac Park in Washington, D.C.

The name "Solar Decathlon" is used because the winning team is the one with the highest cumulative score in ten different events. Table 1 shows how the scoring was broken down for 2011. Half of the contests were measured and the other half were subjectively evaluated by a jury. All contests had the same point basis.

Table 1. The Solar Decathlon had 10 contests.

Measured Contests	**Juried Contests**
Appliances	Engineering
Hot Water	Architecture
Comfort Zone	Market Appeal
Energy Balance	Communications
Affordability	Home Entertainment

The "Affordability" contest was particularly compelling for 2011. To emphasize the importance of cost effective net zero energy construction, the DOE imposed a cost ceiling of $250,000 on all homes and hired an estimating firm to conduct independent appraisals. Homes that were over budget got penalized on a pro-rated basis.

Solar Decathlon Competition

A paper presented at the 2011 ASEE Annual Conference discussed our team's organizational strategy and planning for the Solar Decathlon through 2010.[3] By the spring of 2011, work had shifted to construction planning, including ideas for disassembly and transporting the home. Actual construction began in April of 2011 and the home was essentially complete by July. Although students were heavily involved in all phases of the project, some aspects of construction were completed by outside contractors. This schedule allowed about two months of commissioning work to make sure all aspects of the home were fully operational.

One of the more challenging aspects of the project was transporting the home to Washington, DC in September of 2011. The team used four large trucks and several trailers for the home, furnishings, and tools. Figure 2 shows one of section of the home after it was loaded onto a trailer and shrink wrapped. The pitched roof in the foreground is a roof section and the box at the rear of the trailer is a base unit with a floor and walls. Although the transportation and re-assembly process was very labor intensive, the move to Washington, DC went surprisingly well.

Figure 2. One part of the home shrink wrapped for transportation.

Figure 3 is the home as it was displayed in Washington, D.C. The home had a practical, familiar, and comfortable look that was well received by the judges and more than 18,000 members of the general public who came in for a tour. The home also performed extremely well from a technical perspective, finishing near the top in every one of the five measured contests. The team was rewarded for their two years of hard work with a 2nd place overall finish.

Figure 3. The 2nd place home on display at West Potomac Park.

Very few of the houses displayed in past Solar Decathlons have become full time residences.[4] In fact, of the 100 houses that have competed since 2002, only five are occupied on a daily basis. Of those that have become full time residences, only two have been placed in communities, while none have been placed into a typical residential neighborhood - where the bulk of Americans live. Keeping true to its goal of being a "real home for a real family", our solar decathlon home has been placed in the Chatham Square, a community in Lafayette, IN that is part of a broader neighborhood revitalization effort. The home will be put on display through the summer of 2012 and then sold to a private resident, where it will be monitored long term to support ongoing research into the long term performance of cost effective homes that are supposed to be net zero in terms of their annual demand for electricity from the electric grid.

Lessons Learned

Now that the Solar Decathlon project is over, we have several observations and suggestions for universities who are considering similar efforts:

Leadership Opportunity for Engineering Technology

Historically Solar Decathlon teams have been comprised of students from university programs that have an overarching emphasis on architecture or engineering. Because the initial competitions sought to promote new ideas and concepts that might move use of renewable energy to the next level, the teams were required to rely heavily on new and innovative uses of technology to achieve that goal. While innovation is still important, many of the technologies required to reach net-zero energy use in a small residence are well developed now. As the Solar Decathlon competition enters the second decade of its existence, there is the potential to shift from technology development to a greater emphasis on technology application. That is a domain where Engineering Technology can provide substantial leadership.

Engineering technology programs are well prepared to transform the innovative thinking involved in design and production of a research-based net-zero residence to one that applies existing technologies in an effective and efficient manner. Because engineering technology programs have a solid understanding of value engineering to reach solutions that meet a consumer demand, their more widespread participation in the Solar Decathlon competition should be encouraged.

Engineering technology programs have the potential to transform the innovation at the Solar Decathlon from futuristic technologies to realistic design innovations that can be used today by building contractors and energy conscious homeowners. In past Solar Decathlon competitions the goal was just to show that a home can operate at net-zero energy. That goal has been achieved and future Solar Decathlon competitions should begin to address the more current question of how to make a net-zero house affordable and attractive to the wide range of housing consumers throughout the world. That type of practical design innovation is where Engineering Technology programs can excel.

Institutional Support

Even though the Solar Decathlon emphasized work by students, resources from an entire university were needed to be successful. Figure 4 highlights some of the key contributors to our team. The Facilities Department provided technical advice to students and oversight for construction. The Development Office assisted with fundraising efforts. Government Relations helped with the event logistics in Washington D.C. The university's Research Foundation provided the land and infrastructure that allowed the house to be built. Marketing & Communications worked with students on outreach to media. The business office maintained the budget and handled all the billing, including unusual invoices for shipping a house across the country on three large trucks.

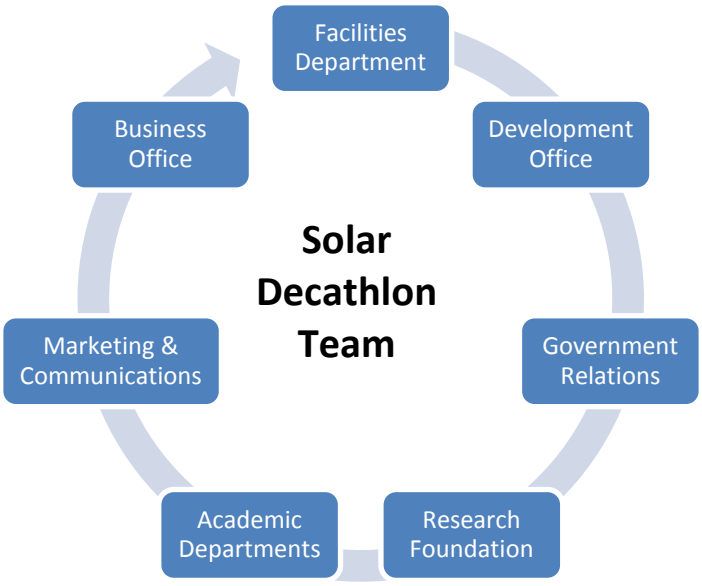

Figure 4. Much of the university was involved in the Solar Decathlon effort.

Aggressive Fundraising

Multidisciplinary design projects are expensive and the Solar Decathlon is no exception. The team spent $700,000 to have the home designed, built, transported, displayed in the competition, and re-built on a permanent foundation. As shown in Figure 5, construction was the single biggest expense, approximately 1/2 of the total cost. The construction costs includes more funding for safety materials, tools, and contractor support than at a typical residential jobsite; mainly because the house is being built by students. Other significant expenses included promotional materials that explained solar-powered housing to college students and the general public, transportation (physically moving the house to and from Washington, D.C.), summer salary for students who built and commissioned the house in the summer of 2011, and lodging for students at the Solar Decathlon competition.

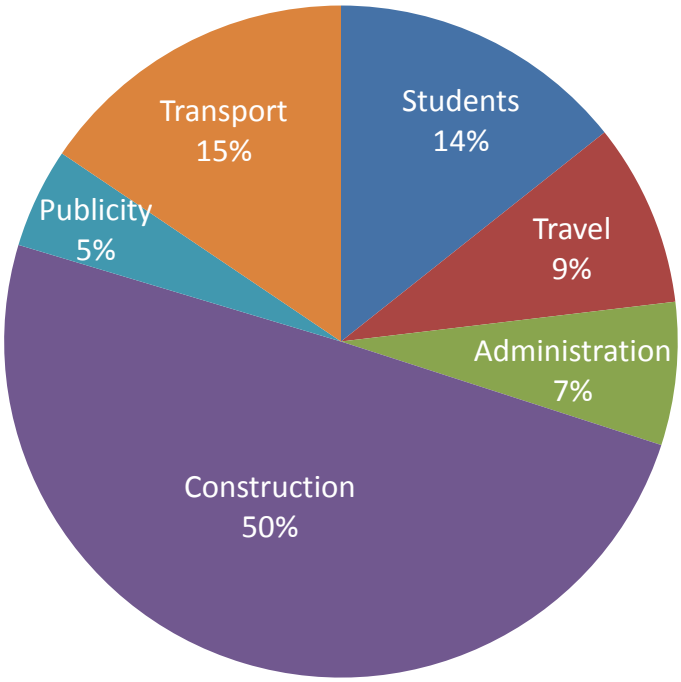

Figure 5. Construction was only half of the overall solar decathlon cost.

Establishing a budget for a Solar Decathlon house is one thing, but actually raising the funding is another issue. $700,000 is a lot of money, particularly in a difficult economy. Figure 6 shows that 2/3 of the funding came from cash donations and gifts in kind from corporate sponsors. Many of these organizations participated because they were good friends of higher education, but they also recognized and valued the exposure associated with a high-profile event like the Solar Decathlon. The remaining funds came from a variety of government sources. The U.S. Department of Energy provided $100,000 for all participating teams.

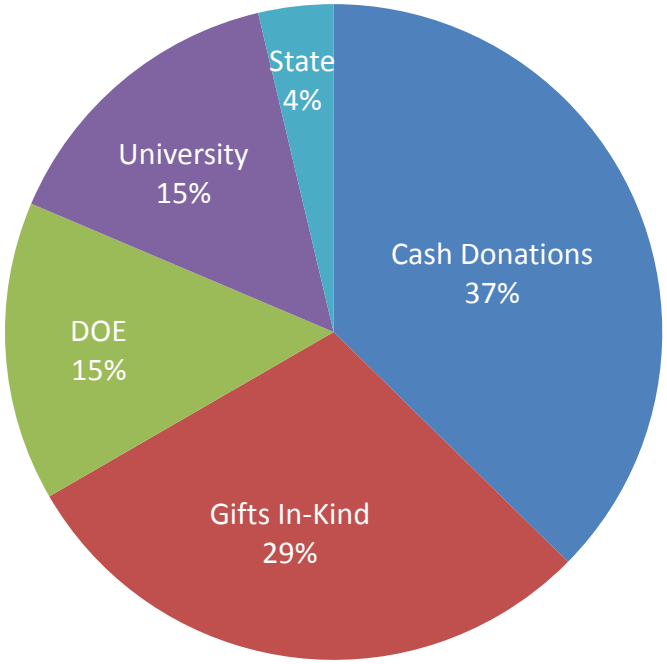

Figure 6. Corporate partners provided 2/3 of the funding through cash donations and gifts.

Plan Ahead

Participation in the Solar Decathlon required significantly more effort across all aspects of the project than any of the faculty involved could have imagined. Some of this effort came from the multiple areas of activity that faculty members or university staff encountered during the Solar Decathlon project that they were not routinely involved with. Although a detailed account of all of the unexpected challenges that were encountered is beyond the scope of this paper, a few areas are worth noting. One overarching challenge is at the university level. Although universities may regularly manage and pay for construction related activities, they are typically not organized to follow the flow of construction related expenditures through college or departmental business channels. Purchasing and contracting procedures should be worked out long before construction begins to avoid delays that occur because approvals for large expenditures require predetermined procedures and multiple layers of approval.

Working with the administrative requirements of the Solar Decathlon program and the Department of Energy also requires a significant amount of effort. The deliverables required by DOE are substantially more involved than is common for all but the largest and most complex residential or commercial construction projects. Even seasoned construction managers would be surprised by the documentation requirements for this small construction project. Some of the detailed documentation is needed to keep the teams moving forward during the two year process, some is required to justify phased payment of the DOE funds provided, and considerable detail is needed to facilitate the judging. DOE also required extensive information to assure the safety of everyone involved in the process.

Another area to plan for well in advance is transportation. In addition to being a complex process, transport can be very expensive. The cost of transportation was second only to actual construction costs. Although some of the transportation cost can be mitigated by considering transport during the building design process; distance, size, weight, and Department of Transportation requirements for the multiple states that the home must transit through all play an important role. Failure to account for any of these variables can create additional cost, delays in delivery, or even damage to important house components. One 2011 Solar Decathlon team experienced a significant delivery delay due to Department of Transportation regulatory issues that stopped the delivery of their primary house module while in transit to Washington, D.C.

Outcomes of Solar Decathlon

Many different universities have participated in the Solar Decathlon since it started in 2002. Although each team has a unique approach to the competition and understanding of its value to their home institution, several common outcomes appear in literature.[3] The following summary highlights these common themes in the context of our own team's experience.

Cross Campus Collaboration

Our Solar Decathlon team included more than 200 hundred students and 10 faculty members from majors and departments that wouldn't normally have close contact with each other. Although the project was led by the College of Technology, contributions by Liberal Arts,

Engineering, Health & Human Sciences, Agriculture, and Management were crucial to the final product. This diversity became a core strength for the team. One student manger noted that:

> *The main reason I joined the team was to work on an interdisciplinary project and learn from peers with different backgrounds than my own. I wanted to learn to communicate with engineers, architects, etc. and work in a collaborative environment. I treated this project as a job and I feel my peers during the two years did the same. There is no doubt in my mind that it has prepared me for my future career.*

Broader Societal Impacts

Although it wasn't necessarily obvious at first, everyone on the Solar Decathlon team came to appreciate the significance of this project in terms of demonstrating that sustainable, low energy housing could also be affordable, comfortable, and attractive. One of the proudest moments for students was changing the mindset of typical homeowners who stopped by for a tour and were skeptical about whether energy efficiency and solar energy were really viable.

Meet Educational Outcomes

It is certain that the Solar Decathlon project will be highlighted when the Engineering Technology programs at our institution undergo accreditation in the fall of 2012. The Accreditation Board for Engineering & Technology (ABET) requires that both Technology and Engineering programs incorporate standards and other realistic constraints into their educational programs. The design process for the Solar Decathlon home included not only standards, but also brought economic, environmental, manufacturing, ethics, safety, health, social, teamwork, and marketing issues along with it. It is hard to imagine a better way to expose students to the broad range of issues they'll face during their careers.

Design Innovations

The 2011 Solar Decathlon has launched the development of at least one new student invention that has already achieved a provisional patent. The Biowall is an active air filtration system that uses plants to remove CO_2 and volatile organic compounds. The visibility from the Solar Decathlon provided a launching point for additional research that could lead to a full patent and development into a commercially viable product.

Industry Collaboration and Research

The 2011 Solar Decathlon helped establish or expand several industry partnerships. Corporations that began their involvement as a sponsor of the home ended up recruiting our graduates for full time employment opportunities. They have also continued working with faculty on ideas for funded research.

Community Outreach

It was amazing to see how the university community embraced the Solar Decathlon entry. A series of successful open houses were held before the competition and each one drew long lines of spectators. Now that the competition is over and the home has been re-built in Lafayette's Chatham Square neighborhood, plans are underway for ongoing community education and research.

Prestige

Although publicity for its own sake was never a stated goal for the project, there is no denying that the visibility of the project has been helpful to the college and the university. Media coverage featuring our home or our students has appeared in the New York Times, Washington Post, Wall Street Journal, USA Today, and ABC News. Articles on some aspect of the home were also featured in web/print versions of National Geographic, Popular Mechanics, and Architect magazine. In addition to helping recruit talented new students, the successful outcome of the competition is a source of pride among loyal university alumni.

Conclusions

The Solar Decathlon is a great opportunity for universities to showcase the talent of their students in a high-profile event that draws large crowds and international media attention. It is also an opportunity to help address the environmental and energy security issues facing our country by raising student and public awareness of the potential for commercially viable low energy residential construction. The event is also very exciting and fun for students and faculty who participate.

Faculty and universities who want to compete in this type of design competition need to understand the high level of commitment required for successful participation. Significant funding and university support are needed. Our team worked with corporate sponsors and government agencies to raise $700,000 in just one year. Additional support from many academic departments and many administrative units at the university was also needed. In fact, the teamwork aspect of the Solar Decathlon might be one of the lasting legacies of the entire project for our institution.

Acknowledgment

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