National coverage on the *Today Show.* The highest ranking—ninth place—for a first-time team. These were just two results from UK’s impressive showing at the U.S. Department of Energy’s Solar Decathlon last fall.

The decathlon, held every two years since 2002, challenges teams from 20 universities worldwide to build an 800-square-foot solar-powered house on their home campus, transport the house to the National Mall in Washington, D.C., and compete—rain or shine.

Why a Solar Decathlon? Residential buildings account for 20 percent of U.S. energy usage. DOE Secretary Steven Chu says, “More efficient buildings powered with renewable energy can and must play a major role in meeting the energy challenge. Students represent the next generation of clean-energy pioneers and entrepreneurs, and this event is a great example of what American innovation can accomplish.”

The House That UK Built

By Alicia P. Gregory

The solar panels on the front of UK’s house catch the morning sun during the 2009 Solar Decathlon on the National Mall. The deck provides recreational space for a Kentucky tailgate staple—cornhole.
UK’s S.KY Blue (“S” for solar, “KY” for Kentucky) team was comprised of students, faculty and staff from six colleges (agriculture, arts and sciences, communications and information studies, design, engineering, and medicine) and 16 centers and departments at UK. The team was led by Donald Colliver, a professor of biosystems and agricultural engineering in the College of Agriculture, and Gregory Luhan, the associate dean for research in the College of Design.

When you ask the students on the S.KY Blue team what they took away from the experience, you get a wide range of responses: “You look to your left and to your right and see the Washington Monument on one side and Capitol on the other. It’s an amazing, incredible experience to build on the National Mall. How many students get to do that?” answers Josh Duddey, who is pursuing his graduate degree in architecture at UK. Both Duddey and his cohort Kellin Vellenoweth started working on the solar house as undergrads and stayed at UK as graduate students to complete this project. Vellenoweth cites practical lessons learned like “you’ve got to have something to nail to” and “just because it looks like it works on paper, doesn’t mean it works in the field.”

But the student consensus was, as their mentor Luhan puts it, that the most important result was “proof-of-concept. This project demonstrated to the students that their ideas are buildable, have market appeal, and can compete against the world.” And it proved to Kentucky, and the world, that it’s possible to construct a Top-10, beautifully designed, energy-efficient, solar-powered house today.

**Solar Today**

While it was on the National Mall, UK’s house had as many as 6,000 visitors a day, with 250,000 total visitors to the competition. Sometimes 100 people at a time were inside the 800-square-foot house. Vellenoweth laughs as he points out: “It was remarkable how many people you could fit in there, without feeling cramped.”

Luhan reveals the two most asked questions by visitors touring the S.KY Blue house: “How much does it cost?” and “Is this something I can do right now?”

The house cost a little less than $500,000 to construct. The team had a budget of $750,000 that included money

The interior features Shaker-inspired built-ins, including a table that slides out of the wall and chairs that hang flat on the wall. The dining table can sit up to eight people. When the table is folded into the wall, the living room gains 96 square feet of space.
for the team to travel to Washington for a preliminary meeting with Solar Decathlon officials, $75,000 for photovoltaic (PV) panels (the technology that converts solar radiation to electricity) and wiring, transportation of eight truckloads to and from the Mall, and travel and housing in Washington for almost a month for 30 team members.

“None of this would have been possible without the sponsorship of E.ON, UK and several hundred folks locally and nationally,” Luhan asserts. The team received $250,000 from E.ON-U.S., the Louisville-based subsidiary of the world’s largest investor-owned energy services provider and a longtime industrial partner with UK. The team had the help of more than 50 sponsors (through monetary donations, products, materials, and labor). Luhan says 175 students were involved during the two-year project, with a core of 10 design students and five engineering students who spent four months doing the physical construction of the house and the 2,300-square-foot deck.

And, yes, you can build a solar house today. It’s pricey mainly because many of the items in the house were custom made and the technology is so new that demand isn’t high enough to bring down the cost of manufacturing it. Like anything else, it’s about supply and demand. By combining what Luhan calls “leading-edge technologies”—discoveries coming directly from UK laboratories—and third-generation Energy Star appliances from GE (these products, not even on the market yet, use 30 percent less energy than the appliances available now), he says the UK team demonstrated solar power is marketable. “One of our mantras for the project was ‘By Kentucky, for the world.’ The solar house project has helped put the University of Kentucky on the global map. President Lee Todd is always challenging us to compete on the international level, and we’ve proven we can compete.”

The campus and then the world will get a chance to see the S.KY Blue house while it’s on display in front of the Main Building until September 2010 when it will serve as the Lexington Convention and Visitors Bureau’s welcome center at the Alltech FEI World Equestrian Games. Luhan says 1.5 million people are expected to attend the games. “What better way to demonstrate the ingenuity of Kentuckians than to showcase this house when the world comes to Lexington.”

**Kentucky Tradition & Innovation**

Visitors to UK’s solar house will see a design that melds leading-edge technology with Kentucky’s traditional aesthetics. The house reflects the popular architectural “Kentucky shotgun” design. All of the rooms feed off a single long hallway that runs the length of house. The interior features native Kentucky maple and cherry woodwork, as well as Shaker-style built-in cabinetry and chairs that fold flat and hang on pegs in the main living area when not in use. A large table, which works at a regular dining height or can be raised to counter level for additional kitchen prep space, folds into a panel in the wall. These space-saving features expand the open feeling of the house.

Luhan draws attention to the skylights as well as the low windows placed at the floor in many of the rooms.
“Frank Lloyd Wright had this great idea that you should allow light to come in low and then reflect up deep into the house. One hundred percent of the occupied spaces have natural daylight.”

The exterior, too, bridges aesthetics with technology. It features pixilated photos of Kentucky’s iconic horse farm fences. “We worked with local artists, like UK grad Lee Ann Paynter, to take photographs of Kentucky landscapes. We wrote our own computer scripts to take those photos and turn them into pixels, and then turn pixels into perforations that were punched into the cement fiberboard that wraps around the back of the house.” High-efficiency LEDs (light-emitting diodes) were mounted behind the perforations to illuminate the photos after dark. It’s a uniquely Kentucky twist on night-time lighting for the exterior deck space.

As far as its technology, the S.KY Blue house is one-of-a-kind. The roof is covered with PV panels that can tilt up and down throughout the year to catch the sun at the best angle. Rainwater collected on the roof is used inside to flush the toilet and wash clothes, and outside to supplement irrigation.

Luhan says their roof and deck water capture design holds 2,018 gallons in the driest month, October, which averages 2.7 inches of rain. “With a single low-flush toilet and Energy Star washing machine, our total water consumption is around 1,700 gallons per month.” The excess water is diverted, purposefully, into the landscape.

Plant water-demand controls, developed and tested by the College of Agriculture’s Richard Warner, detect when plants need moisture, deliver a pulse of water, and then check again to see if more water is needed. “This technology has been shown to reduce water usage by 40 percent while maintaining the quality and amount of vegetable production,” Colliver says.

Inside the house, Luhan explains that the UK team had two goals: generate as much energy and use as little energy as possible. Air conditioning is an energy hog, so the UK team employed an electrochromic system that turns glass from clear to a dark tint (like sunglasses) to reduce the heat gain inside the house. Colliver explains, “During the winter you want sun to shine into the space.

Anne Fugazzi, who earned her bachelor’s degree at UK and is now a grad student in the architecture program, was involved in cost estimating, project manual preparation, and woodwork finishing for the S.KY Blue house. “I take so much pride in this experience. I put my blood, sweat and tears into this house, and I wouldn’t have had it any other way. I learned to work together with engineers, how to problem solve, use tools and building techniques that I never pictured myself doing. I had the opportunity to understand the design process from a concept to a fully functional, 800-square-foot house that embodies forward thinking and high design. This experience has truly prepared me for my future far more than any other experience I’ve had at UK.”
and warm it up, but in the summer you don’t want that heat. In our house if you need less sun, all you do is flip a switch that sends a tiny amount of energy to electrically ‘charge’ the glass to turn it from clear to tinted.”

This glass-tinting system is tied to a larger system—the Automated Weather Adaptive Response Energy system (AWARE)—that controls heating, cooling and ventilation. Developed at UK, this system receives zip-code-specific short-term (24- to 72-hour) weather forecasts every three hours, evaluates the various energy storage options available, and selects the best energy plan. The plan that optimizes energy consumption and generation is then implemented for the next three hours.

Jeffrey Kellow, a grad student in biosystems and agricultural engineering, and Josh Shank, an undergrad in electrical engineering, designed the user interface for AWARE. Kellow, who earned his B.S. in mechanical engineering from UK, explains: “The homeowner can adjust the system and view a display of home energy usage from a touch screen in the living room. I wrote the control code for the home in Visual Basic, which integrated the heating, cooling and ventilation systems, and allowed for control based on the weather forecasts.”

Colliver says, “On a single panel, the homeowner can see every circuit and item consuming energy. Nobody else at the decathlon had anything close to that. In fact, the AWARE system is what drew the attention of the editors of NBC’s Today Show.” The national morning show featured UK, as well as Team Germany, Team Boston and Rice University. To see Kellow talk about the system on the Today Show, visit: www.uky.edu/solarhouse/media.html.

Above and Beyond a Contest

The decathlon gets its name from the 10 specific areas of competition: architecture, engineering, market viability, lighting design, communications, comfort, appliances, hot water, lighting, and transportation.
water, home entertainment, and net metering. UK placed in the Top 10 in three of the contests: 5th in net metering, 7th in appliances, and 8th in home entertainment.

Arguably, net metering is the most important competition, the one that is central to the goal of a solar house—producing as much or more energy than you consume. (You might have heard of the notion of “net zero.” This means you produce exactly the same amount of energy as you use.) Each house was equipped with a utility meter that measured how much net energy the house produced and consumed over the course of the competition. Teams scored points for producing as much or more energy than they consumed. Ultimately, the goal is that a solar house would draw electricity from the utility grid only when the sun wasn’t producing enough power and, optimally, send any “extra” energy to the grid for public use.

Luhan says he expected UK to do well in net metering. “With the third-most photovoltaic panels in the competition—behind Team Germany and Team Spain—we should have been able to generate a ton of energy, and we did. The key was using as little energy as possible.” But Mother Nature wasn’t a team player. “The last three days of the competition it rained,” Colliver says somberly. “It rained long and hard. We had two inches in three days. It was cloudy.”

In response to the three-day waterlog, some of the other teams—including Team Germany which won first place at the Solar Decathlon—chose to not compete in all of the contests. Luhan says, “Even Team Germany, who produced more energy than anyone else, decided to close the doors to tours, not compete in all of the events, and have meals catered in instead of cooking them at the house.” It was their prerogative to sacrifice the points from the “smaller” contests to hedge their bet of winning the net metering contest (which Team Germany did). But Colliver says UK took a different path. “We chose to operate the house as intended—to continue giving tours, to wash clothes, to cook meals, to light the house, to have other teams over to watch TV. And we still scored fifth in net metering.”

“Could we have gained more points by shutting everything down? Probably,” Luhan says with a smile. “But we proved beyond a shadow of a doubt the validity of our design. From my personal standpoint, I don’t think we would have been able to show the validity, the proof-of-concept, if we had competed in that way.”

“We achieved our goals,” Colliver says. “My personal goal was to write a proposal that would get us accepted into the competition, to get into the Top 20. We had some very stiff competition from some of the biggest schools in America, not to mention Puerto Rico, Canada and Europe. The decathlon didn’t release the number of proposals, but I know that the team that came in first in 2002 and 2005, and third in 2007 submitted a proposal and was not selected to participate in 2009.” Colliver draws...
Making it into this competition is for engineers and architects what the Sweet 16 is to NCAA basketball teams. It’s huge!

“My second goal was to score well in the net metering contest. We scored fifth. We achieved net zero. The numerical results are great, but they weren’t the only things we gained.”

Soon after the S.KY Blue team returned from the decathlon, they presented their design in Chicago at the Illinois Institute of Technology, and at USG Corp, a company that makes drywall for commercial and residential buildings. Luhan says, “One of the major folks at USG is Warren Buffett. He’s trying to design a house that operates on a dollar a day. Six years ago USG tried to market a very similar solar concept, but couldn’t find a foothold for it. When our students presented their product, that they built in four months, USG was pretty excited from a potential donor standpoint for future competitions.”

Colliver emphasizes the impact on the students: “All of the great things this team achieved pale in comparison to those ‘Ah-ha!’ moments when a student said, ‘It finally gelled.’

“This is my 30th year teaching, and I’ve had more teachable moments in this project than in the 29 years prior, combined. You can describe things in equations and work through homework problems, but at one o’clock in the morning when the student finds out he has to put in a bigger pipe because the pump he installed isn’t going to supply sufficient water flow, that’s a real-world educational opportunity. You go back to the basic principles they learned in class—what are the key parameters and how did you solve it on the computer? Let’s talk about how those parameters impact the problem so you can solve it in the field.

“Our students had a tremendous number of ‘Ah-ha!’ moments. The learning that took place during this project—that’s the lasting value of Solar Decathlon.”

Making Solar Accessible
“The quarter-inch-thick Solar Decathlon rule book required a wheelchair ramp to make the house ADA compliant so that the public could tour it,” Donald Colliver explains. “But our team went above and beyond by making our entire house accessible. (The 1990 Americans with Disabilities Act requires all public spaces to be equipped to accommodate people with disabilities.) "A small house has its own unique design challenges, and then to make it large enough so that you can make all the turns in a wheelchair adds another layer of complexity,” says Colliver. “But it was rewarding. In looking at potential markets for the solar house, we identified the ‘aging in place’ community—people who want to stay in their home as they grow older.”

Luhan adds: “We designed a house that would succeed on the National Mall and have an immediate impact upon its return. Our design sets into play many of the philosophies of the original ‘green’ generation, the people that started the sustainability and recycling movements who are now in their 60s. We wanted to create a product that was desirable for both the 20-something and the 60-something. We took a transgenerational approach, with built-in adaptability and durable materials. Rather than having to do demolition to renovate your home as you age, the house adapts to you.”

Pneumatic controls raise the dining table to the height of the kitchen counter. The kitchen counter raises and lowers, and so does the bathroom vanity. “Instead of a small toilet room separated from the shower, we have a 6-foot by 8-foot bathroom. The outlets and control panels are at a comfortable height for everyone.” Luhan adds that by adding a module, the one-bedroom, one-bath house can easily become a three-bedroom, two-bath house without sacrificing energy performance or efficiency.

“This accessibility and adaptability was something we came up with as a team that we valued. And the design we created by following the ADA rules made our space just ‘feel’ better. We designed the house to have a lifetime outside the competition,” adds architecture grad student Kellin Vellenoweth.

Josh Ayoroa, an architecture grad student with a background in tool and die manufacturing, says, “We didn’t work around the clock—18- to 20-hour days for four months—to build something that would be useful for only a month. We will continue to learn from the house.” The S.KY Blue house will be a “living laboratory,” where UK students and researchers will be able to study the efficiency of new technology and refine adaptive systems like AWARE (see p. 10). Ayoroa says, “I’ve learned that if I choose to pursue green design, I’ll probably be able to spend the rest of my life looking at this design challenge, finding new solutions and making innovations.”