

**DOE/NREL Solar Decathlon:
Environmental Education
for Engineers and The Public**

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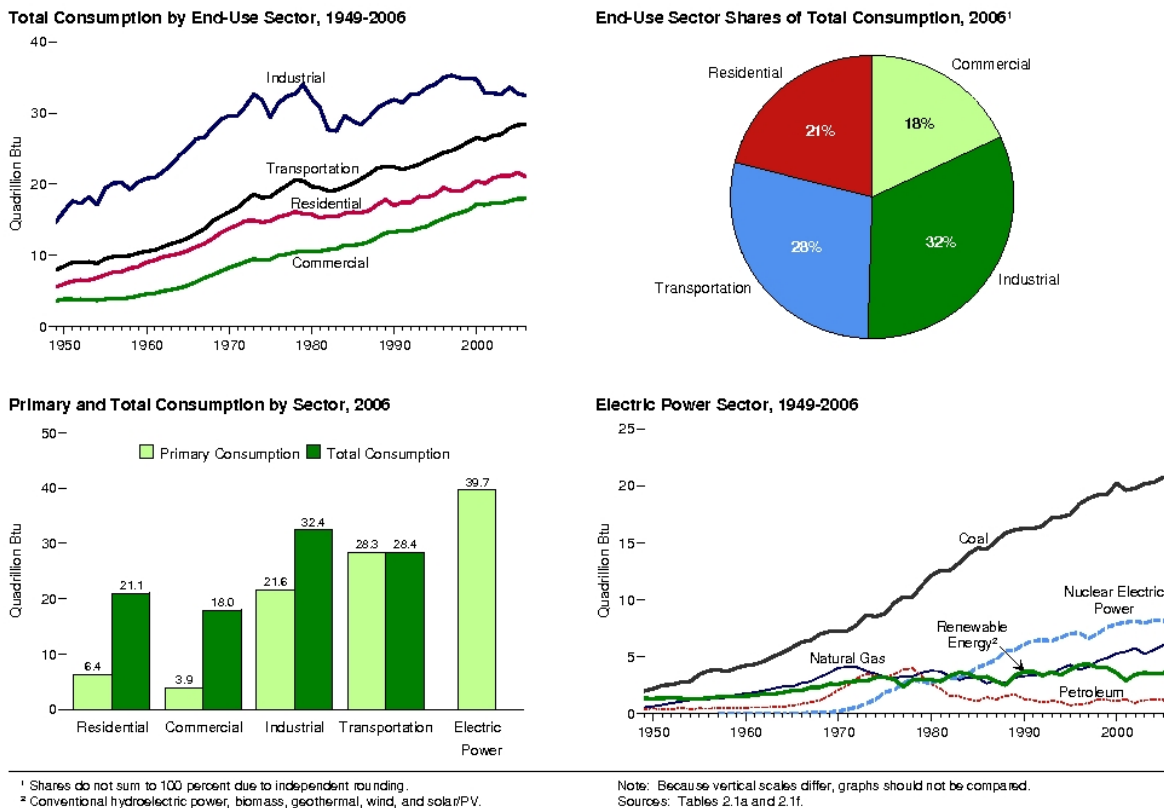
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Introduction

The Solar Decathlon is a biannual competition presented and partially sponsored by the US Department of Energy (DOE) and the National Renewable Energy Laboratory (NREL) in which university teams are selected to build model solar homes for display and adjudication on the National Mall. The competing teams design, build, and test their projects on their home campuses, then transport the homes to the National Mall where they form a temporary Solar Village that is open to the public for about a week. The homes are designed to be completely solar powered with energy to spare for powering an electric vehicle. The event has highly technical activities that are open only to professionals and competitors, as well as workshops geared toward regular homeowners on topics like boosting efficiency in residential buildings, and basics of passive solar design. The Decathlon can be thought of as part auto show, part Flower Show, and part Extreme Makeover Home Edition.

The relevance of the event as an instrument to provide information and stir interest in solar energy and good sustainability practices in residential construction is underscored by increased public conversation on climate change, shifts in the housing market, and the anticipated publication of LEED Residential standards. The cluster of graphs below, furnished by the DOE Energy Information Administration, show that residential energy use is a significant chunk of overall US consumption. I would argue that private residences are an interesting position for energy efficiency improvements because of the small scale, quick startup, and perceived value of such improvements. Since homeowners tend to be very invested in the long-term viability and quality of their homes, they are often willing to research and invest in sustainable solutions. These projects are driven by the homeowner's volition, so it is possible to see movement more quickly and easily than within a large government, corporate, or industrial infrastructure, especially if funding opportunities exist.

Figure 2.1a Energy Consumption by Sector Overview



Source: DOE Energy Information Administration

Some Solar Basics

While a thorough discussion of solar technology is obviously too broad a topic for this format, it is appropriate to give a very brief run-down of basic types of solar collectors. Solar radiation reaches the earth as shortwave radiation (light), and bounces back into space as longwave radiation (heat).¹

A well-documented and interesting property of glass is that it is transparent to shortwave solar radiation such as infrared and visible light, but opaque to longwave radiation. In short, glass lets in light and traps heat, which makes it a better greenhouse material than plexiglass, for example. Clark Snell's book *The Good House Book: A Common-sense Guide to Alternative Homebuilding* does a good job of explaining this phenomenon in simple language.²

Solar installations that go beyond simply using sunlight, such as windows and solar concentrators,

fall broadly into two categories, thermal and photovoltaic (PV). Thermal systems directly use heat from the sun to do work, while PV systems use special substrates to transform solar radiation into electricity. PV systems to date have relatively low efficiency, but the electricity they produce can be used directly for many applications. On the other hand, thermal systems simply sop up heat from the sun. The simplest examples are standing in front of a closed window on a hot summer day, or putting a dark-colored basin full of water in the sun on a warm day and observing how much it heats up. Solar thermal systems can be very effective for heating air (in the case of passive solar building design) or water or a glycol mix which can be used directly for domestic hot water or home heating. Transforming heat into electricity or some other form of energy requires some engineering and always results in some loss of efficiency. The common distinction between “active” and “passive” systems can be somewhat misleading, but generally refers to systems that are pump-assisted or completely free-standing (relying on convection), respectively. The exhibits at the Solar Decathlon use all these techniques in their designs.

The Competition

Goal and Structure

The goal of the competition is stated in the RFP for 2009 projects:

“The Solar Decathlon is a key strategy to achieve an important goal for NREL and DOE, namely, to foster development and facilitate widespread adoption of solar-powered homes that demonstrate solar technologies in marketable applications, through technology development and key partnerships. ... A critical long-range outcome of the Solar Decathlon project is the development and demonstration of solar-powered homes in which, by the year 2015, the whole-house, levelized energy cost has been reduced to \$0.10/kWh, while complying with the criteria associated with the ten contests that comprise the competition.”

Getting to a price point of \$0.10/kWh is a significant goal, in view of the fact that currently, solar electricity goes for about \$0.30/kWh.³ A further goal is to encourage collaborations between students in different disciplines “to achieve the goal of developing and demonstrating solar technologies in marketable residential applications.”⁴

Proposal Requirements

The competition is international, and is open to any accredited higher learning institution. Teams submit proposals in response to a detailed RFP published by NREL, and 20 or fewer teams are chosen from the pool of applicants to receive funding and be invited to showcase their project on the Mall. The RFP for 2009 was published even before the end of the 2007 competition, and proposals are due December 7, 2007, so planning starts quite early. Funding is given in two chunks of \$50,000

over two years. Student teams are expected to do the rest of the fundraising themselves, petitioning for donations of a money and materials from private and corporate sponsors. In fact, 25% of the proposal evaluation hinges on “Fund Raising and Team Support.”

Teams must meet a detailed set of expectations even before presenting on the Mall. Each team must design, build, and test a solar home, acquire an electric car for the Moving Around contest, and provide detailed deliverables like performance modeling, economic and energy analyses, a business and fund-raising plan, project manuals, an informational website, safety plans, and even a dinner party menu to fulfill the cooking requirement.

History and Competition

The first Solar Decathlon was held in 2002 with fourteen teams competing and over 100,000 visitors.⁵ It was repeated in 2005 (18 teams) and 2007 (20 teams), and NREL plans to hold it every two years until 2015.⁶ Below is a table of competing teams at each past Decathlon.

Solar Decathlon Teams by year		
2002⁷	2005⁸	2007⁹
<ul style="list-style-type: none"> ●Carnegie Mellon ●University of Colorado at Boulder ●University of Puerto Rico ●University of Texas at Austin ●Auburn University ●Crowder College ●University of Delaware ●University of Maryland ●University of Missouri-Rolla and Rolla Technical Institute ●Texas A&M University ●Tuskegee University ●University of North Carolina at Charlotte ●University of Virginia ●Virginia Tech 	<ul style="list-style-type: none"> ●Pittsburgh Synergy: Carnegie Mellon, University of Pittsburgh, and The Art Institute of Pittsburgh ●University of Colorado, Denver and Boulder ●Universidad de Puerto Rico ●California Polytechnic State University ●Canadian Solar Decathlon: Concordia University and Université de Montréal ●Cornell University ●University of Maryland ●Crowder College ●University of Massachusetts Dartmouth ●Florida International University ●University of Michigan ●New York Institute of Technology ●University of Missouri-Rolla and Rolla Technical Institute ●University of Texas at Austin ●Rhode Island School of Design ●Virginia Polytechnic Institute 	<ul style="list-style-type: none"> ●Carnegie Mellon University ●University of Colorado at Boulder ●University of Texas at Austin ●Technische Universität Darmstadt ●Cornell University ●Texas A&M University ●Georgia Institute of Technology ●Universidad Politécnica de Madrid ●Kansas Project Solar House (Kansas State University and University of Kansas) ●Universidad de Puerto Rico ●Lawrence Technological University ●Massachusetts Institute of Technology ●University of Cincinnati ●New York Institute of Technology ●University of Illinois at Urbana-Champaign ●Penn State ●University of Maryland ●Santa Clara University

	and State University ●Universidad Politécnica de Madrid ●Washington State University	●University of Missouri – Rolla ●Team Montréal (École de Technologie Supérieure, Université de Montréal, McGill University)
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The University of Colorado was the overall winner in 2002 and 2005, and the German Technische Universität Darmstadt team took first place in 2007. The ten judging criteria have changed over the years, as illustrated in the following table:

Contests and Scoring		
2002¹⁰	2005¹¹	2007¹²
Design & Livability	Architecture — 200 points	Architecture — 200 points
Presentation & Simulation	Dwelling — 100 points	Engineering — 150 points
Graphics & Communication	Documentation — 100 points	Market Viability — 150 points
Comfort Zone	Communications — 100 points	Communications — 100 points
Refrigeration	Comfort Zone — 100 points	Comfort Zone — 100 points
Hot Water	Appliances — 100 points	Appliances — 100 points
Energy Balance	Hot Water — 100 points	Hot Water — 100 points
Lighting	Lighting — 100 points	Lighting — 100 points
Home Business	Energy Balance — 100 points	Energy Balance — 100 points
Getting Around	Getting Around — 100 points	Getting Around — 100 points

Important themes that have carried across the scoring changes are the importance of attractive and livable architecture that does not expect consumers to live in Jetsons houses, the use of sustainable building materials from waste wood support beams to shipping container shells, communication about the design and materials of the home both at the event and after via a team website, and sufficient energy production for comfortable living and an electric car. Some builds made an effort to make their projects theoretically affordable to regular consumers, while many were designed with high-end amenities. The 2007 contest included a Market Viability contest which hopefully leveraged the contest to move solar technology closer to the mainstream.

The 2007 context descriptions give good insight into the level of detail sought by the judges. To start, each home must be completely powered only by the sunlight that falls on the Mall during the competition, which points given for excess energy to power a solar car. The 2009 RFP has been amended such that the next Decathlon will feature a site-wide power grid to eliminate the need for each house to furnish its own battery storage. Footprint is limited to 800 square feet (700 for 2009) not counting decks or porches, with no basement and no disturbance to the ground below.

Next, individual contests are as conventional as “firmness” (“the house's strength, suitability, and appropriateness of materials for the building”) and as whimsical as “delight” (“surprises, unusual

use of ordinary materials, or use of extraordinary materials in the house"). Measurables include items such as maintaining indoor temperature between 72°F - 76°F and relative humidity between 40% - 55%. Refrigerators and freezer temperatures must be maintained, teams must wash and dry 12 towels for two days, cook meals and use a dishwasher for four days, and operate electronics like TVs and computers for six to eight hours per day.

The communication contest underscores the importance of the competition as a public education tool. Teams are required to give tours of their home as well as provide a web site and materials that clearly and consistently communicate the goals and key design features of the home. The jury of Internet and public relations professionals judge the teams on clarity, informativeness, and ease of use of the communication tools. The Decathlon as a whole employs a variety of communication tools, including a web site, press releases, videos, blogs, podcasts, and even the obligatory MySpace page.

The houses are open every day of the competition except for one, when they are only open to judges. The public is invited to workshops like Solar for the Homeowner and Renovating Green, as well as Ask The Expert sessions. In 2007, the Thursday of the competition was set aside as Building Industry day with special workshops for professionals.

After the competition, many teams devise plans to sell or redeploy the homes as either educational exhibits on their home campuses, special housing for University-affiliated residents, or as marketable products for sale.

Sponsorship

The major sponsors for 2007 were National Renewable Energy Laboratory (NREL), The American Institute of Architects (AIA), The American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE), The National Association of Home Builders (NAHB), U.S. Green Building Council (USGBC), BP, Sprint, Blue Egg media, and Honeywell, as well as a number of other organizations and manufacturers. The homes prominently feature products such as countertops and flooring made of sustainable materials, and the University of Cincinnati 2007 entry was sheathed in a rain screen made of salvaged steel roofing material. The heavy emphasis on manufacturers' products makes it clear that the competition is definitely not a pure science endeavor, but that is not its intention, and many visitors seem happy to find out about the array of products they can seek out for their own renovation projects. The Decathlon website features searchable product lists by team, which can be helpful to consumers and builders.



Rain shell made of salvaged steel roofing from University of Cincinnati. Source: Inhabitat.com

Trends From Year To Year

I attended in 2005 and 2007 and saw a few salient trends each time, perhaps indicating upcoming trends in building materials. In 2005, reused shipping containers were all the rage as shells, whereas in 2007, SIPs (structural insulated panels) and rain shells were very popular structural materials. 2005 saw many structural beams made of scrap wood compressed and bound with plant-based resin, and in 2007, futuristic aerogels were the insulator of choice. Rain barrels, green roofs and landscaping with native plants are always big hits, and 2007 saw several lovely examples of green walls. Alternative countertop materials such as recycled paper and glass and sustainably harvested flooring materials made strong showings both years I attended.

The solar homes are filled with interesting design and engineering innovations, such as the much-photographed self-adjusting solar collectors built into louvers surrounding the winning 2007 entry from Technische Universität Darmstadt. Other entries have included aerogel-filled skylights with astronomical R-values, phase-change materials embedded in walls to collect and release heat as needed, an attractive room divider/heat exchanger made of flexible copper tubing, and even a solar-powered hydrogen fuel cell system. Décor ranges from somewhat traditional to quite modern, but I have found all the homes to be attractive and well laid-out. CNN's Money column was impressed by these features: "Think an indoor waterfall that, improbably, sucks moisture from the air - it's spiked with calcium chloride - and curbs the need for air conditioning. Think a stove powered by magnets,

and insulation made from recycled blue jeans.”¹³ The Decathlon is heavy on both creative engineering and “wow” factor.



Solar shutters on Darmstadt University entry. Source: Inhabitat.com

Stengths, Weaknesses, and Critique

Oddly, virtually the only critique I found about the event showed up as articles and comments on various blogs. A blog called 765 complained about the “obligatory” green elements such as a shipping containers and solar panels slanted for optimal solar gain, as well as “bland kit-of-parts architecture, assembled to an instruction manual provided by Dwell Magazine.”¹⁴ Personally, I find reused building materials quite attractive and interesting, and I don't understand a critique of properly oriented solar collectors. More compelling were the comments in response to New York Times blogger David Pogue's positive review. Commenters questioned whether the homes would be reused or simply added to a landfill, what impact they made to the lawn of the Mall, and if they actually had a positive effect on runoff. The comment thread spawned an interesting discussion of energy policy in the US, and electricity buy-back practices in different states and countries. The most vociferous criticisms pointed out that DOE/NREL funding is a pittance compared to the actual costs of the projects, hinting that DOE is not serious about funding solar research and that the projects do not do a good job of mainstreaming solar tech. One commenter claimed to have overheard a participant call the competition a “PR stunt”.¹⁵ Also questionable is the heavy-handed

marketing by major funder BP, which maintains a website and blog to publicize their participation in the Decathlon. BP has certainly undergone its share of scrutiny for creating a public image that focuses on alternative energy while continuing with petroleum at the core of its business model.

While some of these critiques are more helpful than others, overall, the event fulfills its mission of bringing together students, professionals, and the public to showcase a mix of cutting-edge engineering and consumer-oriented solutions, even if it sometimes looks like a manufacturer showcase. I especially like the focus on footprint, because a compact floor plan can mean more efficient systems, lower footprint impact, and denser development from a planning perspective.

The sheer size of the competition makes it complex to export to other situations, but certainly there are many countries whose energy departments would be capable of supporting such an exhibit. The detailed electronic resources that accompany all the projects and the competition as a whole make core messages of the event accessible to those who cannot visit in person.

Conclusion

There is informative critique about the corporate funding, DOE's commitment to energy conservation versus the desire for a green dog and pony show, and applicability for regular homeowners. These critiques are useful for contextualizing the event and seeking improvements, but overall, I think it is an extraordinary multi-layered educational opportunity. It seems to offer truly enriching, hands-on learning opportunities for students and professionals in engineering, design, architecture, and marketing, as well as a platform for new green building products and techniques, many of which are available to the public.

I feel that my personal experience with the event is somewhat telling, because I toured the Decathlon as both an interested homeowner and a graduate student. I saw the 2005 exhibits before beginning my MES coursework, and when I attended in 2007, I had completed nearly two thirds of my coursework, including an in-depth paper on flat-plate versus evacuated tube solar collectors for domestic hot water. Of course my experience was quite different from 2005 to 2007, but I found both visits very enjoyable and informative. In 2005 I did not feel overwhelmed or excluded, and in 2007 I did not feel bored or unchallenged.

The multi-layered appeal as well as the extremely tangible showcase format of the event make it a very appealing and impressive educational tool for several different groups. I believe that the Decathlon strikes an effective balance between appealing to professionals and non-professionals which can and should be emulated by other educational events, though the scale of the event makes duplication prohibitive.

- 1 <http://www.physicalgeography.net/fundamentals/7i.html>
- 2 <http://books.google.com/books?id=xwLKa8-FRVoC&pg=PA83&lpg=PA83&dq=solar+longwave+shortwave+light+heat+glass&source=web&ots=hoKGkqcyvi&sig=Ptr8kW1-3rxoQvQdHu5jWn5W7IU>
- 3 <http://www.solarbuzz.com/SolarPrices.htm>
- 4 http://www.solardecathlon.org/pdfs/2009_rfp.pdf
- 5 http://www.solardecathlon.org/past_decathlons.html
- 6 http://www.solardecathlon.org/pdfs/2009_rfp.pdf
- 7 <http://www.solardecathlon.org/2002/teams.html>
- 8 [ibid.](#)
- 9 <http://www.solardecathlon.org/teams.html>
- 10 http://www.solardecathlon.org/2002/contests_results.html
- 11 http://www.solardecathlon.org/2005/contests_scoring.html
- 12 http://www.solardecathlon.org/contests_scoring.html
- 13 http://money.cnn.com/2007/10/12/magazines/fortune/solar_decathalon.fortune/
- 14 <http://765.blogspot.com/2007/10/apollo-soyuz-aesthetics-of-engineering.html>
- 15 <http://pogue.blogs.nytimes.com/2007/11/01/the-future-of-solar-powered-homes/>