WINNING TEAMS AND INNOVATIVE TECHNOLOGIES FROM THE 2005 SOLAR DECATHLON

HEARING

BEFORE THE

SUBCOMMITTEE ON ENERGY

COMMITTEE ON SCIENCE

HOUSE OF REPRESENTATIVES

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WINNING TEAMS AND INNOVATIVE TECHNOLOGIES FROM THE 2005 SOLAR DECATHLON

WEDNESDAY, NOVEMBER 2, 2005

HOUSE OF REPRESENTATIVES,
SUBCOMMITTEE ON ENERGY,
COMMITTEE ON SCIENCE,
Washington, DC.

The Subcommittee met, pursuant to call, at 2:03 p.m., in Room 2318 of the Rayburn House Office Building, Hon. Judy Biggert [Chairwoman of the Subcommittee] presiding.

COMMITTEE ON SCIENCE
SUBCOMMITTEE ON ENERGY
U.S. HOUSE OF REPRESENTATIVES

Winning Teams and Innovative Technologies
from the 2005 Solar Decathlon

Wednesday, November 2, 2005

2:00 PM – 4:00 PM
2318 Rayburn House Office Building

Witness List

Mr. Richard F. Moorer
Deputy Assistant Secretary for Technology Development
Office of Energy Efficiency and Renewable Energy
The Department of Energy

Mr. Robert P. Schubert
Professor and Team Faculty Coordinator
College of Architecture and Urban Studies
Virginia Polytechnic Institute

Mr. Jeffrey R. Lyng
Graduate Student and Team Project Manager
Civil, Environmental, and Architectural Engineering
University of Colorado

Mr. Jonathan R. Knowles
Professor and Team Faculty Advisor
Department of Architecture
Rhode Island School of Design

Mr. David G. Schieren
Graduate Student and Energy Team Leader
Energy Management
New York Institute of Technology

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HEARING CHARTER

SUBCOMMITTEE ON ENERGY
COMMITTEE ON SCIENCE
U.S. HOUSE OF REPRESENTATIVES

Winning Teams and Innovative Technologies From the 2005 Solar Decathlon

WEDNESDAY, NOVEMBER 2, 2005
2:00 P.M.–4:00 P.M.
2318 RAYBURN HOUSE OFFICE BUILDING

1. Purpose

On Wednesday, November 2, the Energy Subcommittee of the House Committee on Science will hold a hearing to showcase winning teams and energy technology highlights from the 2005 Solar Decathlon, a Department of Energy sponsored competition in which student teams design and build homes powered entirely by solar energy. The Subcommittee will also examine the research and policy implications of the Decathlon, including steps necessary to make solar power more viable in the mainstream market.

2. Witnesses

Richard F. Moorer, Deputy Assistant Secretary for Technology Development, Office of Energy Efficiency and Renewable Energy, Department of Energy.

David G. Schieren, Graduate Student and Energy Team Leader, Energy Management, New York Institute of Technology.

Jeffrey R. Lyng, Graduate Student and Team Project Manager, Civil, Environmental, and Architectural Engineering, University of Colorado.

Jonathan R. Knowles, Professor and Team Advisor, Department of Architecture, Rhode Island School of Design.

Robert P. Schubert, Professor and Team Advisor, Department of Architecture, Virginia Polytechnic Institute.

3. Overarching Questions

- What are some of the innovative solar and efficiency technologies the teams chose to incorporate into their homes? Which of these technologies are experimental and which are ready for (or in) the market?
- What are the main technical and other barriers to greater use of solar energy? How can contests such as the Solar Decathlon help move both renewable and efficiency technologies into the mainstream building market?

4. Background on Decathlon

Purpose of Decathlon

The Solar Decathlon is a competition developed by the U.S. Department of Energy's (DOE) Office of Energy Efficiency and Renewable Energy (EERE) in partnership with the National Renewable Energy Lab (NREL) and several non-governmental sponsors.[1] According to DOE, the purpose of the Decathlon is—

- to encourage young people to pursue careers in science and engineering;
- to acquaint college students in science, engineering and architecture with solar power and energy efficiency;

[1] Information on sponsors can be found on the Decathlon website: *http://www.eere.energy.gov/solar_decathlon/sponsors.html* The main sponsors were: The American Institute of Architects, National Association of Home Builders, BP Solar, DIY Network and Sprint Nextel. Several other organizations and companies provided additional support.

- to encourage participating students to think in new ways about the way we use our energy;
- to push research and development of energy efficiency and energy production technologies, helping the U.S. maintain its technological competitive edge; and
- to educate consumers about what they can do to add solar power or reduce energy use in their own homes in ways that maintain their lifestyles.

The Competition

DOE held the first Solar Decathlon on the National Mall in 2002, and the second from October 6–16 of this year. Current plans are to hold the decathlon every two years in the future. The homes are open to the public for several hours a day during the competition. More than 100,000 visitors toured the solar homes last month, despite the relentless rain that plagued the competition.

Teams wanting to participate must submit proposals two years in advance of the competition. The proposals are reviewed by the Solar Decathlon Proposal Review Committee, consisting of architects, engineers, scientists and other experts chosen by DOE, to determine if they stand a reasonable chance of carrying the project through to completion, while meeting strict structural and safety requirements. For the 2005 Decathlon, The Review Committee selected 20 teams in 2003 from a field of 24. DOE allotted $5000 to each of the 20 teams. Total federal contribution to the decathlon is estimated to be $1 million, including management and oversight. Teams had to obtain all additional funding, materials, and other forms of assistance from outside donors. Most teams ended up with a total budget between $200,000 and $300,000 for their projects, including travel costs and the expenses associated with shipping their house to the National Mall for the contest. In the end, 18 teams succeeded in bringing homes to the National Mall for the competition.

Teams are made up of undergraduate and graduate students pursuing degrees in engineering, architecture, computer science, public relations, marketing, and other disciplines, working together to design and build their solar-powered homes. Each team has at least one faculty advisor, but students fill the project management and other leadership roles. Faculty advisors come from various academic disciplines, including engineering, architecture and design.

Houses are restricted to a maximum of 800 square feet of total building footprint and must produce sufficient energy to carry out all normal household functions: food cooking and storage, clothes washing and drying, dishwashing, bathing, as well as provide sufficient power for normal light levels at night and occasional use of appliances such as televisions and computers.

Each house is judged on 10 attributes (see the Appendix for more information on each contest):

1. Architecture
2. Dwelling
3. Documentation
4. Communications
5. Comfort zone
6. Appliances
7. Hot water
8. Lighting
9. Energy balance
10. Getting around (ability to charge an electric car).

Each competition is judged by a jury or panel of professionals chosen by DOE for their renown in their respective fields of architecture, interior design, public affairs, energy analysis, engineering or lighting. Each category is worth 100 points, except for architecture, which is worth 200 points. A winner is declared in each of the 10 contests, and points are summed to determine the overall winner. Some contests are won by objectively measuring performance (for example, providing adequate electricity to power appliances or lighting) and others are subjectively evaluated (for example, architecture and communications). Out of a total possible 1100 points, the top three teams of 2005—University of Colorado, Cornell University and California Polytechnic Institute—scored greater than 800 points. However, a number of teams that didn't make it into the top three overall did score in the top three in one or more of the 10 competitions. Among the teams represented at this hearing, Virginia Polytechnic Institute received first place in both architecture and dwelling, and second place in energy balance; and New York Institute of Technology received third place in both architecture and dwelling.

The Technologies

The decathlon houses featured technologies for energy efficiency, heating and cooling, passive and active solar thermal systems, photovoltaic solar electricity, and onsite energy storage, both electrical and thermal. Many of the technologies used are available to all consumers in their local home-improvement store, but some are still in the experimental stage. Below is a general description of the types of technologies that teams used in the decathlon homes.

Energy efficiency is the key to powering a house using only solar energy. By using each kilowatt-hour wisely, teams attempt to minimize the amount of energy they need to produce and store. For example, teams used highly efficient appliances and lighting, including fluorescent and solid-state lighting, to reduce the homes' total electricity demand, both directly and indirectly—efficient appliances emit less heat into the living space and therefore also lower air conditioning demand. Wall panels and windows were also chosen for their insulation rating and ability to pass or filter sunlight. While minimizing airflow to and from the outdoors is important to energy efficiency, all homes require ventilation to control humidity and provide fresh air. Many teams used Energy Recovery Ventilators, which use heat exchangers[2] to heat or cool incoming fresh air, recapturing 60 to 80 percent of the conditioned temperatures that would otherwise be lost. Many of these technologies are readily available to builders and consumers now. However, most teams also used some experimental or custom-built energy technologies and systems to reduce their energy demand.

All 18 houses used photovoltaic (PV) solar cells to directly convert sunlight to electricity. Most schools used the traditional silicon-based solar panels that are mounted on rooftops, and one of the teams used thin-film PVs that can be integrated into the roofline.

Solar hot water heaters, which use the sun to heat either water or a heat-transfer fluid in collectors, provided all hot water needs for the houses. In a typical house, where solar systems can reduce the need for conventional water heating by about two-thirds, the plumbing from a solar heater may connect to a house's existing water heater, which stays inactive as long as the water coming in is hot or hotter than the temperature setting on the indoor water heater. When it falls below this temperature, the water heater can kick in to make up the difference. One decathlon team captured waste heat from their refrigerator—a water-cooled unit designed for boats—to pre-heat their hot water. Others added thermal collectors behind the PV panels, which boosted electrical output (PVs are less efficient when they get very hot) and increased the total amount of solar energy captured per square foot of collector.

All houses also incorporated elements of passive solar and daylighting designs. The term "passive" implies that no mechanical means, such as pumps or fans, are required in the design. For example, passive solar designs can include natural ventilation for cooling, or, for heating, large south-facing windows and building materials that absorb and slowly release the sun's heat. In cold climates, south-facing windows designed to let the sun's heat in while insulating against the cold are ideal. In hot and moderate climates, the strategy is to admit light while rejecting heat. Interior spaces requiring the most light, heat, and cooling are located along the south face of the building, with less used space to the north. Most houses have open floor plans to allow more sun inside.

A few of the more unique technology choices, such as the hydrogen fuel-cells used by the New York Institute of Technology, and the phase-change heating and cooling system used by the Rhode Island School of Design, will be highlighted during the hearing.

5. Solar Energy in the Marketplace[3]

History

In 1954, Bell Labs introduced the first solar photovoltaic device that produced a useful amount of electricity, and by 1958, solar cells were being used in small-scale scientific and commercial applications, in particular for the space program. The energy crisis of the 1970s stimulated broader interest in solar power in the United States and elsewhere. Prohibitive prices (approximately 30 times current prices) made large-scale applications unfeasible. However, industry developments and research during the 1970's and 1980's made PV feasible for remote applications (especially for the telecommunications industry) and a cycle of increasing production and decreasing costs began which continues today.

New, next-generation PV materials currently under development may yet bring dramatic decreases in price. DOE research and development (R&D) funding for PV

[2] Heat exchangers are devices specifically designed for the efficient transfer of heat from one fluid to another over a solid surface. In the case of an energy recovery ventilator, the heat from the stale exhaust air is used to preheat the fresh-stream air coming into the house. In the case of cooling, heat is instead pulled from the incoming air.

[3] All facts and figures (except R&D spending) under this heading come from the Solar Energy Industries Association (SEIA): *http://www.seia.org*

reached a peak in 1980 of $260 million (inflation adjusted to 1999 dollars). The 1980's saw significant cuts, down to a low of $44 million in 1988 (inflation adjusted to 1999 dollars). Current DOE spending for PV R&D is $76.3 million, and the fiscal year 2006 request is $75 million. Small PV systems may also play a role in the transition to a hydrogen economy, as they can produce hydrogen through electrolysis, as demonstrated by the New York Institute of Technology decathlon team.

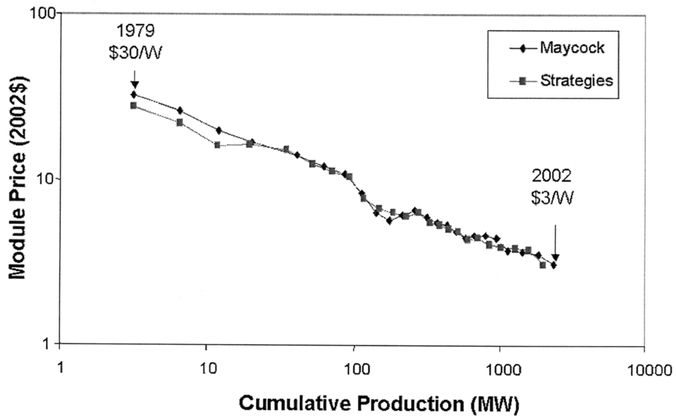

Figure 1. Relationship between PV module price and cumulative production, 1979-2002 (Source: SEIA)

Consumer Economics

A typical home PV system is two kilowatts (kW) capacity and costs $14,000 to $20,000 to install. This is enough to power an average-size home built to high energy efficiency standards. Using typical financing assumptions, a home PV system will generate power at a fixed and constant $.25—$.35/kW-hour over its 25-year-plus lifetime. The cost of PV is still higher than the equivalent retail cost of electricity that it offsets for the user—as high as $.14/kW-hour currently in parts of the U.S. However, costs for PV modules have historically decreased by 5–7 percent per year, with cost decreases to date apparently tied to manufacturing volume, as shown in Fig. 1. Integration of PV into the construction of new homes can also lower the installation cost and allow the equipment to be paid for in the mortgage, adding minimally to the monthly payment. Federal and State tax incentives, rebates and loan guarantees help lower the cost even further for many customers.

The Global Market and Eroding U.S. Leadership

Global PV market growth has averaged at least 25 percent annually over the last 10 years, with worldwide growth rates for the last five years at well over 35 percent (equivalent to a doubling of installed power every four years or less). However, PV still accounts for a small percentage of electricity generation worldwide. Figure 2 shows the cumulative worldwide PV manufactured between 1996 and 2004. There is approximately 4,000 megawatts (MW) of PV generating capacity worldwide, in addition to 354 MW of concentrating solar power[4] and possibly as much as 70 Gigawatts (GW) of solar heating capacity.[5]

[4] Concentrating Solar Power devices optically focus or concentrate the thermal energy of the sun to drive a generator or heat engine. They do so by means of lenses or more commonly mirrors arranged in a dish, trough or tower configuration.

[5] International Energy Agency Solar Heating and Cooling Program, http://www.iea-shc.org

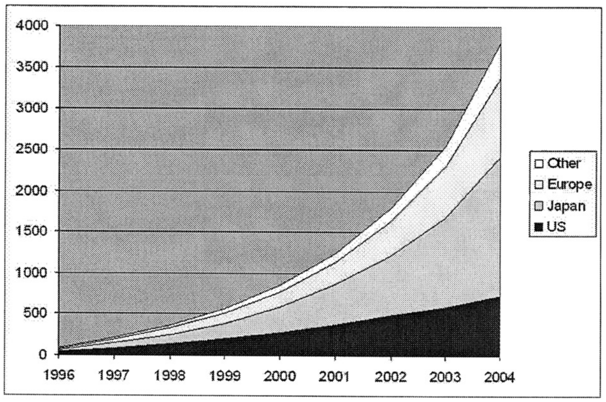

Figure 2. Cumulative PV manufactured (MW), 1996-2004 (Source: SEIA)

The United States was once the leader in solar technologies, but in 2004, U.S. companies manufactured only 11 percent of photovoltaics (in terms of MW output) available worldwide. Japan surpassed the U.S. as the global manufacturing leader in 1999, and Germany has since eclipsed the U.S. as well. Japan has manufactured approximately 44 percent; Europe, 25 percent; and the U.S., 19 percent of PV available in the market in the last decade. The percentages for installed capacity closely track the percentages for manufacturing output. The U.S. had approximately 365 MW of installed capacity by the end of 2004—roughly equivalent to the output of a standard coal-fired plant, or approximately 0.04 percent of U.S. electricity production. Germany and Japan are ahead in installed capacity in large part because they both instituted significant incentive programs for solar. Since its passage in 2000, the *German Renewable Energy Sources Act* ensures that utilities get paid 3–4 times the retail rates for electricity generated by solar installations. Ten years ago, Japan instituted a successful rebate program that is slowly being phased out. Despite its position as laggard in both manufacturing and installed capacity, the U.S. has tremendous growth potential for solar energy, as illustrated by the solar intensity map in Fig. 3. Here in the U.S., California is taking the lead with over 100 MW of installed grid capacity to date, but as the side-by-side comparison with sunshine in Germany demonstrates, even states that are less sunny than California can benefit from solar energy—most of the U.S. has a much better solar resource than Germany.

While few analysts expect that solar manufacturing capacity can continue to expand at this pace, if the growth rate of the last five years could be maintained, peak solar capacity could match today's domestic coal-fired capacity by 2025. Even then, since coal capacity is available more hours of the day than solar, the total output of kilowatt-hours from the solar capacity would be less.

Electricity demand varies throughout the day, as air conditioning and commercial activities peak in the afternoon. Base load is the amount of electricity needed to run all the systems that operate day and night: refrigerators, water heaters, traffic lights, etc. Absent an economical storage system, solar energy may not be ideal for base load electricity demand, but it is ideally suited to peak load production, since its output profile tends to match the demand. Peak load electricity from fossil fuels tends to be the least energy efficient, most expensive and most polluting, because utilities tend to operate their best plants first. As a distributed form of energy, solar can help offset the peak demand from polluting sources with zero emissions. Experts therefore expect that solar will act as a contributor to the overall mix of energy, but that we will still need to rely on coal, nuclear and gas generation.

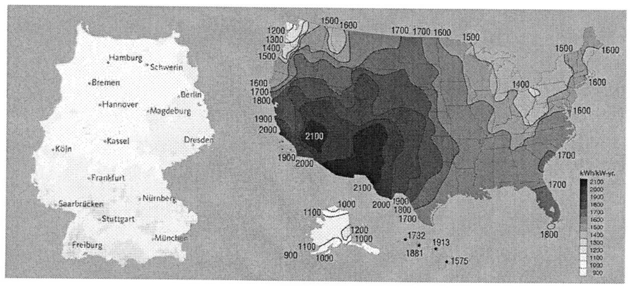

Figure 3. A comparison of solar intensity in Germany versus the United States (Source: SEIA)

6. Witness Questions

Mr. Schieren, Mr. Lyng, Mr. Knowles, Mr. Schubert:

- Please briefly describe the key features of your house.
- Given your experience, what do you think are the main technical and other barriers to greater use of solar energy? Do you have any suggestions for what might be done to overcome those barriers? How do you see the competition itself as helping to move both solar and efficiency technologies into the mainstream building market?
- What sources of information did you draw on to figure out how to build your house? What problems arose in designing or constructing your house that surprised you?
- Would your house be commercially viable? If not, what changes would make it more attractive to the mainstream home buyer?

Mr. Moorer:

- Please summarize the history of the Solar Decathlon.
- Please describe the major goals of the Solar Decathlon. To what extent are these goals being met?
- What, if anything, will you do differently for the 2007 competition?
- How do you see competitions such as the Solar Decathlon furthering the movement of solar and energy efficiency technologies into the mainstream building market?

APPENDIX

THE TEN CONTESTS

Architecture (200 points)

Teams are required to design and build attractive, high-performance houses that integrate solar and energy efficiency technologies seamlessly into the homes' designs. Scoring well in Architecture is crucial; teams can earn up to 200 points, twice the number of points available in the other contests.

Dwelling (100 points)

Experts from the residential buildings industry will award points based on their evaluations of the "livability" and "buildability" of the homes. Are the spaces designed well for everyday living—doing laundry and getting work done? Are the houses comfortable to live in and simple to care for? Are the houses' features easily reproducible? And would the houses attract buyers?

Documentation (100 points)

The Documentation contest awards points based on how well the teams analyzed their designs for energy performance and how thoroughly they documented the design process. Teams must document all stages, including the schematic design, design development, construction, and "as-built" phases of the Solar Decathlon project.

Communications (100 points)

Panels of judges with expertise in communications and public relations will judge the teams' Web sites and house tours and award points based on the success of the teams in delivering clear and consistent messages and images that represent the teams' visions and results.

Comfort Zone (100 points)

Teams will be judged on their ability to provide interior comfort in their houses by controlling temperature and humidity. Full points will be rewarded for maintaining narrow temperature and relative humidity ranges inside their houses. The teams will also be judged on indoor environmental and air qualities.

Appliances (100 points)

The Appliance contest is designed to replicate appliance energy use in the average American home in the United States, where appliances account for 20% of energy use. To earn points, student teams must maintain a certain temperature in their refrigerators and freezers, wash and dry clothing, cook meals, use a dishwasher to clean the dishes, as well as leave the television on for six hours a day and the computer on for eight hours a day.

Hot Water (100 points)

Teams can score points in the Hot Water contest by successfully completing the "shower tests," which entails delivering 15 gallons of hot water in 10 minutes or less. They will also be judged on how innovative the hot water system is, and the system's ability to deliver sufficient hot water throughout the year, including when guests visit.

Lighting (100 points)

Teams can score points in numerous ways, but this contest judges the amount of illumination supplied by both electric lights and daylighting. Lighting levels in each room of a team's house are continuously monitored and recorded. If a house maintains lighting levels within an optimal range, full points are awarded. Teams can also earn points from a panel of judges that will subjectively evaluate the teams' lighting designs, which are required to integrate both electric and natural light, from both a functional and an aesthetic standpoint.

Energy Balance (100 points)

Energy Balance will be scored by measuring the amount of energy going into the batteries from the solar electric system and the amount of electrical energy being drawn from the batteries to meet the houses' electrical needs. Teams earn full points if their battery systems have as much stored energy at the end of the competition as they did at the beginning.

Getting Around (100 points)

In the Getting Around contest, student teams use electricity generated by their solar electric systems to "fuel" their street-legal, commercially available electric vehicles. Teams then must log as many miles as they can—based on how much “extra” energy they have generated. Points will be awarded based on how many miles each team is able to drive.

Chairwoman BIGGERT. Good afternoon. The hearing of the Energy Subcommittee of the Science Committee will come to order.

I will recognize myself for an opening statement for five minutes.

In mid-October, 18 teams of undergraduate and graduate students from universities across the country assembled on the National Mall to demonstrate something amazing. After two years of work, they gathered in our nation's capital to demonstrate how a home could be powered entirely by solar energy. These students and their projects faced some serious challenges. After nearly two months baking in the sun, the Washington area received its first measurable rainfall on the opening day of the decathlon.

While I was not down in Washington at the time, I understand it was cloudy and rainy just about every day thereafter through the last day of the event. We were back in our Districts at the time, and we had no rain in the Chicago area, but it really was a deluge here. Now that kind of weather isn't so uncommon in Illinois, and during the winters in Chicago, we can sometimes go for weeks without seeing the sun.

But despite the conditions, the teams persevered, and their technologies worked, for the most part, and they needed to work in order to demonstrate the viability of solar power in places like Chicago in the wintertime. In the end, the projects were evaluated based on ten different criteria, many of the same criteria that Americans use to evaluate their choices when buying a home.

Today, we are going to hear from some of the winners of the 2005 Solar Decathlon as they show-and-tell us about the homes they designed and built for the decathlon. We hope to have some fun here, but we also want to engage these teams of young scientists and engineers in a serious conversation about the potential for solar energy in this country.

As the Chairman of the Subcommittee and a member of the Education Committee, I am especially pleased about the number of students actively involved in the Decathlon and in this important dialogue today. I think it is safe to say that the Members of this subcommittee are very much looking forward to learning more from you.

We hope that you will talk today about the kinds of technology and designs you used. We hope you will share with us what obstacles you believe must still be overcome before the Nation can benefit from the widespread use of passive and active solar-thermal systems, photovoltaic, solar energy, and on-site energy storage, both electrical and thermal.

Finally, we hope you will discuss the benefits of a competition such as the Solar Decathlon and about what we can do, as policymakers, to move more solar and efficiency technologies into the mainstream building market.

By 2025, our demand for energy is expected to grow by 50 percent, and energy for our buildings will drive a significant portion of that demand. Today, buildings alone use ⅓ of our total domestic energy and 40 percent of our electricity. Solar energy has many advantages, and I know you will talk about that. And I think we are really optimistic about this competition as young scientists, engineers, and architects, the future builders of America learn about the latest energy technologies. They learn to work together to balance aesthetics with energy utility to make their homes attractive to the average buyer. And finally, they inspire their peers, the public, and policy-makers to think in new ways about how we use our energy. This is the kind of inspiration the Nation needs as we continue to confront a variety of energy challenges.

So again, let me extend a special thanks to the exceptional students, as well as their faculty advisors, for participating in the Decathlon and for joining us here today.

I also want to welcome our witness from the Department of Energy. The Department is to be commended for partnering with the National Renewable Energy Laboratory, the American Institute of Architects, the National Association of Home Builders, BP, the Do-It-Yourself Network, and Sprint to host the Decathlon.

We look forward to the testimony of all witnesses today.

[The prepared statement of Chairwoman Biggert follows:]

PREPARED STATEMENT OF CHAIRMAN JUDY BIGGERT

Good afternoon, and welcome to this Energy Subcommittee hearing on the 2005 Solar Decathlon, and the winning technologies previewed at that event.

In mid-October, 18 teams of undergraduate and graduate students from universities across the country assembled on the National Mall to demonstrate something amazing. After two years of work, they gathered in our nation's capital to demonstrate how a home could be powered entirely by solar energy.

These students and their projects faced some serious challenges. After nearly two months baking in the sun, the Washington area received its first measurable rainfall on the opening day of the decathlon. While I was not in Washington at the time, I understand it was cloudy and rainy just about every day thereafter through the last day of the event.

Now, that kind of weather isn't so uncommon in my home State of Illinois. During winters in Chicago, we sometimes go for weeks without seeing the sun.

So despite the conditions, the teams persevered and their technologies worked, for the most part. And they needed to work in order to demonstrate the viability of solar power in places like Chicago in the wintertime. In the end, the projects were evaluated based on 10 different criteria, many of the same criteria that Americans use to evaluate their choices when buying a home.

Today, we're going to hear from some of the winners of the 2005 Solar Decathlon, as they "show-and-tell" us about the homes they designed and built for the Decathlon. We hope to have some fun here, but we also want to engage these teams of young scientists and engineers in a serious conversation about the potential for solar energy in this country.

As the Chairman of this subcommittee and a Member of the Education Committee, I am especially pleased about the number of students actively involved in the Decathlon, and in this important dialogue today. I think it is safe to say that the Members of this subcommittee are very much looking forward to learning more from you. We hope you will talk today about the kinds of technologies and designs you used. We hope you will share with us what obstacles you believe must still be overcome before the Nation can benefit from the widespread use of passive and active solar thermal systems, photovoltaic solar electricity, and on-site energy storage, both electrical and thermal. Finally, we hope you will discuss the benefits of a competition such as the Solar Decathlon and about what we can do, as policy-makers, to help move solar and efficiency technologies into the mainstream building market.

By 2025, our demand for energy is expected to grow by 50 percent, and energy for our buildings will drive a significant portion of that demand. Today, buildings alone use one-third of our total domestic energy and forty percent of our electricity. Solar energy has many advantages: it's made in America, non-polluting, abundant, and easy to build and permit. If we could produce just a fraction of the power for our buildings from the sun and, at the same time, reduce our total energy demand by using smarter technologies and designs, the impact on our energy outlook would be tremendous.

That is why we are so optimistic about this competition. Young scientists, engineers, and architects—the future builders of America—learn about the latest energy technologies. They learn to work together to balance aesthetics with energy utility to make their homes attractive to the average buyer. Finally, they inspire their peers, the public, and policy-makers to think in new ways about how we use our energy. This is the kind of inspiration the Nation needs as we continue to confront a variety of energy challenges.

So again, let me extend our special thanks to the exceptional students, as well as their faculty advisors, for participating in the Decathlon and for joining us here today. I also want to welcome our witness from the Department of Energy. The Department is to be commended for partnering with the National Renewable Energy Laboratory, the American Institute of Architects, the National Association of Home Builders, BP, the D.I.Y. Network, and Sprint to host the Decathlon.

We look forward to the testimony of all the witnesses here today. With that, I will yield to the Subcommittee's Ranking Member, Mr. Honda, for his opening statement.

Chairwoman BIGGERT. And with that, I yield to the Subcommittee's Ranking Member, Mr. Honda, for his opening statement.

Mr. HONDA. Thank you, Madame Chairwoman.

And just out of curiosity in the audience, how many of these graduate students are here, or students are here?

All right. There are—we have got women on there, too. Some of our folks say are there any women out there? I say I am sure there are, you know.

And welcome to all of you. And Mr. Lyng, welcome to you.

And Madame Chairman, thank you for holding this hearing today. I guess you call it the second biennium of the Solar Decathlon, and I wanted to thank the witnesses for being here today. And it is especially nice to have the students here with us. You bring a different perspective to us than our usual witnesses, because you have a different perspective on life.

I am the kind of person that bought the first hybrid car, and when my battery didn't work completely well that kicks over the engine, I put a solar panel on the back to see if I could keep the—my battery alive until they figured out the glitch in my car.

But as a nation, we have not followed that same line of thinking in terms of using solar power for an alternative source. The United States was once a leader in solar technology, and the first solar cell that was produced that has produced a useful amount of electricity was invented here. But the last year, only 11 percent of the photovoltaic generating capacity was manufactured here in this country, and our track record at installing solar generating capacity is equally poor.

By the end of 2004, the United States installed photovoltaic generating capacity was only about equal to what a standard coal-fired power plant produces, or approximately 0.04 percent of the U.S. electricity production.

We have fallen behind other nations, such as Germany and Japan, which saw solar installation increase as a result of meaningful incentive programs. And I guess that is where our housing developers come in where we can look at those areas.

But all is not lost. A quick glance at a solar resource map shows that most of the United States has far greater potential for solar power than Germany, a nation that has succeeded in bringing solar along with proper incentives.

This means that the United States has tremendous growth potential for solar energy. And my own State of California has taken the lead with over 100 megawatts of installed grid capacity to date.

It has taken a commitment to get to this point, though, because a typical home photovoltaic system is not cheap to purchase nor to install. If you do the math to figure out how much the electricity costs, it turns out that it is still higher than the typical retail cost for electricity, but I am willing to try it and put it on my roof.

That is why we need federal and State tax incentives, rebates, and loan guarantees to help consumers make the decision to adopt the technology. And to succeed, this cost of solar-produced electricity must be reduced. Fortunately, as more cells are manufactured, the cost for photovoltaic modules has decreased five to seven percent per year. As we convince more consumers to make choices to install these systems, the prices will continue to decline, and the cost of power will eventually become comparable to other sources.

But we need to convince them to make that choice. And to do so, we need to show them that solar power can work, even if it isn't a brilliantly sunny day in the desert. On my dashboard here and at home, I have a solar-powered, what do you call those things, flashlight, because I figured as long as the sun shines through it, there is still light, at least three or four or five hours out of the 24, I still have batteries that will produce light for me. So I am ready for anything with my flashlight battery.

So I look forward to listening to your experiences in this year's decathlon where the weather wasn't much like that. And hopefully, all of you who are here today will provide us the avenue and light the way for us. And just to be a little corny, to paraphrase that song, you are the sunshine of our lives.

Thank you very much for being here.

Thank you, Madame Chair.

[The prepared statement of Mr. Honda follows:]

PREPARED STATEMENT OF REPRESENTATIVE MICHAEL M. HONDA

Madam Chairwoman, thank you for holding this hearing today on the Solar Decathlon.

Thanks to the witnesses for being here today. It is especially nice to have the students with us. You bring a different perspective to us than our usual witnesses do.

I'm the kind of person who drives a hybrid car and wants to keep the battery charged with a solar cell when I don't drive it for a while.

But as a nation, we have not followed that same line of thinking. The United States was once the leader in solar technologies. The first solar cell that produced a useful amount of electricity was invented here.

But last year, only 11 percent of the photovoltaic generating capacity was manufactured here. And our track record at installing solar generating capacity is equally poor.

By the end of 2004, the United States installed photovoltaic generating capacity was only about equal to what a standard coal-fired power plant produces, or approximately 0.04 percent of U.S. electricity production.

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But all is not lost. A quick glance at a solar resource map shows that most of the United States has far greater potential for solar power than Germany, a nation that has succeeded in bringing solar along with the proper incentives.

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As we convince more consumers to make the choice to install these systems, the prices will continue to decline and the cost of power will eventually become comparable to other sources.

But we need to convince them to make that choice. And to do so, we need to show them that solar power can work even if it isn't a brilliantly sunny day in the desert. So I look forward to hearing about your experiences in this year's Decathlon, which wasn't like that.

Chairwoman BIGGERT. I can see this is going to be an interesting hearing.

Any additional opening statement submitted by the Members may be added to the record.

[The prepared statement of Mr. Costello follows:]

PREPARED STATEMENT OF REPRESENTATIVE JERRY F. COSTELLO

Good morning. I want to thank the witnesses for appearing before our committee to examine the research and policy implications of the 2005 Solar Decathlon Competition.

The U.S. Department of Energy (DOE) held the first Solar Decathlon on the National Mall in 2002 and recently held its second competition from October 6–16th of this year. The competition was developed by the DOE's Office of Energy Efficiency and Renewable Energy in partnership with the National Renewable Energy Lab and several non-governmental sponsors. The Decathlon aims to encourage young people to pursue careers in science and engineering and to help students think creatively about how we use and conserve energy.

I believe one of the most valuable attributes of the competition is advancing research and development of energy efficiency and energy production technologies in order to help the U.S. regain our technological competitive edge.

The U.S. was once the leader in solar technologies, but in 2004, U.S. companies manufactured only 11 percent of photovoltaics available worldwide. In 1999, Japan surpassed the U.S. as the global manufacturing leader and recently Germany has also moved ahead. Despite our staggering position in both manufacturing and installed production capacity, I believe the U.S. has tremendous growth potential for solar energy and must strive to integrate renewable and efficiency technologies into the building market for more consumer to understand all of the benefits solar energy has to offer both economically and environmentally. In order to document and communicate the benefits of solar technology to consumers, with the hopes of regaining our competitive edge in the global market place, educational competitions, such as the Solar Decathlon, help spur new ideas and concepts and I look forward to hearing from several participants who excelled in the competition this year.

[The prepared statement of Ms. Johnson follows:]

PREPARED STATEMENT OF REPRESENTATIVE EDDIE BERNICE JOHNSON

Thank you, Mr. Chairman and Ranking Member.

I am pleased to welcome our witnesses to today's Energy Subcommittee hearing.

My District, in Dallas, Texas, would greatly value the technologies showcased in the decathlon competition.

Energy efficiency, solar heating and cooling, solar thermal systems and electricity, and improved solar energy storage are the wave of the future.

We as a nation must decrease our dependence on coal and fossil fuels. These energy sources are limited and will only grow more expensive and supply decreases and demand increases.

I have been a consistent, strong advocate of more federal dollars being put toward energy research. As a Texan, I understand the power and value of the energy industry.

To quote Ralph Waldo Emerson, "Build a better mousetrap, and the world will beat a path to your door." Build a better method of capturing, generating and storing energy, and the world will beat a path to your door.

The Science Committee should take a more proactive role in encouraging Congress and the Administration to invest more in energy efficiency research and development.

Witnesses, many of you represent the future of innovation in energy research. Once again, I welcome you and appreciate your contributions to today's hearing.

Thank you, Madame Chairman. I yield back.

[The prepared statement of Mr. Lipinski follows:]

PREPARED STATEMENT OF REPRESENTATIVE DANIEL LIPINSKI

I would like to congratulate all of you and your teams on successfully participating in the 2005 Solar Decathlon. This program is notable not just for the opportunities it provides to students, but also for exposing the general public to new and innovative ways to increase energy efficiency.

Solar power holds great hope as an energy source that is not only environmentally-friendly, but also helps reduce our dependence on foreign energy sources, especially oil. As we face sky-rocketing costs for natural gas to heat our homes this winter, the work done in this competition is especially relevant.

I have been interested in the potential of solar power for more than 25 years. My 8th grade science fair project examined the future role of solar energy. As an example, I built a radio powered by a photovoltaic cell.

Today we can see how far the use of solar energy has progressed in the tremendous work of these students in the Solar Decathlon. As an engineer myself, it is especially fascinating to see the design innovations that were developed and used in these solar houses that also have real world applications.

I know that this is not easy work, and I applaud everyone who has put the time and effort into these important projects. Just as my science project helped inspire me to pursue an engineering degree, I hope that the Solar Decathlon inspires more young Americans to pursue degrees in science and engineering. For the continued security and economic success of America, we must continue to do all we can to maintain our technological competitive edge. This continues to be one of my highest priorities in Congress and on the Science Committee.

Chairwoman BIGGERT. And at this time, I'd like to introduce our witnesses.

First, on our left, is Richard Moorer. He is the Deputy Assistant Secretary for Technology Development at the Office of Energy Efficiency and Renewable Energy at the Department of Energy. Next, we have Bob Schubert. He is the Associate Dean for Research and Outreach and a Professor in the College of Architecture and Urban Studies at Virginia Polytechnic Institute. He serves as the Faculty Coordinator for Virginia Tech team. Jeff Lyng is a graduate student and the Team Project Manager for the University of Colorado, team—the overall winner in the Decathlon. Jeff is completing his Master's degree in civil engineering and the building systems program at Colorado. Jonathan Knowles is a Professor of Architecture and serves as a Faculty Advisor to the Rhode Island School of Design team. Welcome. And David Schieren is the Energy Team Leader for the New York Institute of Technology where he is pursuing a Master's of science in energy management. I also want to thank the University of Maryland team for submitting written testimony for this hearing. *[The information appears in Appendix 2: Additional Material for the Record.]*

As the witnesses know, spoken testimony will be limited to five minutes each, after which the Members will have five minutes each to ask questions.

So we will begin with Mr. Moorer. You are recognized for five minutes.

STATEMENT OF MR. RICHARD F. MOORER, DEPUTY ASSISTANT SECRETARY FOR TECHNOLOGY DEVELOPMENT, OFFICE OF ENERGY EFFICIENCY AND RENEWABLE ENERGY, THE DEPARTMENT OF ENERGY

Mr. MOORER. Madame Chair, Members of the Subcommittee, I appreciate the opportunity to testify on the Solar Decathlon, a contest that originated in the Department of Energy's Solar Technology Program.

In October 2000, DOE issued a challenge to our nation's colleges and universities to design, build, and operate the most livable, energy-efficient, completely solar-powered house in a major competition. The Solar Decathlon houses had to provide all the home energy needs of a typical family of six using only the power of the sun. The winner of the competition would be the team that best blends aesthetics and modern conveniences with maximum energy production and optimal efficiency. The schools submitted proposals, and a committee of DOE and National Renewable Energy Laboratory experts in solar energy and energy efficient design selected 14 teams to compete in this contest.

The first Solar Decathlon took place from September 26 to October the 6th, 2002, on the National Mall in Washington, DC. Each team received $5,000 in seed money from DOE. The university teams had to raise all of their own funds to purchase materials, transport, and build their house on the National Mall. The first event was well attended, with more than 100,000 people visiting the solar village on the Mall, eager to see the pioneering designs.

A second competition was held this year. A request for proposals was issued in 2003, and 24 proposals were received. Twenty teams were selected, and each entrant then had two years to assemble a multi-disciplinary team, raise all of the necessary funding, select and procure materials, and design and build their house on campus before transporting it to Washington, DC.

The 2005 Solar Decathlon was held from October 6 through the 16th. This year's designs had clearly improved over the 2002 designs. The attention to architectural detail, soundness of structural engineering, and integration of energy systems surpassed expectations and generated excitement to the over 120,000 visitors that walked through the village and toured the homes.

The University of Colorado repeated as the overall winner this year, followed by Cornell University in second place, and California Polytechnic State University finishing third.

There are two overarching goals of this competition. The first goal is to encourage young people to pursue careers in science and engineering and to acquaint college students in science, engineering, and architecture with solar power and energy efficiency technologies. The contest encourages participating students to think creatively about the way we use our energy and to explore the benefits of using renewable energy and energy-efficient technologies to help maintain our lifestyles.

The second overarching goal is to encourage consumers to use solar energy and energy-efficient technologies. Off-the-shelf solar technology is ready today to provide power for homes, and energy efficiency technologies available at your local hardware store can significantly reduce the energy homes use. Consumers toured the homes and took part in workshops at the Solar Decathlon to learn what they can do to tap solar power or reduce energy use in their own homes.

The Solar Decathlon appears to be a good way to promote outreach. All of the teams told their visitors about easy ways to save energy, such as using compact fluorescent lights and Energy Star appliances. The public also learned about solar energy systems, radiant floor heating, day lighting techniques, and new building materials, such as structural insulated panels, or SIPs.

To help educate builders, architects, and other professionals in the housing industry, DOE, together with its sponsors, organized a "building industry day." Builders and architects were invited to come to the Solar Decathlon on Friday, October the 7th, for workshops and guided tours specially designed to encourage technology transfer. Many of the workshops were full to capacity with standing room only.

Subject to available funding, DOE intends the Solar Decathlon to become a 10-year, biennial effort to design appealing, energy-efficient, cost-competitive solar homes for all household energy needs. In addition, we hope to encourage a fully developed and refined set of design and cost specifications for the houses, an industry better prepared to produce and build similar designs, and an educate public ready to accept them.

Based on lessons learned, DOE is going to make three major improvements to the Decathlon: first, tie the competition more closely to DOE's Solar Program goals by placing greater emphasis on systems integration and cost-effectiveness; second, to improve public outreach to communicate the benefits of these technologies to a wider audience; and third, to provide increased federal funding to enable the teams to design and develop more cost-competitive structures.

Madame Chair, that completes my prepared statement, and I would be happy to answer any questions the Subcommittee might have.

[The prepared statement of Mr. Moorer follows:]

PREPARED STATEMENT OF RICHARD F. MOORER

Madame Chair, Members of the Subcommittee, I appreciate the opportunity to testify on the Solar Decathlon, a contest that originated in the Department of Energy's (DOE) Solar Technology Program.

History of the Solar Decathlon

In October 2000, DOE issued a challenge to our nation's colleges and universities to design, build, and operate the most livable, energy-efficient, completely solar-powered house in a major competition. The Solar Decathlon houses had to provide all the home energy needs of a typical family of six using only the power of the sun. The winner of the competition would be the team that best blends aesthetics and modern conveniences with maximum energy production and optimal efficiency. The schools submitted proposals, and a committee of DOE and National Renewable Energy Laboratory experts in solar energy and energy efficient design selected 14 teams to compete in this contest.

The first Solar Decathlon took place from September 26 to October 6, 2002, on the National Mall in Washington, DC. Each team received $5,000 in seed money from DOE. The university teams had to raise all their own funds to purchase materials, transport and build their house on the National Mall. The first event was well attended, with more than 100,000 people visiting the solar village on the Mall, eager to see the pioneering designs. Each team's home included a kitchen, living room, bedroom, bathroom, and home office space, with a maximum building footprint of 800 ft2 (74.3 m2), equivalent to a small apartment. Though they shared these common requirements, the home designs for this first-ever Solar Decathlon varied widely, from traditional to contemporary. Beyond sophisticated energy systems, many homes were beautifully finished and furnished inside and out, with thoughtful integration of design aesthetics, consumer appeal, and comfort.

As the name implies, the Solar Decathlon is an event in which each team's performance is evaluated in 10 categories: architecture, dwelling, documentation, communications, comfort zone, appliances, hot water, lighting, energy balance, and getting around. There is a winner in each category, and an overall winner for the team that accumulates the most points. Each participating team invested a tremendous amount of time, money, passion, and creativity into this competition. Teams were composed of architects, engineers, designers, communicators, fundraisers, and builders. Some teams had to overcome daunting obstacles, such as having to ship the entry from Puerto Rico by boat, or having a section of the home fall off the truck en route.

The overall winner of the 2002 competition, the University of Colorado, used a strategy of dependable technologies. Whereas the competition encouraged innovation, the limited duration of the event left little room for equipment failures or system malfunctions, which many other teams experienced. The Colorado team used a large (7.5 kW) photovoltaic (PV) array and designed the house well based on its understanding of the energy flows, having performed very comprehensive modeling of the home. The University of Virginia placed second, and Auburn University placed third overall in the competition.

A second competition was held in 2005. A request for proposals was issued in 2003, and 24 proposals were received. Twenty teams were selected, including a team from the University of Madrid in Spain and Concordia University in Canada. Each entrant then had two years to assemble a multidisciplinary team, raise all necessary funding, select and procure materials, and design and build their house on campus before transporting it to Washington, DC. Two of the original twenty, the University of Virginia and the University of Southern California, were unable to raise the necessary support and dropped out of the competition.

The 2005 Solar Decathlon was held from October 6–16. The 2005 designs had clearly improved over the 2002 designs. The attention to architectural detail, soundness of structural engineering, and integration of energy systems surpassed expectation and generated excitement to the over 120,000 visitors who walked through the village and toured the homes. Again, the University of Colorado took first place, followed by Cornell University in second place, and California Polytechnic State University finishing third.

Goals

There are two overarching goals of the competition. *The first goal is to encourage young people to pursue careers in science and engineering* and to acquaint college students in science, engineering and architecture with solar power and energy efficiency technologies. The contest encourages participating students to think creatively about the way we use our energy and to explore the benefits of using renewable energy and energy efficiency technologies to help maintain our lifestyles.

The Solar Decathlon has attracted students to learn about solar energy and energy efficiency. Some of the schools recruited 50 or more students to join their Solar Decathlon teams. Many of the students received credit for their work in addition to gaining valuable hands-on learning. The students also gain valuable experience to help them find jobs after graduation in the fields of energy research, engineering, or design.

The second overarching goal is to encourage consumers to use solar energy and energy efficiency technologies. Off-the-shelf solar technology is ready today to provide power for homes, and energy efficiency technologies available at your local hardware store can significantly reduce the energy homes use. Consumers can tour the homes and take part in workshops at the Solar Decathlon to learn what they can do to tap solar power or reduce energy use in their own homes.

The Solar Decathlon appears to be a good way to promote outreach. Over 120,000 visitors toured the houses this year and learned from the students how the houses were designed and what technologies were incorporated. All the teams told their visitors about easy ways to save energy, such as using compact fluorescent lights and Energy Star appliances. The public also learned about solar energy systems, radiant floor heating, day lighting schemes and new building materials such as structural insulated panels (SIPs).

To help educate builders, architects, and other professionals in the housing industry, DOE, together with its sponsors, organized a "building industry day." Builders and architects were invited to come to the Solar Decathlon on Friday, October 7th for workshops and guided tours specially designed to encourage technology transfer. Many of the workshops were full to capacity with standing room only.

2007 and Beyond

The Department believes that the 2002 and 2005 Solar Decathlons advanced the two overarching goals described above. As a result, Department plans to hold successive events every two years, with the next event in 2007, subject to available funding.

Based on lessons learned, DOE is going to make three major improvements to the Solar Decathlon: 1) tie the competition more closely to DOE's solar program goals by placing greater emphasis on system integration and cost effectiveness, 2) improve public outreach to communicate the benefits of these technologies to a wider audience, and 3) provide increased federal funding to enable the teams to design and develop more cost-competitive structures.

The Department believes that competitions such as the Solar Decathlon maximize creativity and innovation, and generate strong motivation and interest. The Solar Decathlon may also foster the technology transfer process. The competition provides the opportunity for aspiring young architects and engineers to be creative, innovative, and design and develop new ideas. The empty lot provides a place to build, to test, and to learn what works best.

Subject to available funding, DOE intends the Solar Decathlon to become a ten-year, biennial effort to design appealing, energy efficient, cost-competitive solar houses for all household energy needs: heat and electricity. In addition, we hope to encourage a fully developed and refined set of design and cost specifications for the houses, an industry better prepared to produce and build similar designs, and an educated public ready to accept them.

DOE conducted a survey of the participating 2005 Solar Decathlon teams. Most teams struggled to raise funds over the past three years since the first event was held, with two dropping out due to lack of support. In response, Secretary Bodman announced that the Department would increase its financial support for the 20 best proposals selected through a competitive process from $5k to $50K per year over two years, subject to available funding.

Technology Transfer

The Solar Decathlon is specifically designed to help teams integrate solar energy and energy efficient building technologies and practices into their designs. This was accomplished by fully involving DOE's Solar Program and Building Technologies program in Solar Decathlon team activities including materials development, pre-competition meetings, and contest design. In addition, the inclusion of sponsors like the American Institute of Architects and BP Solar was intended to significantly improve outreach capability with professional builders, architects and solar equipment manufacturers in the U.S.

Specific Solar Decathlon activities were designed to foster technology transfer by appealing to builders and/or to consumers intending to build or renovate their homes using solar and/or energy efficiency technologies. These included:

- Building Industry Day on October 7. Builders and allied trades from the Washington Metropolitan area, as well as seven nearby states, were invited to participate in a special day set aside for builder-oriented tours of the homes and a series of technical workshops designed to help them understand how best to use and install energy efficient products and solar technologies in building projects.
- A series of workshops geared for the general public was held every day from October 8–16 to encourage the installation and use of energy efficiency and solar energy technologies. The workshops were designed to help consumers understand how to go about installing these technologies in their homes in order to reduce their use of energy.
- A concerted media outreach campaign about the Solar Decathlon was undertaken to provide in-depth information about the competition and about energy efficiency and renewable energy technologies. The resulting (and continuing) media coverage has helped the public understand that energy efficiency and solar energy technologies are available off-the-shelf today and, when installed, can significantly reduce home energy use.
- A product directory, searchable both by team and by product type (windows, appliances, solar panels, etc.), is prominently featured on the Solar Decathlon web site home page. The product directory is designed to help people locate the products and technologies featured in each of the Solar Decathlon homes.

- "The Anatomy of a House" educational exhibit was developed to help builders and the public understand individual energy efficiency and solar energy technologies (windows, insulation, solar hot water technology, etc.) and how they work under the "skin" of a house. Also included in this exhibit was an interactive display explaining how net metering works in a home using a photovoltaic system connected to the utility grid.

And, finally, an unanticipated way in which these technologies can be moved into the marketplace is through the students themselves. Several builders and businessmen, impressed by the skills and knowledge of the Solar Decathlon students, were actively recruiting them for jobs.

Madame Chair, that completes my prepared statement, and I would be happy to answer any questions the Subcommittee might have.

BIOGRAPHY FOR RICHARD F. MOORER

Mr. Moorer is the Deputy Assistant Secretary for Technology Development within the Office of Energy Efficiency and Renewable Energy at the Department of Energy. Mr. Moorer is the first Deputy Assistant Secretary to hold this position which was created on July 1, 2002, by the re-organization of the Office of Energy Efficiency and Renewable Energy. In this position, Mr. Moorer has responsibility for the entire energy efficiency and renewable energy portfolio, which is now organized into eleven major program areas.

Prior to this position, Mr. Moorer was the Associate Deputy Assistant Secretary for Transportation Technologies. He was responsible for the Department of Energy's strategic planning, analysis and budget development on efficient automotive systems and alternative fuels and for the development and implementation of the alternative fuel vehicle provisions of the Energy Policy Act. Mr. Moorer also served as the head of the Department's Bioenergy Task Force.

Formerly, he was the Director of the Biofuels Systems Division (BSD) of the U.S. Department of Energy (DOE) Conservation and Renewable Energy Program's Office of Transportation Technologies. He was responsible for the management and oversight of the Department's Biofuels Systems programs. These programs focus on the research and development of innovative and economical processes that produce and convert biomass feedstocks to alcohol fuels, biomass-based gasoline and bio-diesel fuel. In this position he developed the DOE Renewable Energy Transportation Fuels Initiative. In addition, he was instrumental in developing the transportation technology section of the National Energy Strategy.

Mr. Moorer spent 12 years working on advanced conversion processes to produce alcohol fuels for the transportation sector. During this time, he conducted several feasibility studies on biomass alcohol production and focused the efforts of the Department's research and development efforts on the most promising conversion technologies. Mr. Moorer also served as Program Manager for the biochemical conversion technology program with the Biofuels and Municipal Waste Technology (BMWT) Division.

Mr. Moorer's previous government experience included a position with the U.S. Environmental Protection Agency for three years. During that time, Mr. Moorer was involved with the registration of pesticides and the study of the energy and environmental impacts of agriculture. In addition, Mr. Moorer conducted research on the environmental effects of heavy metals on marine life with the National Marine Water Quality Laboratory in Narragansett, Rhode Island.

Mr. Moorer obtained his Bachelor of Science degree in Zoology from Duke University in 1974 and his MBA from Virginia Polytechnic Institute in 1990. He and his wife Kathleen reside in Bethesda, Maryland.

Chairwoman BIGGERT. Thank you very much.

And we'll move next to Mr. Schubert for five minutes. You are recognized.

STATEMENT OF MR. ROBERT P. SCHUBERT, PROFESSOR AND TEAM FACULTY COORDINATOR, COLLEGE OF ARCHITECTURE AND URBAN STUDIES, VIRGINIA POLYTECHNIC INSTITUTE

Mr. SCHUBERT. Madame Chair, before I start, I would like to acknowledge two of my colleagues that have joined me: Professors

Robert Denae and Joe Wheelard directly behind me. This is part of the core team faculty advisors that produced this project.

Before we address the specific questions provided, we would like to acquaint you with some aspects of our building produced for the 2005 Solar Decathlon competition.

The Virginia Tech Solar House integrates technology and architecture. The house achieved a balance between the two as reflected by winning the juried competition elements of Architecture, Dwelling, Daylighting, and tying for first place in Electric Lighting.

Some of the key features included an efficient plan. The house is comprised of a small 580 square foot rectangular plan wrapped on three sides with a translucent skin and covered with a hovering curved roof inclined towards the sun.

A floating roof. The particular shape of the roof, a lightweight stressed skin, folded-plate filled with foam insulation, is designed to set the solar panels at an optimum angle for energy collection and integrates the panels into the roof form.

The north core module. A thick linear core defines a massive north wall and houses the batteries, electrical, and mechanical equipment, and serves functions such as the kitchen, laundry, storage, and closets. Constructed of expanded polystyrene panels that are lightweight, easily assembled, and yield a high insulation value, this module could be manufactured separately and utilized in many applications.

A translucent wall assembly. Two layers of aerogel filled polycarbonate panels transmit beautiful diffused light while delivering an extremely high insulation value. There will be no need for electric lights from sunrise to sunset.

A tunable wall. Between the polycarbonate panels are three systems: a pair of reflective and absorptive motorized shades allow user control of light and heat transmission; linear actuated vents top and bottom provide ventilation for further thermal control; and, dimmer controlled LED lights allow the user to make the wall any color, no pain required.

Innovative engineered systems. Our energy-efficient ground source heat pumps powered by the solar electric panels provide environmental conditioning in the form of heating and cooling while delivering heat through a radiant floor that offers the best in terms of efficiency and quality. There is little air noise or movement and the ambient temperature can be kept lower, saving energy.

Transportation. A lowboy chassis serving as the floor and foundation structure was designed to receive a detachable gooseneck and rear axles for transport. A truss on each side of the 48-foot span reflects—resists deflection while in transit and rotates down 90 degrees to create a deck surrounding the house when stationary.

Now I would like to respond to the questions that were provided.

Some of the main technical and other barriers to greater use of solar energy are: inertia of public perception towards the status quo; perception of increased complexity of new systems versus conventional systems; conservatism of building industry and their adversity to risk; cost, time of return on investment; and there are few new architectural ideas relative to new technology.

Some suggestions for what might be done to overcome those barriers are: increased incentives for solar installation, such as tax and mortgage incentives, low interest loans, and utility credits; create a national awards program for solar design; encourage numerous and repetitive small-scale applications; regional centers that promote the use of solar energy, similar to agricultural extension programs, working in conjunction with state energy offices; require utilities to generate a percentage of power from solar energy; federal energy subsidies redirected to encourage a higher percentage of renewable energy; in addition to a long—week-long competition on the Mall, recreate the solar village for a longer period in an expo type of forum.

The Solar Decathlon Competition is an effective means to seed the potentials of solar energy in the public consciousness. It touches people from all walks of life and from diverse economic and social backgrounds. As witnessed in the competition of 2002 and 2005, there is widespread and growing public interest in solar energy. Integral with the competition, all aspects of the house are considered with respect to conservation of energy. Particularly the Virginia Tech house, demonstration was made that a solar dwelling can offer a desirable and rich lifestyle.

Its competitive content activates top research universities to further their research efforts and to draw unique collaborations with industry.

The Solar Decathlon of 2002 provided a wealth of information in our own experience of designing and building a house as well as observing the houses from other research institutions.

Our 2005 house integrates the research from the previous work and lessons learned from other houses. In addition to on-campus expertise, a network of manufacturers and professionals having ties to Virginia Tech was used to develop and refine ideas. And an extensive student network researched a wide range of materials, processes, and technologies, some of which were integrated into our design.

Two of the problems we encountered were: an inordinate amount of time, energy, and cost associated with our transportation strategy; percentage of time utilized to raise in-kind donations and extreme difficulty in raising cash contributions.

We feel our house would be commercially viable, placed within the context of a commercially manufactured housing. Winning the Architecture and Dwelling Awards in the competition, the Virginia Tech house demonstrated its appeal to a discriminating set of judges. The Virginia Tech Solar House offers various possibilities for components that will conserve energy and improve the quality of residential building.

In conclusion, we would like to leave with this final thought.

We approach a watershed. Our lifetime has experienced an increased dependence on technology. Almost every amenity we enjoy is dependent upon centralized systems whose working and control are far removed from localized areas. A short curtailment of services sends neighborhoods and regions into temporary states of chaos. In the recent case of hurricane damage, available supplies of gasoline could not be accessed due to lack of electrical service. Whether from natural disaster or terrorist threat, large-scale technologies have exposed growing risks. We must reduce the risk of widespread technological failure by providing alternative distributed power solutions and backing up centralized energy systems with grass roots capability of generating power. With continued support and research of solar energy, this vision is achievable for the next generation.

Thank you.

[The prepared statement of Mr. Schubert follows:]

PREPARED STATEMENT OF ROBERT P. SCHUBERT

Accompanied by Robert Dunay, Chair, Industrial Design Program and Joseph Wheeler, Lead Faculty Advisor, Solar Decathlon Project.

The Virginia Tech Solar House

The Solar Decathlon of 2002 was an educational watershed challenging the relation between academia and practice and between research and its corresponding contribution to society. The knowledge derived from the 2002 competition has been integrated into the Virginia Tech house of 2005 to produce a work that combines innovative technology and daily life styles. This new project has achieved a high level of complexity expressed in an elegant simplicity. The initial theme of the *art of integration* has been realized through a design of a solar house that demonstrates a comfortable living and working environment, excellence in sustainable construction, and strong architectonic expression. The project presents forms that look to the future embodied with a sense of the sustainable and the beautiful.

Mission

The mission of the Virginia Tech Solar Decathlon Team is to inform and educate the public about issues of energy (particularly solar) and to give students energy expertise through a design-build process of innovative research and testing through application.

Our multi-disciplinary team strives to achieve the following goals:

- **To illustrate how solar energy can improve the quality of life. Solar energy is clean; it significantly reduces pollutant emissions; and solar energy is renewable, thereby increasing our nation's energy security.**
- To make the public aware of how energy is used in their daily lives, and to illustrate the energy consumption of daily activities.
- To demonstrate that market-ready technologies exist that can meet the energy requirements of our daily activities by tapping into the sun's power.
- To demonstrate that sustainable materials and technologies can comprise a beautiful structure in which to live, work, and play.
- To examine a project in a prototypical manner to develop solutions that can be reproduced and realized through manufacturing techniques with economic benefit.
- To challenge conventional practice through interdisciplinary collaboration and corporate partnerships.

Beginning of Oral Presentation of Questions to be Addressed in the Testimony

Before we address the specific questions provided, we would like to acquaint you with some of aspects of our building produced for the 2005 Solar Decathlon competition.

The Virginia Tech Solar house integrates technology and architecture. The house achieved a balance between the two as reflected by winning the juried competition elements of Architecture, Dwelling, Daylighting and tying for first place in electric lighting.

Some of the key features include:

- **efficient plan—**The house is comprised of a small (580 sq. ft.) *rectangular plan* wrapped on three sides with a *translucent skin* and covered with a hovering curved *roof* inclined toward the sun.
- **floating roof—**The particular shape of the roof, a lightweight stressed skin, folded-plate filled with foam insulation, is designed to set the solar panels at an optimum angle for energy collection and integrate the panels into the roof form.
- **north core module—**A thick linear core defines a massive north wall and houses the batteries, electrical and mechanical equipment, and service func-

tions such as the kitchen, laundry, storage, and closets. Constructed of expanded polystyrene panels that are lightweight, easily assembled, and yield a high insulation value, this module could be manufactured separately and utilized in many applications.

- **translucent wall assembly—**Two layers of aerogel filled polycarbonate panels transmit beautiful diffuse light while delivering an extremely high insulation value. There will be no need for electric lights from sunrise to sunset.
- **tunable walls—**Between the polycarbonate panels are three systems. A pair of reflective and absorptive motorized shades allow user control of light and heat transmission; linear actuated vents top and bottom provide ventilation for further thermal control; and, dimmer controlled LED lights allow the user to make the wall any color, no paint required.
- **innovative engineered systems—**Our energy efficient ground source heat pumps powered by the solar electric panels provide environmental conditioning in the form of heating and cooling while delivering heat through a radiant floor that offers the best in terms of efficiency and quality. There is little air noise or movement and the ambient temperature can be kept lower saving energy.
- **transportation—**A lowboy chassis serving as the floor and foundation structure was designed to receive a detachable gooseneck and rear axels for transport. A truss on each side of the 48-foot span resists deflection while in transit and rotates down 90 degrees to create a deck surrounding the house when stationary.

In response to the specific questions:

1. Some of the main technical and other barriers to greater use of solar energy are:

- Inertia of public perception towards the status quo
- Perception of increased complexity of new system vs. conventional systems
- Conservatism of building industry and their adversity to risk
- Cost—time of return on investment
- There are few new architectural ideas relative to new technology

Some suggestions for what might be done to overcome those barrier are:

- Increased incentives for solar installations such as tax and mortgage incentives, low interest loans, and utility credits
- Create a National Awards Program for solar design
- Encourage numerous and repetitive small-scale applications
- Regional centers that promote the use of solar energy (similar to agricultural extension programs) working in conjunction with state energy offices
- Require utilities to generate a percentage of power from solar energy
- Federal energy subsidies redirected to encourage a higher percentage of renewable energy
- In addition to a week-long competition on the Mall, re-create the solar village for a longer period in an Expo type of forum

The Solar Decathlon Competition is an effective means to seed the potentials of solar energy in the public consciousness.

- It touches people from all walks of life and from diverse economic and social backgrounds. As witnessed in the competition of 2002 and 2005, there is widespread and growing public interest in solar energy. Integral with the competition, all aspects of the house are considered with respect to conservation of energy. Particularly the Virginia Tech house, demonstration was made that a solar dwelling can offer a desirable and rich lifestyle.
- Its competitive content activates top research universities to further their research efforts and to draw unique collaborations with industry. The competition allows partnerships to be formed. Among many corporations, Virginia Tech worked with GE Specialty Film and Sheet and Cabot Corporation to produce a wall that delivers great light and high insulation. Likewise, collaboration with California Closets has the corporation, for the first time, building cabinet prototypes from a Dow Chemical wheat board that is sustainable and non detrimental to the environment.

2. *The Solar Decathlon of 2002 provided a wealth of information in our own experience of designing and building a house as well as observing the houses from other research institutions.*
   - Our 2005 house integrates the research from the previous work and lessons learned from other houses.
   - In addition to on campus expertise, a network of manufacturers and professionals having ties to Virginia Tech was used to develop and refine ideas.
   - A student network researched a wide range of materials, processes and technologies, some of which were integrated into our design.
   - The United States Green Building Council's (USGBC) draft LEED Residential program provides us with an outline to reduce indoor air pollutants, minimize global warming, reduce waste, include recycled content, represent low embodied energy in manufacture and harvest, limit destruction to habitat, and rapidly renew.

Two of the problems we encountered were:

- An inordinate amount of time, energy and cost associated with our transportation strategy
- Percentage of time utilized to raise in-kind donations and extreme difficulty in raising cash contributions

3. *Our house would be commercially viable:*
   - Placed within the context of commercially manufactured housing.
   - Winning the Architecture and Dwelling Awards in the competition, the Virginia Tech house demonstrated its appeal to a discriminating set of judges.
   - The Virginia Tech Solar House offers various possibilities for components that will conserve energy and improve the quality of residential building.

In conclusion, we would like to leave with this final thought:

We approach a watershed. Our lifetime has experienced an increased dependence on technology. Almost every amenity we enjoy is dependent upon centralized systems whose working and control are far removed from localized areas. A short curtailment of services sends neighborhoods and regions into temporary states of chaos. In the recent case of hurricane damage, available supplies of gasoline could not be accessed due to lack of electrical service. Whether from natural disaster or terrorist threat, large-scale technologies have exposed growing risks. We must reduce the risk of widespread technological failure by providing alternative distributed power solutions and backing up centralized systems with grass roots capability of generating power. With continued support and research of solar energy, this vision is achievable for the next generation.

BIOGRAPHY FOR ROBERT P. SCHUBERT

Associate Dean for Research and Outreach; Full Professor, College of Architecture and Urban Studies, Virginia Tech, Blacksburg, Virginia 24061–0205

Place of Birth: Gordonsville, Virginia

Citizenship: USA

Date of Birth: 24 May 1951

Marital Status: Married—three children

Robert P. Schubert is a professor and member of the College of Architecture and Urban Studies at Virginia Polytechnic Institute and State University. Professor Schubert's research has been in the area of energy and building design with an emphasis on promoting architectural solutions that minimize the dependence on non-renewable energy sources and environmental degrading processes. This work is represented in a co-authored book, *Alternative Energy Sources in Building Design,* 1974. His more recent efforts have focused on the development and evaluation of tools that help to guide and evaluate the consequences of design decisions.

Professor Schubert is currently serving as the Associate Dean for Research and Outreach for the College of Architecture and Urban Studies. During his tenure as Research Dean, the college reached the highest level of funding attained during the history of the school, placing the college in the top three of its peer institutions. Other administrative accomplishments include creating and instituting the College's Scholarship Enhancement Grant Program designed to support both faculty and students. He has served on the Board of Directors of the Architectural Research Centers Consortium, a consortium of thirty-four national and international schools of architecture involved in building related research; and Director of the Master of Science Program in the College of Architecture. He was a recipient of the Teaching Excellence Award. Dean Schubert's most recent activities include Faculty Coordinator for Virginia Tech's entry in the International Solar Decathlon competition held in Washington, DC in 2002 and in 2005.

Chairwoman BIGGERT. Thank you very much.

And now, Mr. Lyng, you are recognized.

STATEMENT OF MR. JEFFREY R. LYNG, GRADUATE STUDENT AND TEAM PROJECT MANAGER, CIVIL, ENVIRONMENTAL, AND ARCHITECTURAL ENGINEERING, UNIVERSITY OF COLORADO

Mr. LYNG. Madame Chairman and Members of the Subcommittee on Energy, on behalf of the University of Colorado, I would like to thank you for the opportunity to speak with you today.

I would also like to acknowledge the U.S. Department of Energy, the National Renewable Energy Laboratory, and each of the contest sponsors for their work in fostering the Solar Decathlon and their commitment to improving the future of energy. Most importantly, I would like to recognize all of the 2005 Solar Decathlon teams, especially those not represented here today, for their unwavering dedication to energy.

I am here today to give you a fresh perspective as a young professional in the renewable energy industry, but more importantly as a fellow Solar Decathlete. I am here to tell the story of a new generation of solar patriots.

For student competitors, the Solar Decathlon offers a learning experience rarely seen in academia. These design/build projects are training a highly skilled workforce able to do more with less. The Solar Decathlon embodies much more than job training, however. It symbolizes a sincere effort on the part of students, teachers, industry professionals, and government leaders to solve some of the most immediate energy production problems facing our world. Furthermore, it symbolizes the empowerment of a new generation.

I could continue on with accolades about the competition and describe for you how powerful it was to participate in a demonstration of solar energy during a week of overcast weather or how inspiring it was to see over 120,000 visitors on the National Mall. But that is not why we are here. We are here because we acknowledge the potential of the Solar Decathlon competition to spark innovation, ingenuity, and change. We also recognize that the competition can be improved. Through mutual collaboration and our discussions here today, I hope that we can tailor this competition to more closely address the mounting concerns of energy cost and reliability that the mainstream homeowner is faced with every day.

Having devoted the past three years of my life to the CU Solar Decathlon Project and spoken with thousands of people who toured the Bio-S(h)IP during the week of the competition, I am excited to participate in your efforts to strengthening it. I would like to share with you three personal observations of my experiences which address the questions outlined for our discussion and offer solutions within the context of the Solar Decathlon competition.

Observation one: some visitors undoubtedly walked away from the competition misinformed about solar energy. For many members of the public, the Solar Decathlon was their first introduction for solar—to solar energy. This misinformation was not due to a lack of knowledge or enthusiasm on the part of the Solar Decathletes. It was the result of a fundamental flaw, I believe, of the competition: the need to be off-grid.

For many visitors, their impressions of solar technology from touring the homes are that it requires huge battery banks, should cover every square foot of your home, and probably requires hiring someone to staff your mechanical room 24/7. I believe that transitioning the competition from a stand-alone application to a grid-tied application with smaller arrays, little, if any, on-site energy storage, and net metering on each house can only result in homes more closely aligned with what the typical consumer can actually expect to live in.

Observation two: while the competition is a great showcase for individual technologies and products, it is not a great showcase of integrated building approaches. Shortly after returning to Colorado from the decathlon competition, I spent three days at a builder conference attended by many production homebuilders. I felt like I had gone from one end of the residential building spectrum to the other. It could be argued that CU Solar Decathlon house is perhaps the most custom home in the State of Colorado right now, and likewise for the other homes in their Districts. In the design process, we pushed the last percentage point of efficiency for maximum energy production. Contrast that with the production home market in which an unfortunate number of products are right now being designed and built all around the country with no regard to the benefits of an east-west solar orientation or the advantages of building homes even slightly above current energy code.

It is tragic to think that none of the 18 homes that were showcased on the National Mall last month might ever be built. There exists an inherent and ever-widening disconnect between the homes Solar Decathletes give form to and the realities that the production home market in the United States provide. I believe that the competition falls short of offering real solutions to how these homes can be incorporated into the large subdivisions. We must find ways to facilitate energy efficient and solar technology transfer from the Solar Decathlon competition to the production home market if we aspire to appeal to the average home buyer.

Observation three: the true economic viability of each home is not well understood. Perhaps the biggest surprise for me was the—through this entire process was how much of my time was consumed in fundraising. There was a talk of pulling the plug this spring and a very real concern that the defending champions would not be able to compete due to lack of funding.

The CU Solar Decathlon team's budget for the 2005 project was $500,000. Assuming a comparable budget for all teams in 2007, the $100,000 pledge to each competing university from the DOE leaves a substantial 80 percent cost sharing on the part of students participating. That level of fundraising can distort design.

Alleviating the burden of fundraising would have several positive ramifications. It would increase the quality of each design. It would ensure a more objective approach to showcasing only the best technologies. And it would provide a means for accurate accounting of the true retail cost of each home.

The Solar Decathlon competition must not be perceived as a novelty or political distraction. It must play a supporting role in creating a new future of energy if we are to achieve what Richard Nixon was referring to in 1973 when he said, "Let us set as our national goal, in the spirit of Apollo, with the determination of the Manhattan Project, that by the end of this decade we will have developed the potential to meet our own energy needs without depending upon any foreign energy source."

Thirty years later, we can all agree we didn't make it. But why didn't we make it? We didn't get to the Moon by encouraging college students to build bottle rockets on the National Mall.

Achieving energy independence will take much more than just collaborative efforts on the part of students, builders, researchers, and policymakers to bring this to fruition. It will take federal leadership beyond these collaborations to make it happen.

Each Solar Decathlete is doing their part in keeping the candle lit for solar energy. It is now time for Members of this committee and all Members of Congress to lead the way in carrying the torch.

Thank you.

[The prepared statement of Mr. Lyng follows:]

PREPARED STATEMENT OF JEFFREY R. LYNG

Madam Chairman and Members of the Subcommittee on Energy:

On behalf of the University of Colorado College of Architecture & Planning and College of Engineering and Applied Science, I would like to thank you for the opportunity to speak with you today.

I would like to acknowledge the U.S. Department of Energy, the National Renewable Energy Laboratory, and each of the contest sponsors for their work in fostering the Solar Decathlon and their commitment to improving the future of energy. Most importantly, I would like to recognize all of the 2005 Solar Decathlon teams, especially those not represented here today, for their unwavering dedication to solar energy.

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Having devoted the past three years of my life to the CU Solar Decathlon Project and spoken with thousands of people who toured the CU Bio-S(h)IP during the week of the competition, I am excited to participate in your efforts to strengthening it. I would like to share with you three personal observations from my experiences which address the questions outlined for our discussion and offer solutions within the context of the Solar Decathlon competition.

1. Some visitors undoubtedly walked away from the competition misinformed about solar energy.

For many members of the public, the Solar Decathlon was their first introduction to solar energy. This misinformation was not due to a lack of knowledge or enthusiasm on the part of Solar Decathletes. It was the result of a fundamental flaw of the competition; the need to be off-grid.

For many visitors, their impressions of solar technology from touring the homes are that it requires huge battery banks, should cover every square foot of your roof and probably requires hiring someone to staff your mechanical room 24/7 to operate it. I believe that transitioning the competition from a stand-alone application to a grid-tied application with smaller arrays, little if any on-site energy storage and net metering on each house can only result in homes more closely aligned with what the typical consumer can actually expect to live in.

I am exceedingly proud of the CU Team for winning the Communications contest. We invested thousands of hours into streamlining our messaging to the public, yet that message was still sometimes misconstrued. We must fix this problem of grid interconnectedness before the 2007 event if the public is to comprehend the true merits of solar energy or else run the risk of leaving the wrong impression.

2. While the competition is a great showcase for individual technologies and products, it is not a great showcase of integrated building approaches.

I'd like to share with you my experiences this past week. Shortly after returning to Colorado from the Solar Decathlon competition, I spent three days at a builder conference well attended by many production home builders. I felt like I'd gone from one end of the residential building spectrum to another. It could be argued that the CU Solar Decathlon house is perhaps the most custom home in the State of Colorado right now, and likewise for each of the other homes in their respective states. In the design process, we pushed the last percentage point of efficiency for maximum energy production. Contrast that with the production home market in which an unfortunate number of products are right now being designed and built all around the country with no regard to the benefits of an east-west solar orientation or the advantages of building homes even slightly above current energy code.

It is tragic to think that none of the 18 homes that were showcased on the National Mall last month might ever be built again. There exists an inherent and ever-widening disconnect between the homes Solar Decathletes give form to and the realities of the production home market in the U.S. I believe that the competition falls short of offering real solutions to how these homes can be incorporated into the large subdivisions. We must find ways to facilitate energy efficient and solar technology transfer from the Solar Decathlon competition to the production home market if we aspire to appeal to the average home buyer.

3. The true economic viability of each home is not well understood.

Perhaps the biggest surprise for me through this entire process was how much of my time was consumed by fundraising. There was talk of "pulling the plug" this spring and a very real concern that the defending champions would not be able to compete due to lack of funding.

The CU Solar Decathlon Team's budget for the 2005 project was $500,000. Assuming a comparable budget for all teams in 2007, the $100,000 pledge to each competing university from the DOE leaves a substantial 80 percent cost sharing on the part of the students participating. That level of fundraising can distort design.

Alleviating the burden of fundraising would have several positive ramifications.

1. It would increase the quality of each design by allowing teams to devote more time to the design and construction phases, rather than fundraising.
2. It would ensure a more objective approach to showcasing only the best technologies, rather than simply those products that teams are able to secure donations for.
3. It would provide a means for accurate accounting of the true retail cost of the each home by eliminating the guess work associated with product donation.

I also recommend abandoning the *Energy Balance* contest for a *Life-Cycle Cost* contest in which teams compete to build the least expensive home to construct and operate. This would be very possible under a net-metering scenario.

The Solar Decathlon competition must not be perceived as a novelty or political distraction. It must play a supporting role in creating a new future of energy use if we are to achieve what Richard Nixon was referring to in 1973 when he said, "Let us set as our national goal, in the spirit of Apollo, with the determination of the Manhattan Project, that by the end of this decade we will have developed the potential to meet our own energy needs without depending upon any foreign energy source."

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Each Solar Decathlete is doing their part in keeping the candle lit for solar energy. It is now time for Members of this committee and all Members of Congress to lead the way in carrying the torch.

Thank you.

Key Features of the 2005 University of Colorado Solar Decathlon House; The Bio-S(h)IP

- Revolutionary Bio-SIP, or bio-based Structural Insulated Panel, wall panels composed of soy-based polyurethane insulation and fully recycled post-consumer waste paper board.
- A single-chassis design, reinventing the "solar mobile home" for the 21st century.
- A 6.8 kW photovoltaic (PV) array comprised of 34 SunPower SPR–200 watt panels with an efficiency of 16.1 percent (among the highest in the industry).
- Building integrated photovoltaic (BIPV) array to serve as shading devices over south façade windows.
- Evacuated-tube solar thermal collectors that supply over 80 percent of space heating and hot water needs.
- High-efficiency, ductless air conditioning units.
- Radiant in-floor heating system with innovative controls for energy efficiency and improved comfort.
- Translucent double-skinned polycarbonate clerestory windows filled with high-insulation hydrophobic silica gel powder.
- Low-e, double-paned windows with attractive fiberglass frames that boast an R–14 COG (center of glass) value.
- An energy recovery ventilator (ERV) to provide efficient ventilation, heat recovery and air filtration.
- Low-power, high-performance kitchen appliances including a combination washer/dryer, an induction stovetop, a high-insulation refrigerator, and a combination microwave and electric convection oven.

Please refer to the Bio-S(h)IP User Manual for a more detailed overview of the key features in the 2005 University of Colorado Solar Decathlon House.

1. Given your experience, what do you think are the main technical and other barriers to greater use of solar energy? Do you have any suggestions for what might be done to overcome those barriers? How do you see the competition itself as helping to move both solar and efficiency technologies into the mainstream building market?

I believe that there remain technical, educational, institutional and financial barriers to greater market penetration of solar energy.

Technical barriers

There is ample research yet to be done to increase efficiencies; reduce up-front costs and increase integration.

Educational barriers

Currently in the U.S., there are only a handful of universities that offer degree programs in renewable energy. I discovered the Building Systems Program at the University of Colorado at Boulder through the DOE Solar Decathlon website on the 2002 event.

Institutional barriers

There exists an inherent and ever-widening disconnect between the homes Solar Decathletes give form to and the realities of the production home market in the U.S. I believe that the competition falls short of offering real solutions to how these homes can be incorporated into the large subdivisions. We must find ways to facilitate energy efficient and solar technology transfer from the Solar Decathlon competition to the production home market if we aspire to appeal to the average home buyer.

In addition, partnership with existing government programs and national laboratories is crucial. For example, none of the 2005 Solar Decathlon Teams partnered with the DOE Building America Program.

Financial barriers

The CU Solar Decathlon Team's budget in 2005 was approximately $500,000. DOE funding to each team will increase from $5,000 in 2005 to $100,000 in the 2007 event. At a sponsorship level of $100,000, the DOE is essentially requesting an 80 percent cost share from all of the participating universities. This is a substantial amount of funding for undergraduate and graduate engineers and architects to raise in a 12 to 18 month period. It is certainly not enough time to forge the type of partnerships with sponsors that are likely to donate at higher levels.

Increasing the funding level to $250,000 per team (an approximate cost share of 50 percent) would have several positive ramifications on the competition.

- It would increase the quality of each design by allowing teams to devote more time to the design and construction phases, rather than fundraising.
- It would ensure a more objective approach to showcasing only the best technologies, rather than simply those products that teams are able to secure donations for.
- It would provide a means for accurate accounting of the true retail cost of the each home by eliminating the guess work associated with product donation.

2. What sources of information did you draw on to figure out how to build your house? What problems arose in designing or constructing your house that surprised you?

The University of Colorado won the Documentation contest in what one judge referred to as a "Tour de Force" approach. The CU Team's principle resources were the professors and faculty advisors from both colleges. Team members developed expertise along the way to perform necessary energy modeling and thereby take advantage of the resources available on campus. A wealth of design tools were used by the CU Team through the schematic design phase. For example, six separate design tools were used to model the active and passive solar systems alone in the CU house. This is a testament to the need for further integrated design tools. A trial and error approach to extensive energy simulation dictated the final design from an engineering perspective. The CU Team submitted an exhaustive Schematic Energy Analysis Report early in the design process to organizers at the National Renewable Energy Laboratory.

Perhaps the biggest surprise for me through this entire process has been how much of the entire CU Team's time was consumed by fundraising. Unfortunately, this time would have been better spent concentrating on the design, construction and commissioning phases of the project.

3. Would your house be commercially viable? If not, what changes would make it more attractive to the mainstream home buyer?

The CU Team worked with the largest manufactured home builder in the Nation, Genesis Homes, for the design and construction of the chassis used to transport the Bio-S(h)IP. In addition, the CU Team worked with a client, Prospect New Town (a new-urbanist development in Longmont, Colorado), for the pre-purchase of the home. Further incorporation of the manufactured home process will inevitably drive the retail construction cost of the Bio-S(h)IP down. In addition, all of the products used in the CU house are commercially available today.

Having one of the longest over-land distances to travel to the competition, CU Bio-S(h)IP was principally driven in design by the need to transport it thousands of miles. The average home owner will never move their home anywhere, much less thousands of miles. There is an inherent contradiction here. The mainstream home buyer is not interested in a product that is driven architecturally by the need for mobility. The Bio-S(h)IP was designed in cooperation with a specific client and for the unique purpose of being transported over long distances. For this reason, rather than suggest changes to the Bio-S(h)IP that would render it more attractive to the mainstream market, I offer suggestions for how to tailor future Solar Decathlon competitions in a way that will render the finished products more appealing to the average home buyer.

1. *Re-examine the merit of an 800 square foot limitation.*

   There are many applications for 800 square foot solar-powered buildings; low-income housing, developing world and war-torn area aid relief, and Native American reservations. These are not mainstream home buyer applications, however. According to the National Association of Home Builders, the average size of a homes purchased in the U.S. is now 2,200 square feet.

2. *Consider a grid-tied application including net-metering.*

   Establishing a mini grid for the Solar Village our enabling each team to tie into the local electrical grid would accommodate smaller PV arrays and battery bank sizes and would also give the general public a truer sense of what living with solar would be like for them.

3. *Exchange the Energy Balance contest for a Life-Cycle Cost contest.*

   The cost of construction and operation is of far greater interest to the average home buyer than is the concept of energy balance. With a more diligent accounting of the cost of construction and a net-metering scenario, teams could conceivably compete for the lowest life-cycle cost.

BIOGRAPHY FOR JEFFREY R. LYNG

Jeff Lyng holds a B.S. in Ecology from SUNY–ESF and is presently completing a Master's of Civil Engineering with a focus in renewable energy in the Building Systems Program at the University of Colorado. He was instrumental in founding the University of Colorado Renewable Energy Club (CURE) and also serves on the Board of Directors for the Colorado Alliance for a Sustainable Future (CASF) as the CU student group liaison. Jeff's Master's project will focus on the implementation of Colorado Amendment 37's residential solar set-aside provision in the new home market through existing residential green building programs. He currently serves as the Project Manager for the 2005 CU Solar Decathlon Project and as the Built Green Specialist for the Metro Denver Home Builders Association.

Chairwoman BIGGERT. Thank you very much.

Mr. Knowles, you are recognized for five minutes.

STATEMENT OF MR. JONATHAN R. KNOWLES, PROFESSOR AND TEAM FACULTY ADVISOR, DEPARTMENT OF ARCHITECTURE, RHODE ISLAND SCHOOL OF DESIGN

Mr. KNOWLES. Thank you, Madame Chairwoman and Members of the Subcommittee. I am very pleased to be here today.

I am joined with my testimony with Christina Zanconnie, who is a Bachelor of Architect candidate for 2006 and William Thomas of Arden Engineering, who was our mechanical consultant and contractor for the project.

I am just going to briefly go over some of the strategies we used in designing the project, basically about our planning, our townhouse concept, and some of the technical innovations that we developed.

First is a design overview. The house was designed in, basically, two sections in that the students were interested in interweaving passive and solar strategies, some untried, some new. The south end was the candidate for the passive strategies, and it included a green roof for insulation and water management, and then deepset windows to allow the—to block the hot summer sun and let in the deep winter sun. The north half of the house was our photovoltaic half that included the solar panels and then the technical—the components in what we called the "appliance garage."

By having the house broken into two halves, we allowed the circulation to sort of weave its way between parts of the house in order to manage the 100,000 people that came marching through to sort of demand to know what we were doing, which worked out very well. It was a very efficient plan, and enabled no bottlenecks for all of the visitors to move through the house.

[Slide.]

What you might have noticed in the last slide, and I will turn it back, is that the orientation of our house differed from all others in that it was oriented north-south on the Mall. And this was a discovery by the students that the house could have a townhouse type orientation in that the students were interested in a slim, urban lot to sort of promote ideas of density, conservation, land management, et cetera. So the idea of the house, although we could only build one, was to actually aggregate in series in—on a street, in a dense, urban situation.

And that led to where the front lawn of your townhouse is on your roof. The landscape architecture students in our school designed quite a lovely roof garden. Again, that provided insulation, a fourth room of the house, and helped control the rainwater that was so abundant during the week of the competition. We did have the opportunity to have two lovely dinners on the roof. We hoped to score points with the jury for that, but that didn't work, but we got the dinners nonetheless.

I am describing all of these ideas, because they intertwine. To buy the real estate for the roof garden, we had to make a much smaller system than we had originally anticipated, so we essentially have—or had 24 Sanyo 190-watt panels for a total of 4.6 kilowatts of energy. And we designed the system with 16 batteries for four days of storage. This idea was explored, or for the economy of the panels, 24 panels are a lot less expensive than many more, which made great sound strategy and providence but was horrible here in Washington during the deluge. So our project conked out promptly on Wednesday night, the four days that we had the storage.

Another way to buy the real estate of a smaller solar system, to keep the cost down, is we developed a louver system, we called it the heliotropic louvers, that essentially shed this hot sun off the house. And that effectively lowered our air-conditioning costs, or load, by 40 percent. It also created a dramatic chameleon-like aspect of the house in that the skin of the house moved during the day, changing its character and color. It also had another benefit of setting up a thermal draft. One side of the louver got hot, the other cool, so it set up a micro-convection against the house, again shedding the hot heat of the house away.

And finally, with all of these benefits of being small, efficient, and cost-effective is designing a very efficient air-conditioning and heating system. And we used phase change materials that were suggested and developed with Arden Engineering and Bill Thomas behind me, and essentially it was two containers, one for the hot side, one for the cool side, sounds like that old McDonald's sandwich, that were able to store our energy for future use. The cool side phase change materials are charged by the cool night air. The box is opened up, the air is drawn across the phase change bricks, the box is closed, and then we run water through the box and into radiant ceiling panels, so it is, in essence, a radiant cooling system. In the winter, we use the hot water panels on the roof to provide us with hot water. That again charges the hot box, shown on your right, and again, water is run to the hot box, through the radiant ceiling panels, same tubes to create radiant heating.

With this system, we allowed—we again reduced our cost, and essentially the only thing that is moving that water is small pumps that take very little energy. So we essentially have no chiller. So all of these ideas were interwoven for efficiency and cost and for the size of the house.

And I just want to show briefly some of the best photographs of the construction of the project and, in conclusion, thank the many students who devoted two years of their lives working and constructing this house on the Mall.

Thank you very much.

[The prepared statement of Mr. Knowles follows:]

PREPARED STATEMENT OF JONATHAN R. KNOWLES

Two Ways: Interweaving Passive and Active/Efficiency and Excess

Solar houses are often characterized by the "either/or" of passive or active techniques. "Passive" systems strategically use walls, window placement and overhangs to control solar gain, where "active" systems deploy pumps, piping and mechanisms to collect, store and redistribute the sun's energy. The RISD Solar team's approach interweaves these two strategies by creating a symbiosis between the building envelope and the heating and cooling system each working in both ways. With RISD Solar, building components that are traditionally static, move (through computerized servos and biological means), while elements that are normally part of a mechanized system are visually inert (they move at the chemical and atomic level). The coordination of these two strategies allows the occupant to engage the variability of the surrounding natural environment in unique ways.

RISD's 800 square foot exhibition house is formed by the intersection of two volumes, one, which incorporates "passive" techniques and the other, which houses the "active" components. The north-south orientation rewrites previous rules governing the layout of a solar house, which generally would stretch a building along an east-west axis. With the north-south axis, light changes throughout the day. The house, divided into four discrete domestic spaces: living/kitchen, bathroom/laundry, bedroom/office and garden/prospect, has a main circulation path which is designed to lead a large number of visitors parallel to this east-west movement. A shorter private circuit within the house ends at a secluded roof garden with an extraordinary vista (the U.S. Capital and the Mall). Enclosing these spaces are multi-functioning double skin walls, roof and floors.

Windows and Daylight

Traditional solar homes use an excess of southern glazing in combination with thermal mass to obtain passive heating. In the RISD house, windows are carefully sized and arranged to provide a balance between the correct amount of light and well-insulated walls. To arrive at a the lighting strategy, appropriate light levels were determined based on the functions of the various spaces, then measurements were calculated and daylighting models were tested. The result is three interior spaces with distinct light effects. The south end opens to the changing light of the day with a relatively large southern glass wall. Overhangs, louvers and curtains further control the sun's rays and allow warm light to enter during the winter and keep out harsh overheated sun in the summer. The hall, which is intentionally the darkest area, brings a spot of natural light through a roof hatch that doubles as a skylight. In the bedroom/workspace, high transom windows bounce eastern morning and diffused northern light around the space while smaller windows provide isolated views. The placement of the windows is designed to avoid glare on computer and TV monitors and create a gentle glow.

Well-Insulated Surfaces

One of the primary sustainable systems used in this house is straightforward, affordable and invisible to the eye. The exterior walls, floors and roof of the structure, designed as lightweight and material efficient stressed skin panels, are filled with one of today's best performing building insulation. Between the insulation, cladding, and airspace, these walls attain an R-value (resistance to thermal transference) that is a third more than recommended by Federal Energy Code. Isonyne insulation is blown in and thereby installed to make the building "tight." This means air cannot move through unplanned openings in the floor and walls. Windows and doors also perform better than standard houses as the windows are coated with tin oxide to reflect infrared heat, double-glazed and fully gasketed. Attention to a well-insulated envelope allowed our engineers to reduce the size of their heating and cooling equipment.

Heliotropic Louvers

On the exterior walls of the house, a set of louvers literally moves with the sun. These vertical fins, offset from the main structure, are used to regulate the amount of sun hitting the house and to create a chimney effect of the cool air drawn up from the ground. In the summer, the louvers track the sun with their broad edge, reflecting its rays away from the building and keeping the house cool. In the winter, the louvers track the sun with their thin edge, maximizing the amount of sun hitting the house. A mapping of the solar light angles throughout the year was used to determine the movement of the louvers. The result is a house in motion, changing its character as the Earth spins.

Roof Garden

The roof garden, which is made up of a series of shallow portable planters, provides many advantages. It plays an aesthetic role by extending the form of the house and creating a place of refuge. In addition, the variegated grasses and sedum, chosen because they require minimal water and maintenance, shade the house when full grown in the summer while the herbs can be used in the kitchen. The lightweight soil provides extra insulation, and absorbs water runoff. A water trough collects rainwater for irrigating the garden and use in a grey water system. The garden thus extends the usable living space of the house in area and in spirit.

Solar Surfaces

Like the louvers and garden, the roof of the north end is covered with a second skin. The solar collecting panels shade the light colored roofing membrane, thereby helping to cool the house while also generating energy. These panels provide both the heat and electrical energy for the house and are the first component of the mechanical systems. The RISD solar team's decision was to use as few solar panels as possible in order to make room for the roof garden and reduce the cost of construction. Therefore, they used the most efficient mono-crystalline photovoltaic panels available and energy efficient appliances to reduce the total surface area of the array. The photovoltaic panels each produce 190-Watts to form a 4.6 Kilowatt system for the house. The solar hot water collectors are of the evacuated tube cylinder type, which are more efficient than flat plate collectors and allow solar heat collection in colder climates and cloudy days.

Appliance Garage and Energy Star Appliances and Fixtures

The Appliance Garage, situated at the north end of the house, is a large storage space divided into easily accessible cabinets. This cabinet is made of thin walls to conserve space and uses nanotechnology (nanopaint) to withstand the coldest side of the house. On the exterior, the Garage contains storage space and the electric equipment that converts and stores the electricity produced from the photovoltaic panels (through inverters and batteries). The interior opens up into a home office with filing cabinets, and also includes attic storage and a wardrobe. The flat screen monitor, lights and appliances are all energy efficient and energy star rated. The use of these fixtures reduces the load and the size of the photovoltaic system without compromising functionality.

Building Systems: Heating, Cooling and Ventilation

The core is the most compact component of the house thereby freeing space for the living areas. Acting as the heart, it contains the hot water heating tank, the bathroom, the kitchen, the washer/dryer and access to the roof garden. Above the bathroom is our Sistine ceiling—a carefully designed and built mechanical space where the pumps, manifolds and ventilation equipment are housed. The central location of this high performance equipment minimizes duct and pipe runs, which increases efficiency. Three systems are used to maintain thermal comfort: a solar heating loop that heats both domestic hot water and the space, a cooling loop that is charged by cool night air, and an Energy Recovery Ventilator (ERV) that controls the building's supply and exhaust ventilation.

The heating and cooling systems use the principle of Thermal Energy Storage (TES). The storage is through Phase Change Materials (PCMs). The ability of the Phase Change Materials to store and release latent heat allows this material to store thermal energy in a smaller area, roughly 1/10 the area of water storage. For heating, we store solar thermal energy from the solar collectors during the day for usage during the night or days of no sun. For cooling, we use Phase Change Materials to store nighttime ambient air temperatures 60°F or below for daytime cooling.

Heating and cooling are stored in two separate PCM containers, which use heat exchangers to transfer the stored heating or cooling thermal energies to radiant ceiling panels. The radiant panels are combination panels used for both heating and cooling. This is achieved through a variable speed primary/secondary pumping system located in the mechanical space. Using a hydronic variable speed pumping system allows us to use only the energy needed to heat and cool at a given time and requirement, at very low energy consumption. For comparison, a heat pump sized for the same heating and cooling loads would require 2,250 Watts of power at maximum design conditions. If that heat pump were of the newer variable speed type, the wattage range would be between 550–2250 Watts based on load conditions. Once our system is "charged" (i.e., has heating and cooling stored in the PCMs), our maximum wattage needed to heat and cool our building (because all we are using is pumps) is 167 Watts. If we were to include the energy used by the Energy Recovery Ventilator when, or if, needed to control possible condensation, we would be at a total of 489 Watts. As we are using variable speed pumping and have variable speed control on our ERV, our maximum wattage usage is from 489 Watts down to 135 Watts based on load conditions.

Hydronic radiant cooling and heating systems can remove or add a given amount of thermal energy using less than five percent of the fan energy that would otherwise be necessary if using an all air heating and cooling system. The advantages to our system over conventional heating and cooling technologies are:

- We are using natural ambient conditions to provide the heating and cooling for the building.
- Through the Phase Change Material Storage, we presently have the capacity to store days worth of heating and cooling strictly from environmental sources at design degree days.
- Through the use of radiant heating and radiant cooling, we are able to provide the same heating and cooling capacity as a "conventional" system using much less energy, and at a higher comfort level to the occupants. Another advantage to this system is the effect it has on the thermal envelope heat transfer of the building. Because the heating temperature of the water is lower, the temperature difference across the thermal envelope (walls, roof, etc.) is also lower. This translates into less heat loss out of the building. The same works for the radiant cooling which operates at a higher cooling water temperature than a conventional system. The less temperature difference across a surface, the lower the heat transfer across that surface.
- Our system was designed to be simple, both in operation and installation.

The intent of this system is to show the potential for a building to have long-term energy storage and the use of natural heating and cooling through the use of Phase Change Materials.

Assembly + Structure

Because the competition required that the house be moved from Providence, RI to Washington, DC and back, the house is designed as a modular home that is disassembled into nine individual modules. The RISD team divided their house into many modules so that the internal spaces could be more generous while still conforming to highway restrictions. The modules are bolted together at seams, leaving most of the interior and exterior finishes intact. The exposed "expansion" joints and the strength of the plywood finishes allow the house to be moved without cracking. The entire structure was built with off-the-shelf, low-tech products enabling it to be built on site with minimal shop outsourcing and thus controlling costs. The team was careful to choose materials that met strict requirements. The materials have low embodied energy (i.e., local and recycled), do not aversely effect indoor air quality (low volatile organic compounds and nontoxic glues), do not harm the environment (no CFCs) and are renewable (plywood farmed with sustainable practices, and the use of fast growing cork).

Planning

While RISD built only one house for the Solar Decathlon, the building layout affords site adaptability. It can be used as a freestanding house or an urban townhouse. The orientation of the building favors the north/south axis while an offset of the parts allows for adequate light throughout even if the units are clustered together or repeated. As a “townhouse,” the project responds in a unique way to the questions posed by the organizers of the Solar Decathlon. When the units come together, their displacement in section and in plan creates interstitial spaces that can become oases within the urban context. The idea of the solar village, while not a novel concept, becomes more energy efficient with the aggregation of more units. Uniting design with urban values, our solution addresses the issues of sustainability not only within the individual house, but also on a community scale.

Less and More

Through interweaving strategies of passive and active solar techniques, we have worked to achieve both efficiency and richness. While our wall and mechanical systems work intelligently together to create substantial efficiencies, they also allow for delightful excesses. With zero emissions, the house generates surplus energy. Each one of our techniques is integrated to create a singular design. Paramount to the project has been balancing the need for energy efficiency and production with the principles of thoughtful architectural design.

Questions and Answers

(1) Given your experience, what do you think are the main technical and other barriers to greater use of solar energy? Do you have any suggestions for what might be done to overcome those barriers? How do you see the competition itself as helping to move both solar and efficiency technologies into the mainstream building market?

No barriers currently exist except public accessibility. RISD Solar uses 16 deep-cell batteries, two charge controllers and two invertors to convert and store the sun’s energy from 24 190-Watt Photovoltaic Panels. The system is small, robust and most importantly, off the shelf. The PV panels generate 4,560 Watts of energy and are affordable at a cost of approximately $41,000. This is $9.00 per watt, which is on the lower cost side of a battery backup system. If we assume a 20-year life, with minor maintenance costs, the system generates energy at $.29/kWh. Since our design was intended for an urban environment, battery back-up could be greatly reduced or eliminated, reducing the cost, and reducing electricity costs to $.22/kWh. By comparison, our electric bills in Rhode Island are $.14/kWh or roughly half. Over 20 years, however, the cost of electricity will surpass solar electric. If solar technologies were subsidized to the extent that the oil industry (with the associated transportation industries) are currently subsidized, there would be a boom in the market that would reduce these costs and begin to move the Nation towards energy independence.

Another path to the same goal would be to offer National incentives coordinated through pre-existing State programs. Many States offer grants combined with tax breaks to promote alternative energy, but all State programs are not the same. The cost is usually supported by a small surcharge on the public’s energy bill. An increase in demand, especially supported and advertised at the federal level will bring the market to bear, and with it the research funds to make the technology more affordable. Also, the Federal Government should continue to support University driven research and competitions such as the Solar Decathlon. Differing from conventions and trade shows, the Solar Decathlon is a public demonstration; the houses work and prove that the technology is here now. Nothing presented at the Solar Decathlon is out of the public’s reach. Perhaps the competition itself should expand across the country and become regional, attracting solutions specific to the climates in the East, Midwest and West. Finally, a critical part of our design was the efficiency of our heating and cooling system. This system would require more research and development for it to enter the market as an available product.

(2) What sources of information did you draw on to figure out how to build your house? What problems arose in designing or constructing your house that surprised you?

At RISD we had the opportunity to spend time on critical research about environmental technologies, which is not commonly possible in practice. We used book sources, trade shows, consumer guides and direct evaluation of products. The RISD Solar student team researched and designed every aspect of the house but it was not until we engaged the local building industry did the choices and opportunities become much more clear. For instance, we would have preferred to use factory built SIPs (structurally insulated panels) for the roof, walls and floors but we decided to use a stressed skin panel system instead so these components could be constructed on site and by our own forces. Stress skin panels are very similar to wood frame (or light frame) construction except each panel relies on the interior and exterior sheathing (plywood or oriented strand board) for structural stability. We eventually found a local company that prefabricated the majority of our stress skin panels but we insulated and sheathed the interior surfaces ourselves.

Problems to work out next time include construction tolerances, weight and transport. The RISD Solar house was designed to come apart in too many pieces that were difficult to fit back together. The more pieces, the greater the construction tolerance required, which demands a sophisticated solution to integrate module joints within the design. Also, each stressed skin floor, wall or roof panel weighs approximately 1,000 pounds, which cannot be easily maneuvered by an untrained workforce. When 1,000-pound panels are brought together to form a module, weight becomes a serious issue and cranes or lifts are required to move pieces of the house into place. To move a house, it must be lightweight and easy to assemble and disassemble. The Solar Decathlon competition strongly favors modular homes that can be moved down the highway, set up quickly and taken down as quickly. We were pleased that our room proportions were generous, but more research is required to move a house that does not have the characteristics of a mobile home.

(3) Would your house be commercially viable? If not, what changes would make it more attractive to the mainstream home buyer?

The size of the RISD Solar house could be commercially viable for a very limited market—young professionals or empty nesters. The total RISD Solar budget was $400,000.00, which is expensive for 800 square feet and translates to $500/square foot or the cost of a high-end Manhattan apartment renovation. If transport, travel, lodging, etc., is removed from the budget, the cost is closer to $200/square foot, which is not unreasonable for a new house. That is why the RISD Solar team planned an urban dwelling—the aggregation of units would lower the cost. Efficiency is an important element of our townhouse proposal: mechanical systems are centralized leaving more room for the flexible use of living space; plumbing and air duct runs are minimized lowering the cost of these expensive components; the bathroom space itself is the shower enclosure; and a Murphy (fold away) bed transforms the bedroom into the home office. While all of these space-saving strategies save money and are applicable to today's market, our house would require the addition of more area to be marketable as a house to be sold in the U.S.

BIOGRAPHY FOR JONATHAN R. KNOWLES

Jonathan Knowles is an adjunct Professor of Architecture at the Rhode Island School of Design for the 2005 and 2006 academic year and has been teaching at RISD since 2001. He has taught at the Parsons School of Design, the City College of New York, Cornell and Columbia Universities as well as the State University of New York in Buffalo. Jonathan is also a practicing architect in New York City where he co-founded Briggs Knowles Studio in the fall of 1997 with Laura Briggs. He is currently managing the design and construction of three sustainable townhouses in Harlem and a new Telecommunications Center for the Hispanic Information and Television Network located in the Brooklyn Navy Yard. His degrees, a Bachelor of Architecture and Bachelor of Fine Arts, are from the Rhode Island School of Design.

Chairwoman BIGGERT. Thank you.

And now, Mr. Schieren, you are recognized for five minutes.

STATEMENT OF MR. DAVID G. SCHIEREN, GRADUATE STUDENT AND ENERGY TEAM LEADER, ENERGY MANAGEMENT, NEW YORK INSTITUTE OF TECHNOLOGY

Mr. SCHIEREN. Thank you, Chairman Biggert and distinguished Members of the Energy Subcommittee.

It is a great honor to present the New York Institute of Technology's and the U.S. Merchant Marine Academy's Solar Decathlon project.

I would like to introduce Heather Korb, Lead Architect from NYIT, and Greg Sachs, Lead Engineer from the Merchant Marine Academy, sitting just behind me.

For the past two years, we have been working on an extraordinary project, an advanced solar hydrogen home. Our progress has been realized through extensive interdisciplinary efforts of students, faculty, and staff. We strongly believe that solar energy, renewable hydrogen, and sustainable design offer a future of true energy independence, a clean environment, and a greatly enhanced civilization.

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[Slide.]

First a vision, a philosophy of sustainability, then the design competition, and the project blossomed.

NYIT's project is called Green Machine/Blue Space, a house of two parts working together as one self-sustaining unit.

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[Slide.]

Green Machine is a modified shipping container that houses the mechanics of life, including a kitchen, a bathroom, a roof garden for food production, solar water heating, and hydrogen production and storage. Containers are found everywhere, and we consider them a pre-made space, structurally sound and easily transported by truck, rail, air, and sea.

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[Slide.]

Blue Space is a site-specific design that emphasizes sustainability and minimizes the energy loads through material selection, passive solar strategies, and natural ventilation.

Furniture in the living space is designed as micro-environments to help minimize the use of mechanical heating, cooling, and lighting.

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[Slide.]

To the power systems. Solar panels provide the primary source of energy by converting sunlight into electricity and sending it to the house loads. Surplus energy from the solar panels is sent to an electrolyzer that produces hydrogen gas from water. When there is no sunlight, the fuel cell converts the hydrogen gas back into electricity to power the house.

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[Slide.]

This is a quiet and clean process. The fuel cell byproducts are water and heat, and the water is used again and converted back into hydrogen.

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[Slide.]

We view this as a vital demonstration project. Applying these technologies will help determine how to achieve further advances. This system portends a new energy paradigm based on distributed generation, inherently stronger than the fragile, centralized system of today. We believe that hydrogen can replace fossil fuels.

To specifically address the Subcommittee's questions, in general, solar energy equipment today does an excellent job of powering a home, as demonstrated with the Solar Decathlon entries and many homes across the country. However, there are barriers to overcome before mass adoption, including: lack of public awareness about the benefits of solar energy and the true costs of the current fossil fuel-based system to the environment and national security; the high cost of—and short supply of solar panels and raw materials; the inconsistency and uncertainty of government incentives for homeowners and developers; lack of training for engineers, construction workers, architects, and business people.

The mounting energy crisis and technologic advances have industry, academia, and the government looking to develop hydrogen fuel cells as a viable alternative to fossil fuels. Current barriers to the greater use of hydrogen include: lack of public awareness about the capabilities, safety, and benefits of hydrogen; the need to improve fuel cell, electrolyzer, and energy storage technologies by decreasing costs and improving efficiency, integration, and life span of the equipment.

The government is supporting the development of solar and hydrogen technologies. We would advise increasing this investment and setting out a clear vision, a bold national strategy with specific milestones that lead towards a clean and renewable energy economy.

The Solar Decathlon had a deeply positive impact on helping to move solar and efficiency technologies into the mainstream building market. At our school, it inspired over 100 students and faculty from the architecture, engineering, interior design, and communications departments to work together. The knowledge and experience gained from this project will carry with us, as we become the next generation of leaders in our respective fields.

Through fundraising and PR efforts, our ideas were shared with many leading figures in the building and energy fields. While on the National Mall during the event, the flow of people and the interest they had in solar and efficiency technologies was breathtaking. Everyone wanted solar today.

I can see that my time is almost up here. I just wanted to mention that—to address this question of what major challenges we had and problems that came about. I would certainly agree that fundraising and learning—figuring out how we were going to pay for everything was a major issue for us, and I think likewise with the other teams. And so we also noticed that there was sort of a lack of money available for systems integration research. So it is, you know—there is money available for specific lines, but to put it all together and make it work as a package is something that we are really looking to further.

So with that, I would like to thank you very much for the—for pursuing this important discussion, this important dialogue, and we look forward to moving these issues forward.

Thank you.

[The prepared statement of Mr. Schieren follows:]

PREPARED STATEMENT OF DAVID G. SCHIEREN

I. INTRODUCTION

We thank Chairman Biggert and distinguished Members of the Energy Subcommittee for allowing us to submit this testimony. It is a great honor to present the New York Institute of Technology's (NYIT) and the U.S. Merchant Marine Academy's (USMMA) Solar Decathlon project.

The authors of this document are David Schieren, the Energy Team Leader from NYIT, Heather Korb, Lead Architect from NYIT and Greg Sachs, Lead Engineer from the USMMA.

For the past two years we have been working on an extraordinary project—an advanced Solar Hydrogen home that we believe demonstrates the promise of a secure energy future. We strongly believe in the promise of solar energy, renewable hydrogen and sustainable design. With these tools and resources, supported by substantial research and development, we see a future of true energy independence, a clean environment, and a greatly enhanced civilization.

Our progress has been realized through extensive interdisciplinary team efforts of the full NYIT community—the architecture, engineering, interior design, communications and culinary departments, the administration, staff and countless supporters—and our USMMA partners. Key students, faculty, and staff worked tirelessly, often without remuneration, to pursue this vision of a better world.

II. PROJECT OVERVIEW

1. Philosophy

First a vision, a philosophy of sustainability, then a design competition, and the project blossomed.

NYIT's Solar Home is called Green Machine/Blue Space (Rendering). Green Machine, the life support of the house and Blue Space, the solar-collecting dwelling place, are two parts working together as one self-sustaining unit. Green Machine/Blue Space separates the mechanics of life from leisure space to create a home which can exist anywhere in the world.

2. Designs

i. Green Machine: a Global Design Strategy

- GM is a modified shipping container that houses the mechanics of life including a kitchen, a bathroom, roof garden for food production, solar water heating, and hydrogen production and storage.
- Containers are found in surplus worldwide. We consider them a pre-made space—structurally sound and easily transported by rail, air and sea.
- When modified for climate conditioning and equipped with a self sustaining, non-polluting energy storage system and all the necessities of living comfortably the GM supports life.

ii. Blue Space: a Local Design Strategy

- Blue Space is a dwelling place that is designed to be site-specific.
- The construction, design and materials emphasize sustainability and minimize the energy loads through interior design, passive solar strategies and natural ventilation.
- The Blue Space's size, construction and architecture can change according to the climate and culture of the site.
- Furniture pieces in the living space are designed as micro-environments to help minimize the use of mechanical heating and cooling, and lighting.

iii. Interior Design

The interior space of the home is unique and in harmony with the architecture of the home as well as the local environment.

- Furniture pieces in the living space are designed as micro-environments to help minimize the use of mechanical heating and cooling, and lighting.
- Furniture will be multi-functional suggesting an economy of materials for future homes.
- Materials used will be sustainable and support the energy strategy.

The goal of our project is to exhibit self-sufficiency, energy independence and life in a clean environment where we eliminate pollution and destruction. We design with nature as a model—we produce, use, recycle and begin again—a regenerative cycle of life. Our decision to use a Hydrogen-based energy storage system stemmed from this philosophy.

3. Energy Systems

i. Abstract: Solar-Hydrogen

- Solar panels are the primary source of energy and convert sunlight into electricity and send it to the house loads.
- Surplus solar energy is sent to an electrolyzer that produces hydrogen gas from water.
- When there is no sunlight, the fuel cell converts the hydrogen gas back into electricity to power the house.
- This is a quiet and clean process: The fuel-cell byproducts are water and heat, and the water is used again and converted back into hydrogen.
- This was version 1 of what we think can become a very robust home energy system.
- *This is a vital demonstration project: Applying these technologies will help determine how to improve it.*

ii. Operational Overview

As discussed, this is a solar powered home that uses hydrogen gas as the primary energy storage medium as opposed to a battery based system.

To understand the basic operation of the "Solar-Hydrogen" home, it is constructive to first consider the operation of a typical battery installation. When there is excess PV produced electricity (when energy supplied by the PV array is greater than energy demanded by the house) unused energy is stored in chemical bonds formed within a battery's electrolyte. That energy is stored until demand is greater than supply (when the sun is hidden or after turning on a lot of loads in the house), and the battery discharges.

In a Solar-Hydrogen home, when energy supply is greater than demand, the surplus energy is consumed by the hydrogen generator to produce hydrogen gas. This gas therefore represents stored energy that is stored in a series of low pressure hydrogen tanks. Subsequently, when demand is greater than supply, this gaseous energy is consumed by the fuel-cell to produce electricity.

iii. Radiant Hot Water

The hot water system uses thirty "evacuated tubes" for hot water production. Evacuated tubes are devices which collect solar-radiation from the sun and convert it directly into thermal heat-energy. This heat-energy then directly raises the temperature of a liquid which flows along the end of these tubes. This liquid then circulates in a continuous loop between the evacuated tubes and the hot water tank. The hot-water tank thereby gets warmer and warmer as heat is transferred from the evacuated tubes into the drinking water inside the tank.

4. Benefits

- We believe that hydrogen can replace fossil fuels and end dependency on foreign nations for this critical economic input.
- As this project demonstrates, it can be generated from a locally produced power that is clean and renewable.
- Hydrogen gas is superior to and more versatile than other energy storage technologies, such as batteries.
  - It is versatile:
    - Can be used for house electricity, to heat or cook with.
    - Once stored, it does not discharge. Batteries discharge.
    - It can also be used to quick-fill cars, compared to battery electric cars that take time to charge.
    - It is a clean fuel, there are no negative environmental consequences. Batteries are toxic and must be carefully handled.
- A renewable hydrogen energy system offers the promise of true energy independence and a clean environment.
- This is the model of a new energy paradigm, a *distributed generation energy system*—superior to the vulnerable and cumbersome centralized system of today.

III. QUESTION RESPONSES

Given your experience, what do you think are the main technical and other barriers to greater use of solar energy?

In general, the solar energy equipment and infrastructure available today is high quality, contributing to a boom in photovoltaic installations. As demonstrated with the Solar Decathlon entries and many homes across the country, solar power does an excellent job of powering a home. However, to take solar to the next level (currently well under one percent of U.S. installed generation capacity) there are barriers to overcome, including:

- Lack of public awareness about the benefits of solar energy and the true costs of the current fossil fuel based system to the environment and national security.
- The high cost and short supply of solar panels and raw materials.
- The inconsistency and uncertainty of government incentives for homeowners.
- Lack of training for engineers, construction workers, architects, and business people.
- Efficiency of the panels must be improved.
- Lack of incentives for new property developers to incorporate into structures. How can they recoup their costs? Does a home with solar power sell for a higher price? What tools are there to evaluate this?
- Lack of Utility company support, through public or private initiatives, to build out solar.

What are the main technical and other barriers to greater use of hydrogen?

Hydrogen fuel cell technology has been around for some time, but only recently—because of the mounting energy crises and technological advances have industry, academia and government began to research hydrogen fuel cells as a viable alternative to fossil fuels. This is a long, but worthwhile journey. Current barriers to the greater use of hydrogen include:

- Lack of public awareness about the capabilities, safety and benefits of hydrogen.
- The need to improve fuel cell, electrolyzer and energy storage technologies by decreasing costs and improving efficiency, integration and lifespan of the equipment.
- The lack of hydrogen infrastructure must also be addressed.

Do you have any suggestions for what might be done to overcome those barriers?

The government is supporting the development of solar and hydrogen technologies. We would advise increasing this investment and setting out a clear vision—a bold national strategy—with specific milestones that lead towards a clean and renewable energy economy.

Specific steps that can be taken include:

Solar:

- Build on current federal incentive structure (starting 2006).
- Support State and local governments that are underwriting incentives.
- Promote certainty with the incentives so businesses can invest properly, thereby encouraging long-term planning.
- Attract domestic manufacturing of photovoltaics and solar energy system components.
- Work with utilities to reduce impediments to on-site power generation.
    - Introduce time of use power accounting that charges customers the market value of electricity. For example, power during a hot summer day is in greater demand (air conditioning) and therefore more expensive. This is also when solar panels are producing, they are load following. Therefore people might turn off equipment, or switch to solar.
- Support market mechanisms like Green tags and emissions credits that work to account for the externalities of fossil fuels combustion.

Hydrogen:

- Develop a national strategy to move towards a hydrogen economy.

- Increase support, incentives to promote the renewable generation of hydrogen.
- Support the advancement of fuel cell technology.
- Support the advancement of hydrogen generation.
- Support the advancement of hydrogen storage technologies.
- Support demonstration projects to test and improve the technologies.
- Work to streamline codes and standards for the handling and siting of hydrogen equipment.
- Support market mechanisms like Green tags and emissions credits that work to account for the externalities of fossil fuels combustion.

How do you see the competition itself as helping to move both solar and efficiency technologies into the mainstream building market?

This high-profile competition had a deeply positive impact on helping to move solar and efficiency technologies into the mainstream building market. The core challenge of the Solar Decathlon is to build a beautiful and energy self-sufficient home. At our school, this challenge inspired over 100 students and faculty from the architecture, engineering, interior design, and communications departments to work together to integrate a design vision with engineering and construction realities. The knowledge and experience gained from this project will carry with us as we become the next generation of leaders in our respective fields. The multiplier effect extends this impact from all the Decathletes to our families, friends, donors, and colleagues.

Through fundraising and PR efforts, our ideas were shared with many leading figures in the building and energy fields, in addition to countless homeowners. While still at school, people from the community would stop by the site and ask how they too could use solar. While on the National Mall during the event, the flow of people—and the interest they had in solar and efficiency technologies was breathtaking. Everyone wanted solar today.

This high-profile platform also enabled us to pursue and fund the hydrogen fuel cell energy storage system—a vital demonstration project.

What sources of information did you draw on to figure out how to build your house?

The team drew upon the vast knowledge of our own students and faculty to build our house. Many times we collaborated with private businesses—construction, architecture, engineering firms—and we found many willing partners in our community and beyond. People were ready to support this cause. For the Solar panels and the hydrogen fuel cell system, we looked to private companies and training courses to assist us with the installation of the systems. The USMMA's Alternative Power Program also had specific experience with hydrogen fuel cells.

What problems arose in designing or constructing your house that surprised you?

The team encountered a number of challenges throughout this process. Funding this project was a constant struggle. While there are grants available for specific lines of research, there should be more available for this type of system integration and interdisciplinary endeavor.

Would your house be commercially viable? If not, what changes would make it more attractive to the mainstream home buyers?

With solar power and energy efficient design technologies, it often comes down to a cost/benefit analysis: Is the upfront investment worth the long-term benefits? The NYIT house with the hydrogen fuel cell system is not commercially viable today—though this is what we are working towards. The solar electric, and solar hot water systems, and energy star appliances are, partly because of the incentives that our local utility, the Long Island Power Authority, offer.

The design concept of the house, the site specific dwelling and the modified shipping container with internal mechanics and power systems has many applications in addressing general housing and energy problems across the world. The Green Machine contains everything needed for survival and connects to any type of "Blue Space" with photovoltaics to gather solar power. In tandem the two parts work together as one self-sustaining unit. It is then supported by furniture and interiors.

The benefit of a locally designed and built dwelling place is that it provides the inhabitants with a feeling of comfort and ownership. In addition, local energy production brings peace of mind to homeowners and to our country.

BIOGRAPHY FOR DAVID G. SCHIEREN

David is a graduate student pursuing a Master of Science in Energy Management at the New York Institute of Technology. He is the Energy Team Leader for NYIT's 2005 Solar Decathlon Project, responsible for overseeing all energy systems and developing the Solar Hydrogen Fuel Cell Power System with the United States Merchant Marine Academy's Alternative Power Program. David also took a leadership role in fundraising, corporate partnerships, public relations and communications.

After studying Economics and Japanese at the University of Vermont, David joined Merrill Lynch in the International Equity Sales Department where he advised institutional money managers on purchasing Japanese stocks. Concerned about the global political, energy and environmental situation, David left his capital markets job to pursue a career in clean energy. He has recently co-founded EmPower CES, LLC, of Hewlett, New York.

David is from Hewlett Harbor, N.Y., and now resides in Fort Greene, Brooklyn, N.Y.

DISCUSSION

Chairwoman BIGGERT. Thank you.

We will now turn to Members' questions, and I will recognize myself for five minutes.

Join the club in having to address the issue of fundraising. It is a—I think it is a problem everywhere, but—and obviously all of the teams had to raise a lot of money to design and to build and to transport your houses. That seems to be something that was very apparent in all of the photographs that we saw and everything. And there was no monetary or other prize, other than the recognition and publicity for winning the competition.

So what motivated your teams to participate? And were there any obstacles to the participation, maybe other than the fundraising?

Mr. Schubert.

Mr. SCHUBERT. Well, I think a project of this nature is a natural for us to be involved with. It kind of drew students and faculty to it. I think by having it done once in 2002, there was already kind of acknowledgment and visibility, and so it really wasn't difficult to recruit students to it. And it, again, is one of these projects that allows an interdisciplinary approach to it, and I think the students appreciate being able to work with others across colleges.

Chairwoman BIGGERT. Thank you.

Mr. Lyng, you said that, you know, three years of your life—what motivated your team to participate?

Mr. LYNG. I think for other members of the CU team, certainly myself, and I can't imagine it is terribly different for other team members, it was a drive to do the right thing. And I would echo what—Mr. Schubert's comment. It was not hard to get students interested. It was hard to get students—to keep student interest, because it was a very difficult project to work on. It is a huge amount of time commitment. Fundraising was not a trivial thing for undergraduate and graduate engineers and architects. These are not MBA students. Getting the house here from Colorado was a sincere difficulty. And staying here in DC for four weeks, away from classes. Those were the real legitimate difficulties. But despite all of that, we had 20 students from the University of Colorado come here to participate.

Chairwoman BIGGERT. Mr. Knowles.

Mr. KNOWLES. I think it was—our motivation was primarily to embed issues of sustainable design and alternative energy practices in our curriculum. The Chair of my department was wholeheartedly behind the project as we tried to develop our curriculum to tackle these issues, and this is the perfect project for that in terms of building and having firsthand experience with designing something—students designing something—building something they actually designed.

Again, you are going to hear this all day, the department was fully behind it, but when it became time for fundraising, it is a significant amount of money, and it was very difficult, with other funding issues going on on campus, to have the entire school, you know, put their full efforts behind this project.

Chairwoman BIGGERT. A lot of bake sales.

Mr. KNOWLES. Phone-a-thons, et cetera, pleas, begs. So that was—but that was really our primary concern, and to continue to strengthen our department in terms of issues of sustainability, as Colorado was—has already done.

Chairwoman BIGGERT. Mr. Schieren.

Mr. SCHIEREN. I think that, for our team, opportunity to work on a problem, there is just acknowledgment that there is a problem, many problems that we have to address, but spearheaded by the architecture department setting out a vision, a philosophy from—for making improvements from—for—and I think students felt that they had a direct hand in making progress. So the people, the key team members, I said there were well over 100 people at our school and our partnership, but the key people, say 20 to 30 people, worked tirelessly on this. And the truth is that it is very challenging, but I think that satisfaction only comes when you do a lot of hard work and you have actual results. So people were extremely committed, and still are.

Chairwoman BIGGERT. Thank you.

Just quickly, Mr. Moorer, what kind of research activities can be incorporated into the—such a competition for the Solar Decathlon? And what—are there advantages to having the research incorporated in there?

Mr. MOORER. Well, Madame Chair, if I may——

Chairwoman BIGGERT. Um-hum. Sure.

Mr. MOORER.—respond a little bit to some of the——

Chairwoman BIGGERT. Um-hum.

Mr. MOORER.—comments that have been made so far, I would say that I appreciate the comments from the other witnesses, and we certainly take the students' comments quite seriously. We do a survey at the end of the competition. We certainly consider how we might change and improve the competition, which we are already planning to do for next time. And while some of the suggestions are very good, we really prize the real estate that we are allowed to use for these competitions. As you can imagine, being on the Mall is a fantastic place to be able to conduct this. There are some issues related to trying to do a grid-connected contest there, but this is something that we would certainly be willing to consider.

With respect to this issue of research and development, to some degree, the students are doing that already. I would tell you that a huge benefit out of this competition is the integration that begins to happen between the work that goes on and—things like photovoltaic research and development, and actually how do you integrate that into building design. That has been a missing component, if you will, within some of our own programs at the Department, and this is one way that we see to achieve this integration. And that is an important part of the research and development picture.

Chairwoman BIGGERT. Thank you.

My time is expired.

The gentleman from California, Mr. Honda.

Mr. HONDA. Thank you, Madame Chair.

And I guess Mr. Moorer, you answered a couple of the concerns that Mr. Lyng had brought up as far as his three observations, and I think that they are well thought out and they are probably issues that we should be looking at in the future.

To Mr. Lyng, I just want to let you know that Congressman Udall would have been here, but he is still en route back from Colorado, so I just wanted to make sure you knew that.

Your comments about east-west orientation, it sounded a little like feng shui, and that is just a comment. You don't need to respond.

But I am curious—my sense is that you raised somewhere between $200,000, $300,000, $400,000 to have this project completed and brought over here, and we made some, you know, light remarks about fundraising, but where does your money come from? Did it come from developers or any other sources that made some sense? And then once your projects are completed, what do you do with it? Do you auction it off? Do you sell it to some rich guy that maybe can reimburse you for your costs? Or—it's like 4–H, you know, you get it back. And I also appreciated your comment about being a solar patriot, and I think that is a term we may want to coin, because, you know, being a hydrocarbon man for decades, I am prepared to be a solar patriot.

So if you wouldn't mind answering that question, Mr. Lyng, and then to the rest of the Members—the rest of the witnesses, what is—I heard some barriers mentioned. What are some of the strategies that could be applied to solving the problems so that the university-level students can really pitch in and be worried about coming up with ideas rather than worrying about spending time raising money? Being an elementary school principal, we spent a lot of time raising money selling cookies and jewelry to send kids to science camp. When we invested in our students through the District Office and through, you know, our monies, we found that students were able to concentrate more on their studies than anything else.

So I would appreciate some response, starting with Mr. Lyng.

Mr. LYNG. Yes, thank you, Mr. Honda.

I won't hold it against Congressman Udall for not being here.

Mr. HONDA. I will let him know.

Mr. LYNG. First, to answer your question where did the funding come from, for our project, it came from a number of different sources. About 10 months ago, we entered into a contract with a developer in Colorado for the pre-sale of the home. And that was about ⅓ of our budget. The rest of our funding came from organizations such as the Home Builders Association, who is our single largest cash sponsor, private sponsors, but over half of our funding was in in-kind donations. And it is my feeling that if students had—if everyone had the same project funding level in cash, and teams were asked to purchase the best products on the market, not the ones that they could get donated, then we would see very different homes. And I think that really does drive design more than any of us would like to admit. Fundraising was an enormous obstacle.

What will happen to our house after? It has come back to the CU campus where it will be used for outreach and education for the next eight months. And then it will go to Prospect New Town in Longmont, Colorado, which will be its final location. It will be engaged in a long-term instrumentation and monitoring effort by the National Renewable Energy Lab, and then it will eventually be sold. Someone will actually live in this house. For some people touring the house, they thought that that was quite incredible, but it will be occupied.

Mr. HONDA. And just a quick question for all of you.

I noticed in the photos that the solar panels that are used appeared to be the old style where it is all fixed and it is pretty heavy. Has any thought or any access to some of the new photovoltaic plastics and other kinds of materials—were they available? Or were they even considered, in the area of nano?

Mr. MOORER. Right. No, there were no schools that were using what we would call nanotechnology, if that is where you were going with that particular question, but we did have some schools that were using thin film technology, which there are some companies out there that are manufacturing it. It does look promising, on a cost basis. Right now, there is an interesting situation in the photovoltaic market where there is a shortage of silicon. Basically crystalline silicon is the workhorse of this industry today. And as a result of that, with conventional, typical PV systems, the prices have gone up, supplies are a little tight, and you are seeing some of these other technologies make it into the marketplace, and yes, a few schools did try those technologies.

Chairwoman BIGGERT. Thank you.

The gentleman from Maryland, Mr. Bartlett.

Mr. BARTLETT. Oh, thank you very much.

Let me first ask a follow-up question about the silicon. The thin film, is there any limitation in materials for making the thin film?

Mr. MOORER. No, sir, I don't believe so. We view rather tremendous potential for PV, and there are, of course, more than one type of thin film, but there should not be an issue with that.

Mr. BARTLETT. So the only thing limiting our production there is our manufacturing capacity?

Mr. MOORER. Manufacturing capacity and other barriers that face the entire PV industry. Certainly cost is a big factor, but things like reliability, manufacturability, and efficiency of the system; these are all important factors.

Mr. BARTLETT. The silicon now is down to something less than $5 a watt retail. Where are we with the thin film? Are we competitive?

Mr. MOORER. Yes. Excuse me. They are in the same range at this point. Yes.

Mr. BARTLETT. Yeah. Thin film is not quite so efficient so you need a bigger surface?

Mr. MOORER. Well, when you are talking about something like cadmium, that is not too far—they are not too far apart at this point.

Mr. BARTLETT. Yeah. But the fact that they are not as efficient per square foot really doesn't matter. We have a big globe with lots of room for putting solar. The fact that it is not quite as efficient I don't think is an impediment to going that way.

I am sorry I couldn't be here for your testimony, but I did visit your exhibits on the Mall with considerable interest, because in a former life, I was a homebuilder, and most of the homes I built were passive solar homes. I live in a passive solar home. I have a—really more than one building, several dwellings that are totally off the grid, isolated, and the—beyond the grid in the mountains of West Virginia, so I have a lot of experience with solar.

Your projects were, I think, more important than you and your students realized, if, indeed, the world is facing the phenomenon called "peak oil." Most of the energy used in our society is used in buildings. We are focused more on transportation, because that is where the big threat is with oil, but there is enormous capabilities—potential for reducing energy use in buildings. And what you all are doing with your programs year after year is very helpful in familiarizing the American people. And what you are doing with—is just plain fun, the challenge of making these things with this technology, I am sure, challenges your students. And I saw the large number of people who went there.

I just wanted to thank you for doing this. In the years to come, all of these things that you are now pioneering are going to become increasingly popular and prominent in the homes that we are building, because as we run down the other side of Hubbard's Peak, there is going to be an ever greater and greater demand for having comfortable homes using less and less energy. And you are contributing to that, and I want to thank you very much for doing that.

Chairwoman BIGGERT. The gentleman yields back.

The gentleman from Illinois, Mr. Lipinski, is recognized.

Mr. LIPINSKI. Thank you, Madame Chairman.

I want to echo the comments of my colleagues in thanking you for the work that you have done. It is really critical for us, and I think back to when I was in eighth grade, for eighth grade science fair projects, so it was 26 years ago, I did a solar-powered radio. Back in the '70s, there seemed to be a big emphasis, coming off of, I think, the first big oil crisis. There seemed to big—be a big emphasis then on renewable energy, especially solar energy.

Today, my question really is it is great to see everything that you have done in the Solar Decathlon and what can be done, but where are we really with moving forward with really starting to see these implemented on a large-scale basis? I know that some of this is done to a lesser extent, some of the more simple solar, such as the passive solar homes, are done, but what is the next step? Where do you see this going? Do you see this taking off? And what does it need? What kind of incentives do people need in order to start using more of this? Is it really feasible in terms of the cost to do this, to start putting these—to start seeing more of this in individuals' homes?

So that is a big question, but I sort of want to—that is where I come down to you. You know, it is great to see this. Where are we going? And are we going to see this in the near future?

Whoever wants to start.

Mr. Moorer.

Mr. MOORER. I just might point out that some of the witnesses made reference to the importance of various policy drivers such as tax policy, and I would say certainly, with the recent passage and signing of the *Energy Policy Act of 2005,* that certainly has some important provisions in it to help this industry out, and that is a key piece of the puzzle.

Clearly advancing the research and development is key as well, and we see a lot of potential there to continue driving the cost down. The systems are not in widespread use now for a number of reasons, alluded to earlier, but cost certainly is a huge factor in seeing a broader use of the technology. But that is something that has come down quite dramatically in the last several decades and continues to drop as we continue to work on the technology.

Mr. LIPINSKI. Okay. How much further do we have to go in order to—is there any sense of how many—how long it is going to take? I know for each different—there are so many different aspects of each of these homes, but what do you see being sort of the first widespread usage? Which aspect of these homes?

Mr. SCHIEREN. Well, I would speak to, just briefly, the solar. Let us talk about the solar panels and the use of solar. We are from New York, and specifically Long Island. The Long Island Power Authority, one of our main supporters, offers incentives. In fact, they buy back about—buy down about half the cost. They share about half the cost of an installation. With that incentive, the payback is usually 10 years. So there is a large up-front investment, but the payback is 10 years. And with rising energy prices, many people are interested. So growth rates are rather good. And in fact, in the charter today's—for the—today's hearing, it says, I think PV shipments are so—are increasing about 35 percent a year. So it is growing quite fast. States that offer incentives, utilities that offer incentives are experiencing very high demand. So I think growth is there right now.

Mr. KNOWLES. I would just like to reinforce that point, as an architect in the northeast. Just personally, most New England States, New York included, offer very generous incentives: half price, basically, whether it is a direct grant or a tax incentive to pay for half of the system. But each state has different rules, and this is what I added in my testimony to answer the questions. And I think the Federal Government could either advertise or streamline those rules to make the accessibility to the public much easier. For instance, in New York State, there is a large organization and difficult to penetrate. In Rhode Island, it is actually a small and very generous fund that is available that helped us out. So I think the Federal Government would have a role in sort of merging these programs nationwide in advertising that these are available to the public. And then I think it will take off.

Mr. LIPINSKI. Okay. Anyone else want to——

Mr. SCHUBERT. I would think that, in addition to economic incentives, we need more good examples of how these technologies are integrated that do not require a radical departure from individuals' lifestyles, things that are reliable, transparent to the user, and that their designed from the ground up, not designed in such a way where they are just applied as an afterthought.

Mr. LIPINSKI. It would seem to me that—you had mentioned about people who came and saw these were very interested. When they go home, are they really going to have—where are they going to find out more? Or what—do you really see them taking another step? Where does that take? It seems like these are not things that—they probably look at it and say, "Oh, that is really cool," but that is not practical, because they don't see it anywhere else besides, you know, out in the special project like this.

Mr. SCHUBERT. Well, I think—we stressed conservation above and beyond anything else. And I think what people saw there on the Mall, they got motivated and excited, and the first thing that we would tell them to do is to go back and invest in conservation. And then, once they had done that, then the additional technologies might make sense for them to do. But I think it is through this excitement factor you get them motivated to, you know, pay attention to what they are currently doing, how their existing housing stock can be improved. And there is a wide range of strategies. But—and with a glimpse of what it could be, it helps to, you know, go back and look at what they do have and then kind of bring that along.

Mr. LIPINSKI. Do we have time for Mr. Moorer?

Mr. MOORER. I just wanted to add the fact that in this year's competition, getting to your point, Congressman, we actually had an expo running concurrently with the Decathlon so that, just to your point, if someone came in and got excited about the technologies, we could arm them with information and point them to a place where they could actually talk to manufacturers and installers right there, not too far away from the site of the Decathlon, to take it further, if they were personally interested.

Mr. LIPINSKI. I thank all of you for your work on this.

Chairwoman BIGGERT. Thank you.

I have just a couple of other questions, I—if other Members would like to, also.

Just a couple things. We are talking about solar, and all I can think of is, you know, that you have got the sun coming in, and a lot of you showed how you would be—the windows were set back so that you wouldn't get the hot sun in the summer, but then there are some that used the sun for—the winter sun. All I can think of is my fabrics, and you know—if you don't have the E-glass or whatever, but it also, you know, warms the house, but it is—how do you deal with that? Just have a very modern house with furniture that doesn't fade in the—either the summer or the winter? I mean, that—maybe that is a woman's thing, but it is a—or a decorator.

Nobody wants to tackle that? Do we have——

Mr. KNOWLES. No, it is—I will take a stab.

Chairwoman BIGGERT. Okay.

Mr. KNOWLES. We never—we intended to actually have some curtains in front of our large face—large south-facing glass wall. That glass wall actually completely disappeared. It pivoted open so the whole inside and outside were connected, but we never, you know—with time, never got to that sort of—that very simple, talk about conservation strategy, just robust curtains on the south windows that, you know, cuts the energy coming into the—very simple means.

Chairwoman BIGGERT. But that really isn't what I wanted to ask, but just talking about the transportation, it seemed like that was a real project, and the houses really had to be built to fit the size of a transport, or, you know, even though it might be in pieces, it still is limiting for this contest. And what was it? Eight hundred square feet, about? Was that the maximum?

How, then, would this—the type of houses that you built be used as a model for—you know, for a home that really is—would be a normal-sized, comparable to the average single family home? Would there be any changes from what you have designed?

Mr. LYNG. That is—that question is, I think, very on point with the 800-square foot limitation. I think that is something that we all battled with. And certainly transporting the homes is no small task, getting them from Spain or Puerto Rico. Who—they are not here, but they could tell you what a difficulty that was. I think many of the members of the public that toured the homes could envision that they would be bigger, that you could add another bedroom or perhaps a detached garage. The NAHB, according to the NAHB, the average size of a new home purchase in the United States is now 2,200 square feet, so we are well under that with 800 square feet. For some families, that could be a problem. But it was my experience that members of the public saw the homes as a model and saw how it—they could be expanded in size.

Chairwoman BIGGERT. After looking at a lot of the houses, I would say that the majority of them are very scaleable and that they were dealt with in a modular way so that they could be expanded. And when you think about the energy production components on the buildings themselves and you look at the base energy loads of the building, they are not that far off from the energy loads that you would see in a conventional house. So I think the—you would still have the same size, maybe a little bit larger in terms of the energy collection components, so it is just that there is some flexibility in terms of how the spaces could be added to.

Mr. Moorer, what we face in this committee a lot is how we get from the basic science to the application and then to the commercialization of what is coming out of our national labs or, you know, the basic research. How would you compare the Decathlon's benefits to technology transfer versus the other means the Department uses to push the energy technologies into the mainstream market?

Mr. MOORER. Well, I think it depends on what part of the spectrum we are talking about, because you articulated it very well: it runs from basic research all of the way to a commercial product. I like to think of it as from an idea all of the way to a product in the marketplace, and I think you apply different tools all along the way. And I think this particular competition is a good mechanism to use in this part of the spectrum, if you will. Generally speaking, the students, for the most part, the schools are using what I will call off-the-shelf technology, but they do employ some innovative technologies, and I would say that, in that context, they are doing a good job of showing how one might be able to integrate these technologies. And tech transfer, you know, I think you can argue about what do we mean when we say technology transfer. We have major cost-shared efforts with industry where one might say, "Well, that is a form of technology transfer," but that is much more related to research, pure research and development, where here it is more about outreach, if you will, and some of the goals that I alluded to, trying to introduce these technologies to people that are at the very beginning of their careers and making choices. And so I think it is very effective in the space that we use it in.

Chairwoman BIGGERT. Thank you. Thank you.

Mr. Honda, do you have any——

Mr. HONDA. Yes.

Chairwoman BIGGERT. You are recognized. The——

Mr. HONDA. Thank you, Madame Chair.

Chairwoman BIGGERT.—gentleman is recognized.

Mr. HONDA. Thank you, Madame Chair.

And I guess that that is what Mr. Lyng was sort of eluding to that if they had cash versus in-kind, you know, they may be able to apply more of the up-front technologies that may exist out there, or may even, you know, just transfer some of that technology to the housing. And maybe the Department of Energy can look at a cash pot that the students can apply for rather than going for, you know, in-kind kinds of help.

My question is kind of a follow-up to the Chairperson's question. Sections 917 of the *Energy Policy Act of 2005,* there is a provision that originated in this committee to establish a number of advanced energy efficiency transfer centers around the country to accomplish much of what the decathlon does in Washington and then more. Are you familiar with this bill? And if you are, what problems or opportunities do you see in implementing this provision?

Mr. MOORER. I am sorry, sir. I am not familiar with that particular provision.

Mr. HONDA. Okay.

Mr. MOORER. I will say this. It may not be a surprise that my particular office has a rather large share of the provisions that were provided in the *Energy Policy Act,* and we, right now, are in the business of analyzing all of the provisions that have been made available to us and, in fact, are making some decisions about how to go forward on a number of those.

Mr. HONDA. There may be a response. You are right there.

Mr. MOORER. Yes, it is one of the provisions that is subject to appropriations. We do have a number of provisions in this new law and of course the law came along after we had submitted our 2006 budget request.

Mr. HONDA. Right.

Mr. MOORER.—request, so the—it is not there now, and like I said, we are looking——

Mr. HONDA. Right.

Mr. MOORER.—at all of those provisions to decide what we might ask for in subsequent budget requests.

Mr. HONDA. And then—so having said that, it is gearing up for the appropriations, because it has been authorized, I imagine, to the universities and to the proponents and students. You may want to dedicate, next year, of working towards making sure that there is an appropriation to the tech transfer and then see how some of these appropriations can be allocated towards the decathlon and its use, because it is highlighting this whole arena of alternative energy uses. And I suspect that a lot of your technology and a lot of your ideas can be used by groups like FEMA where there are over 173,000 folks who are displaced from their homes that can use, not only temporary housing, but modular housing that you may be able to come up with that will take advantage of solar power and take them—make them part of the grid rather than just be dependent upon the grid.

So that would be a recommendation and suggestion you may want to look at. You know, it is just me, you know, talking, but you know, there may be some cash there.

Chairwoman BIGGERT. Mr. Lyng, in his testimony, talked about—or a quote from Richard Nixon in 1973, which I think is very apropos, that says, "Let us set as our national goal, in the spirit of Apollo, with the determination of the Manhattan Project, that by the end of this decade we will have developed the potential to meet our own energy needs without depending upon any foreign energy source." Well, he didn't—we haven't made it with that decade, but I think that this committee is very committed to really reduce dramatically our dependence on foreign energy sources and are working on all different types. You know, we have talked about the hydrogen car, nuclear energy, solar, hydro, and I think that we appreciate how you are contributing to being able to reduce our dependency and appreciate all of you for participating in this.

I would love to have all of the graduate students that are here stand up so we can take a good look at you, if you would, please. And undergraduates. Oh, I didn't mean to say just graduate students. I am sorry. All of the—so we congratulate all of you for what you have accomplished, and we—I wanted to see your faces, because I know we will be probably seeing more of you in the years that come as you develop the energy sources that we need. And thank you for all that you have done.

And I would like to thank the panelists for testifying before the Subcommittee today.

If there is no objection, the record will remain open for additional statements from the Members and for answers to any follow-up questions the Subcommittee may ask the panelists.

Without objection, so ordered.

And this hearing is now adjourned.

[Whereupon, at 3:20 p.m., the Subcommittee was adjourned.]

Appendix 1:

ANSWERS TO POST-HEARING QUESTIONS

ANSWERS TO POST-HEARING QUESTIONS

Responses by Richard F. Moorer, Deputy Assistant Secretary for Technology Development, Office of Energy Efficiency and Renewable Energy, U.S. Department of Energy

Questions submitted by Chairman Judy Biggert

Q1. You mention in your testimony that the American Institute of Architects (AIA) is a sponsor of the Decathlon. What commitment, if any, has the AIA given the Department of Energy (DOE) to educate AIA members on the issues associated with the utilization of the designs employed in the structures, the technologies used and the conservation measures employed by the students?

A1. The AIA, through its sponsorship of the Solar Decathlon, has helped educate its members on solar and energy efficiency issues. The AIA uses its Committee on the Environment, whose purpose is to advance and disseminate environmental knowledge and values, to advocate the best design practices for solar and energy efficiency building integration. The Association was a contributor to the Decathlon's outreach to industry professionals such as architects, engineers, builders and other trades who were invited to come down to the Solar Decathlon village and learn about cutting edge building and solar technologies. The AIA also gave its members Solar Decathlon coverage in its publications leading up to and during the event.

Q2. What outreach, outside of the Decathlon, has DOE undertaken to educate the builder-developer community on the utilization of the technologies and conservation measures demonstrated at the Decathlon? What has been the response from the community? Do you have indications that you are making real inroads into this community, especially with respect to reducing perceived risks of using new technology, or are you mainly communicating with those whose philosophies agree with the DOE?

A2. The Department is working with the Nation's home builders to implement renewable and conservation technologies under the Department's Zero Energy Home effort. The builder-developer community has been interested in adopting and installing several technologies utilized in the Solar Decathlon, such as photovoltaics, energy recovery ventilation, and solar water heating technologies. The Department's recent outreach efforts have improved communication with the builder-developer community and resulted in an increase in their understanding and acceptance of solar building technologies. In fact, in 2004, home builders utilized renewable and conservation technologies on more than 300 zero energy homes across the Nation, as well as on thousands of conventionally-powered homes, across the Nation.

Q3. You say in your testimony that you are attempting to use the Decathlon to communicate the benefits of these technologies to a wider audience. What other audiences are you attempting to reach and how are you doing it?

A3. The Solar Decathlon appeals to a wide range of audiences, including builders, students, architects, and the general public. This year, more than 120,000 people visited the Solar Decathlon during its ten days on the National Mall in Washington.

The outreach activities carried out by the Department of Energy and its private sector Solar Decathlon partners succeeded in attracting widespread interest in the competition. The 2005 Decathlon offered visitors a variety of ways to learn about energy efficiency and renewable energy technologies, including publications, exhibits, workshops and tours. In addition, the competition included specially designed programs for builders and students.

Finally, the extensive media coverage of the 2005 Solar Decathlon in newspapers, magazines, television and on the Web has helped inform people about energy efficiency and renewable energy technologies that are available for use in residential housing.

Q4. What is solar energy's relative piece of the energy research pie? How does DOE form long-term plans to direct investments in this area?

A4. The Department of Energy is spending a combined total of approximately $1.5 billion in FY 2006 on applied energy research and development (R&D) programs in the Office of Energy Efficiency and Renewable Energy, the Office of Electricity, the Office of Nuclear Energy, and the Office of Fossil Energy. (This estimate was calculated by combining program-level funding data and includes deployment activities sponsored by each program classified as an R&D program. It excludes program direction.) Of that amount, $83.1 million in FY 2006 is for Solar Energy Technologies.

In FY 2007, we propose a substantial increase in spending on Solar Energy Technologies to $148 million.

The Solar Energy Technologies Program's Multi-Year Program Plan guides long-term investments in solar research. The plan was developed through a collaborative effort of many experts in the solar energy field and has been reviewed by industry. A public version of the 2007–2011 plan is scheduled for release in 2006.

In general, the Solar Program develops its long-term investments by: 1) identifying key market segments for solar technologies; 2) determining market and technical barriers; 3) developing pathways to overcome or reduce such barriers; and 4) defining technical targets to track program progress.

Q5. Section 917 of the Energy Policy Act of 2005 *is a provision that originated in this committee to establish a number of Advanced Energy Efficiency Transfer Centers around the country to accomplish much of what the Decathlon does in Washington and more. Are you familiar with this provision the bill? If so, what problems or opportunities do you see in implementing this provision? Do you know if DOE is planning to request funding for this program in the President's Budget Request for FY 2007?*

A5. I am familiar with Section 917 of the *Energy Policy Act of 2005* (EPAct). The Department stands ready to establish a network of Advanced Energy Efficiency Transfer Centers in the event that funds are appropriated by Congress for such a purpose.

The FY 2007 budget is under development. We are currently considering the issues and opportunities associated with promoting greater use of energy efficiency technologies by consumers.

ANSWERS TO POST-HEARING QUESTIONS

Responses by Robert P. Schubert, Professor and Team Faculty Coordinator, College of Architecture and Urban Studies, Virginia Polytechnic Institute

Questions submitted by Representative Michael M. Honda

Q1. Do the ten criteria used to judge the Decathlon seem to be reasonable? Do you have any suggested modifications to the criteria to make the competition a more "real-world" experience?

A1. For the most part, the ten criteria provide a reasonable metric for the evaluation of a complex set of issues related to the subjective/objective performance of the Solar Decathlon projects. While we have seen the criteria of evaluation evolve from the previous competition in 2002, we feel there is one area that still needs significant improvement, contest element nine, "Energy Balance." To be more representative of a "real-world" situation, a grid-intertie system would be strongly recommended. Upon completion of the 2002 Solar Decathlon competition, this was suggested to the organizers as a more effective means of representing how a building would operate within the context of a neighborhood. As it stands, the houses are being evaluated as a series of autonomous buildings independent of any benefits of being interconnected to a utility network. The current energy balance evaluation of the houses is more representative of an isolated beach house or mountain cabin where there would be no other means of supplying power. The majority of U.S. population is located within reach of a local utility network allowing the benefits of interconnection for a grid-intertie system to be realized for a renewable energy system. This would allow costly batteries to be either eliminated or significantly reduced. This would also allow the Solar Decathlon projects to operate thorough any type of weather condition experienced during the event without necessitating shutting the houses down as was experienced during this last competition. The Virginia Tech team felt this sent the wrong message to the public while the houses were operating during this long period of inclement weather. A better approach would be to interconnect each house to an on-site local utility network where each house would be independently metered to measure the amount of energy either supplied or withdrawn from the grid. We recognize that while providing a simple metric of performance for energy balance, it would necessitate more on-site preparation and associated costs for DOE. We feel strongly that whatever the cost, it would be worth sending the correct message to the public that renewable energy systems are reliable and that reasonable contingencies can be taken during inclement weather.

If for some reason a Solar Decathlon grid-intertie system cannot be reasonably implemented on the National Mall, and battery storage seems to be the only solution, a penalty should be applied for those competitors who use more energy than they generate during the duration of the competition.

Q2. Based on what you know about the Department of Energy's (DOE) energy efficiency and renewable energy programs, what changes should DOE make to its programs to provide the knowledge and support you need to be an effective advocate for the technologies and design philosophies you have used?

A2.

- Increase visibility and awareness of renewable energy systems and conservation strategies above and beyond what is currently being done.
- Special linkages should be made with university programs—architecture, industrial design, landscape architecture, mechanical and electrical engineering—to offer special summer courses for high school students interested in studying at the university. The course content should include energy issues within the context of solar energy.
- Increase public awareness by creating a National Awards Program for solar design.
- Provide design assistance through regional centers that promote the use of solar energy (similar to agricultural extension programs) working in conjunction with state energy offices.
- Promote a residential based LEED assessment (LEED–H) currently under development by the U.S. Green Building Council.
- Develop continuing education programs working with professional organizations such as the American Institute for Architects.

Q3. What are the biggest barriers to the utilization of the design philosophies, energy production technologies and conservation techniques facing the architectural and builder-developer communities? How do you overcome the perception of risk in utilizing new techniques and technologies?

A3.

- One challenge is the negative public image of solar technology as something that is ugly, unreliable and costly. The integration of the technology within new and existing construction as achieved by talented designers should be promoted.
- Large scale builders and the building industry in general are conservative and unwilling to change a model that has been financially successful. The building industry needs to anticipate better changing energy markets and consumer preference for efficiency. A program designed to link large manufacturers of housing and research universities involved in solar energy research should be explored.
- Issues of energy efficiency without compromise to quality of life should be promoted in concert with solar energy. The Virginia Tech house established a very compact, efficient plan that offered a psychologically expansive space.
- Risk can be overcome by presenting to the public instances of solar technologies that does not compromise expected life styles. The Solar Decathlon holds this promise. Perhaps a longer term exposition should be established at another site highlighting the best houses of the competition and allowing for a more rigorous testing and evaluation period.

Q4. To the extent that you are familiar with building codes and standards around the country, generally how much of a barrier do you believe current codes and standards are on the development of the concepts and technologies you have used in your houses?

A4. Largely, we do not see building codes and standards as a major impediment to the deployment of renewable energy sources. However, codes and standards could be used to encourage and promote more widespread use of these technologies. Public apprehension, weak precedent, and lack of demand are the greater barriers.

- The most prominent model building energy standards (International Energy Conservation Code (IECC) and the Model Energy Code (MEC)) that are the basis for most local and State codes give little attention to solar technologies, especially how solar and energy efficiency can work together.
- ENERGY STAR and Green Building (e.g., LEED) certification protocols go beyond these basic codes, as do several custom State and local codes such as those in California (revised Title 24), Florida, Oregon, and Washington, and in Davis (CA), Boulder (CO), and Austin (TX). Still, even these innovative codes and standards need to integrate better efficiency standards and solar technologies for maximum cost-effectiveness.

Q5. What are your perspectives on the future of solar energy research? Is the Federal Government providing sufficient support to feed the research workforce? If not, what are budding energy researchers doing upon graduation?

A5. The Federal Government needs to increase its support for solar energy research and application. Further incentives need to be established to break the inertia of the status quo. Installing solar energy equipment is seen as a financial and technical risk. Support in the form of tax incentives, credits, low interest loans, and utility credits beyond those provided in the *2005 Energy Policy Act* are necessary to mitigate public apprehension.

ANSWERS TO POST-HEARING QUESTIONS

Responses by Jeffrey R. Lyng, Graduate Student and Team Project Manager, Civil, Environmental, and Architectural Engineering, University of Colorado

Questions submitted by Representative Michael M. Honda

Q1. Do the ten criteria used to judge the Decathlon seem to be reasonable? Do you have any suggested modifications to the criteria to make the competition a more "real-world" experience?

A1. Most of the Solar Decathlon (SD) contests are relevant and necessary to flush out superior elements of design. However, one important reality that the ten contests do no address is life-cycle cost. An accurate accounting of the construction, operation and maintenance costs associated with each project would elucidate the "real-world" potential of each team's design. I firmly advocate for the creation of a "Life-Cycle Cost" contest in which teams compete for the overall least cost. The economic viability of Zero Energy Homes (ZEH) is a question that remains central to the public's interest and one which the SD must seek to answer.

Q2. Based on what you know about the Department of Energy's (DOE) energy efficiency and renewable energy programs, what changes should DOE make to its programs to provide the knowledge and support you need to be an effective advocate for the technologies and design philosophies you have used?

A2. The DOE Building America (BA) program is an invaluable resource which has not been leveraged by the SD competition. A partnership between BA teams and local SD teams holds great potential toward ZEH designs that appeal to the general public. The BA program should serve as a springboard of basic building science knowledge from which SD teams incorporate their own innovation and ingenuity to ZEH design. Working in this manner, SD teams will benefit from the knowledge and experience of BA professionals, while BA teams stand to benefit from the creativity and fresh perspective of working with SD teams.

Q3. What are the biggest barriers to the utilization of the design philosophies, energy production technologies and conservation techniques facing the architectural and builder-developer communities? How do you overcome the perception of risk in utilizing new techniques and technologies?

A3. It has been my experience from interaction with custom, semi-custom and production builders in Colorado that the greatest perceived risk associated with energy efficiency and renewable energy technologies is higher capital costs. Internalizing the external environmental costs of standard and alternative building methods is the only way to truly evaluate their viability. Simple payback period affords neither a complete nor truly objective means for comparison, yet it remains a metric commonly referenced. A "Life-Cycle Contest" in the SD competition is a real and tangible step toward the true economic comparison of standard and alternative building practices.

Q4. To the extent that you are familiar with building codes and standards around the country, generally how much of a barrier do you believe current codes and standards are to the deployment of the concepts and technologies you have used in your houses?

A4. The only product used in the CU Bio-S(h)IP which required testing and verification were the bio-base structural insulated panels, or Bio-SIPs. For example, the entire solar electric array used UL-listed equipment and was installed as per the National Electric Code (NEC). The Colorado Division of Housing deemed the CU Bio-S(h)IP a site-built manufactured home, thereby obligating the CU team to a self-inspection process.

Many of the products used in the CU SD entry are common building materials, therefore current building codes and standards pose relatively modest challenges to the widespread deployment of the Bio-S(h)IP concept. The Bio-S(h)IP will be permanently located in Longmont, CO were it currently meets local building codes and standards.

Q5. What are your perspectives on the future of solar energy research? Is the Federal Government providing sufficient support to feed the research workforce? If not, what are budding energy researchers doing upon graduation?

A5. Recent budget cuts to the National Renewable Energy Laboratory (NREL) in Golden, CO leave me with a bleak perspective on the future of solar energy research. This example is strong evidence that the Federal Government is not doing enough to support a renewable energy research workforce.

Students of renewable energy are drawn by an insatiable desire to affect positive environmental change. They are not attracted to the field by research assistantships or other incentives. In fact, few such opportunities exist. Many of my colleagues are unable to find competitive employment in the renewable energy field and must compromise with more traditional jobs within architecture and engineering. A discouragingly few high quality professional jobs exist in the renewable energy today in the U.S.

ANSWERS TO POST-HEARING QUESTIONS

Responses by Jonathan R. Knowles, Professor and Team Faculty Advisor, Department of Architecture, Rhode Island School of Design

Questions submitted by Representative Michael M. Honda

Q1. Do the ten criteria used to judge the Decathlon seem to be reasonable? Do you have any suggested modifications to the criteria to make the competition a more "real-world" experience?

A1. The majority of contests make sense but a couple of criticisms come to mind concerning the electric car and the timing of the event. First, the "Getting Around" contest is incompatible with the "Energy Balance" contest. To run the car sacrifices the performance of the house, as power needs to be diverted from one task to the other. This is especially detrimental to the teams that are trying to be efficient and frugal by having the least amount of photovoltaic panels and batteries. The teams that won the electric car contest lost the energy balance contest yet they had the most photovoltaic panels. The electric car contest demands a large solar array not necessary for the operation of an 800 square foot house. We support the idea of hooking up the houses to a temporary "grid" to measure any access energy available once the other competition requirements have been satisfied.

Second, the timing of the event has two flaws: none of the decathlon submissions fit into the academic calendar and there was not enough time to test the house once assembled in Washington, D.C. Each submittal was due in the middle of the semester or in the middle of the summer, which made it difficult to plan the course work necessary to complete the requirements. The submittals should revolve around the academic calendar and not vice versa. Also, the contest should be held before school starts—the last week of August and the first weeks in September. Students need to keep up with their course work during and after the competition but a mid-semester timeframe does not help. Finally, an extra week should be added to the competition to allow the "bugs" to be worked out before the houses are open to the public. This would have the added benefit of allowing teams to tour the houses and to learn about each other's work.

Though not specifically asked, we would like to suggest that the Department of Energy raise the caliber of judges and the forums for the juries. In general, the judges were neither interesting nor enlightened and the award presentations were too brief to be meaningful. As our students are designing housing using state-of-the-art technologies, the best in the field should be available to evaluate (and have the time) to discuss the projects in detail. Better juries will elevate the debate and will attract more participation.

Q2. Based on what you know about the Department of Energy's (DOE) energy efficiency and renewable energy programs, what changes should DOE make to its programs to provide the knowledge and support you need to be an effective advocate for the technologies and design philosophies you have used?

A2. Specifically, the DOE could do a better job advertising the event, both to the general public and to prospective competitors and they need to follow up on the tremendous efforts given by the students. There are three simple solutions, all of which require more financial backing by the DOE: promote the teams that have competed in the past by inviting them on a nationwide lecture circuit, publish the competition in book form for national release, and embed the competition within inter-school conferences, such as the Association of Collegiate Schools of Architecture (ACSA). A small group of the 2005 Decathlon teams are currently working on this last point within the academic community but the DOE should be spearheading this effort.

Q3. What are the biggest barriers to the utilization of the design philosophies, energy production technologies and conservation techniques facing the architectural and builder-developer communities? How do you overcome the perception of risk in utilizing new techniques and technologies?

A3. The biggest barriers are cultural inertia and education. We did not invent the technologies that we used with RISD Solar; our innovation was their combination and integration. Everything we used is available in the marketplace. However, the United States does not promote solar technologies, which are currently expensive relative to fossil fuels. As long as the United States subsidizes the use of fossil fuels, the solar industry will not be a viable option for the architect or client. If this scenario were reversed, there would be a boom in the market that would reduce these costs and begin to move the Nation towards energy independence. All is needed is a little push from the Federal Government. Finally, good design eliminates risk. Most of the housing industry does not employ architects or engineers nor adheres to strict energy standards. If these practices were national requirements as practiced in Europe, risk would be averted because professionals would back up their systems. Good sustainable design requires more analysis, a design process that includes a knowledgeable team and project commissioning. The nature of the discipline is to be more comprehensive and therefore more reliable than the standard mode of practice. In designing our house, we were careful to make our systems as low-tech as possible. The more sophisticated our design, the less complicated was its operation, which is a sign of good engineering.

Q4. To the extent that you are familiar with building codes and standards around the country, generally how much of a barrier do you believe current codes and standards are to the deployment of the concepts and technologies you have used in your houses?

A4. Speaking as an Architect from the Northeast, I have not encountered any barriers when dealing with building codes or standards. I have encountered barriers within the organizations charged with promoting and funding solar energy because of Byzantine application processes. As I stated in my testimony to Congress, most New England States offer very generous incentives, through direct grants or tax incentives to offset the cost of photovoltaic systems. But each State has different rules. The Federal Government, through the DOE, could advertise these rules to make accessibility to design professionals easier. The Federal Government could also adopt these same programs into a nationwide PV strategy.

Q5. What are your perspectives on the future of solar energy research? Is the Federal Government providing sufficient support to feed the research workforce? If not, where are budding energy researchers doing upon graduation?

A5. The 2005 Solar Decathlon project allowed over 100 students at the Rhode Island School of Design and Brown University to understand the principles of sustainable design and the benefits of integrated building systems. The students will take this expertise with them as they enter the profession and begin to influence clients and contractors. For this reason, RISD is planning to compete again in 2009. The 2005 Solar Decathlon has also inspired our team to begin planning a not-for-profit research institute to coordinate all work relating to the development of a sustainable environment on campus, within Rhode Island and beyond. The Federal Government should promote this type of institutional investment wherever and whenever possible. Our institute will seek funding for projects in urban design, material science, building system integration, emergency relief shelters, and renewable energy. The idea is to cross breed these topics to create friction and inspire innovation. Eventually, it is our hope to be self-sufficient by developing and selling intellectual property, whether ideas or products. Early governmental support would make all the difference to capture the momentum already established on campus.

ANSWERS TO POST-HEARING QUESTIONS

Responses by David G. Schieren, Graduate Student and Energy Team Leader, Energy Management, New York Institute of Technology

Questions submitted by Representative Michael M. Honda

Q1. Do the ten criteria used to judge the Decathlon seem to be reasonable? Do you have any suggested modifications to the criteria to make the competition a more "real-world" experience?

A1. In general, the ten contests used to judge the Decathlon seem reasonable. Should there be modifications to make the competition a more "real-world" experience? First, the purpose of the competition should be defined. The purpose largely seems to be to drive system wide energy benefits by getting the public to use energy efficiency and sustainable design strategies and clean energy generation. The student built homes should epitomize such qualities and serve as benchmarks. The spinoffs of this competition are for people to "feel and touch" the technologies and strategies and then adopt them. Additionally, participants embrace what they learned and implement energy efficiency and renewable energy throughout their careers.

The Solar Decathlon is, in this sense, a very practical demonstration competition in that the spinoffs can be realized in the near-term. The way the Decathlon is currently judged through the 10 contests reflects this. They are practical contests and provide a "real-world" experience.

However, the NYIT team feels that there is perhaps another important component to the competition that is not accounted for adequately. The 10 contests used to judge the competition do not directly include a way to reward innovative energy systems. The high profile of this competition provides for an opportunity to engage in slightly riskier research and development that could have a very positive impact in the medium to long-term. For example, NYIT's home featured a solar-hydrogen energy system, the only one of its kind in the competition. Power from the photovoltaics is first sent to the house to cover the typical electrical loads. Surplus solar energy is then used to generate hydrogen gas, which is stored in tanks. When there is no sunlight, the fuel cell converts the hydrogen gas into electricity to supply the house loads. To the best of our knowledge, this is the first time a solar-hydrogen system has been integrated and demonstrated in a functioning house. NYIT knew that it would be at a competitive disadvantage relative other teams that relied on the traditional battery based energy storage system, because the current efficiency of the hydrogen system is lower.

With significant research and development, the hydrogen home will one day be superior to a solar home that uses batteries for energy storage. Hydrogen gas is a versatile fuel that can be used throughout a home to cook food, heat water, generate electricity and even power efficient fuel cell vehicles.

The Solar Decathlon gave us the platform to pursue this important technology. Partners were excited to work with us because it was such a high profile competition, thus providing the right type of venue to conduct technology application research. These experiences have contributed to our belief that innovation in energy systems design should be rewarded in this competition.

Q2. Based on what you know about the Department of Energy's (DOE) energy efficiency and renewable energy programs, what changes should DOE make to its programs to provide the knowledge and support you need to be an effective advocate for the technologies and design philosophies you have used?

A2. The Department of Energy's (DOE) energy efficiency and renewable energy (EERE) programs engage in very important work that does assist us in our efforts to be effective advocates for the technologies and design philosophies we used in the Solar Decathlon. It is apparent that the purpose of the EERE programs is to advance clean and renewable energy technologies directly through R&D and through education, materials, outreach and various other methods. The NYIT team is reluctant to pass judgment about the utility of the current programs without more complete information to conduct a proper cost/benefit analysis of the existing programs, and the alternative opportunities to allocate resources.

What can be said is that we have directly benefited from the EERE programs.

Solar Decathlon, Student Projects, and Demonstrations

First, the NYIT team has benefited enormously from participating in the Solar Decathlon, a DOE/NREL competition. Certainly just the opportunity to have first hand experience building energy efficient solar homes helped us learn a significant amount. Furthermore, the Solar Decathlon gave us the opportunity to interact with the public, government officials, industry and academia on clean energy, significant in refining our knowledge and cultivating our advocacy skills. There were also direct benefits from working with NREL.

Therefore, we support continued and increased support of the Solar Decathlon. Additionally, NYIT supports the expansion of programs aimed at the application of new strategies and technologies, and we find student projects to be particularly effective. At our school, the Decathlon impacted over 50 students and faculty, in addition to countless friends, family partners and supporters. The students will grow to become future leaders in the building and energy fields. The multiplier effect causes affiliated people to consider energy efficiency and clean energy generation. Publicity brings even wider attention. We would support increased efforts to get students and academic programs involved. We would support increased investment in demonstration projects where the technologies that EERE funds are used. We would also support the EERE seeking feedback from students and the people who design and install the technologies.

Clean Energy Products

A number of companies that we have worked with have been or currently are involved with EERE research programs. Here we have benefited from improved products

Information

Furthermore, we have benefited from the abundant information and educational materials made available from the energy efficiency and renewable energy programs. The team has and continues to acquire vital information and knowledge through the vast materials available on the website.

The DOE's EERE website is a very valuable tool for communicating the results and information gained from the various programs and we support the continued development of this resource. Brochures, reports and other materials made available on the site are also very valuable. This will help us become better advocates.

Hydrogen

All decision-makers are faced with a scarcity of resources, and we respect that the DOE must make rational and difficult budget choices based on cost/benefit analyses and a variety of other factors.

EERE programs span a diverse range of technologies and this seems a smart way to both encourage growth and mitigate risk.

Because the NYIT project involved a Solar-Hydrogen system, we are particularly interested in and have specific knowledge of the Hydrogen, Fuel Cells and Infrastructure Technologies Program. This program follows the general EERE lead in that it invests in a wide array of technologies, basic research and outreach.

A suggestion might be to concentrate funding on renewable and clean ways to generate hydrogen. There is currently an effort to focus on reforming fossil fuels for hydrogen gas. We respect the vital role that fossil fuels have played in economic expansion and improved standards of living. We also respect that fossil fuels will continue to play a major role in our energy system. Even fossil fuel reforming systems are important in the development of the hydrogen economy. Since reformation is currently a less expensive method to generate hydrogen, it is more feasible near-term way to increase usage of fuel cell technology both in the stationary and transportation sectors.

However, we are more interested in the long-term. Consider a future of true energy independence, free of pollution and greenhouse gases. This path involves removing fossil fuels from the equation and we would implore the EERE programs to concentrate efforts on this.

The first Portfolio Priority listed in the Mission section of the EERE website states: PRIORITY 1: Dramatically Reduce or Even End Dependence on Foreign Oil. Our country can achieve this, and we will continue to look to EERE programs to help lead the way.

Q3. What are the biggest barriers to the utilization of the design philosophies, energy production technologies and conservation techniques facing the architectural and builder-developer communities? How do you overcome the perception of risk in utilizing new techniques and technologies?

A3. There are several barriers to the utilization of efficient design philosophies, clean energy production technologies and conservation techniques facing the architectural and builder-developer communities.

One major barrier is that trades people (i.e., engineering, plumbing, concrete/masonry) lack the training to implement energy efficient technologies and strategies.

The experienced people in the field receive the majority of current business and training programs should be promoted to them. There are certainly training programs available, but often times it is costly and the benefits are not adequately marketed. We are familiar with people who take "sabbaticals" from their professions and invest a significant sum to gain the requisite training to become Energy Star qualified builders. This requires substantial risk and is preventing others from this important pursuit.

Additionally, clean energy technologies often require collaboration between multiple trades. Consider a solar hot water production and radiant heating system that requires the coordination of solar specialists, plumbers, masonry, etc. to design and install. This example highlights the need to develop collaboration training.

Continuing with this logic, it would make sense to widen and deepen trade association outreach. Trade associations are powerful advocates and could have broad efficacy in this regard.

The argument in support of training holds not just for experience professionals, but also for students and new entrants. The point is that training the people who do the actual design and installation is an integral piece of the puzzle and should be addressed. Trained and educated professionals are more likely to utilize new technologies.

There are many ways to overcome the perception of risk in utilizing new techniques and technologies. One way is to invest in high profile demonstration projects (e.g. Solar Decathlon) so that people can become familiar with the technology. Our experience is that many people are now interested in the systems used in the NYIT Solar Decathlon house, even though it is still considered new and somewhat risky. Demonstration projects should be further supported and expanded.

Q4. To the extent that you are familiar with building codes and standards around the country, generally how much of a barrier do you believe current codes and standards are to the deployment of the concepts and technologies you have used in your houses?

A4. There are many codes and standards that govern the siting and usage of hydrogen gas. The NYIT team went to great lengths to ensure that our hydrogen house was up to code and could be sited on the National Mall. In one sense, it is very good to undergo a rigorous safety review. However, it is well known that there must be further convergence of hydrogen codes and standards. This is already a major priority for the DOE, DOT, other governmental agencies and private organizations.

Beyond convergence of codes and standards, we would like to see a regulatory approach the puts hydrogen on a level playing field with other fuels, such as gasoline, natural gas and propane. These are different fuels and can require different handling. Nevertheless, efforts should be made to level the playing field.

This is one of the largest impediments to the growth of the hydrogen economy. We think it is a critical issue to address and therefore support dedicating significant resources towards the effort.

Q5. What are your perspectives on the future of solar energy research? Is the Federal Government providing sufficient support to feed the research workforce? If not, where are budding energy researchers doing upon graduation?

A5. We think that the Federal Government should provide increased support for solar energy research. It is unfortunate that the U.S. lost its dominance in solar energy technology to other countries. Solar energy has truly great potential, and can have a dramatic and positive impact on the U.S. economy, national security and environment. It seems we are under investing in a technology that is so vital. According to the DOE's EERE website, spending on photovoltaic research in FY 2004 was approximately $75 million. We would like to see a greater research investment so that the U.S. can take a role in driving the next generation of change in photovoltaic technology.

Appendix 2:

Additional Material for the Record

STATEMENT OF THE UNIVERSITY OF MARYLAND 2005 SOLAR DECATHLON TEAM

To: Chairman Biggert and the House Subcommittee on Energy

From: The University of Maryland 2005 Solar Decathlon Team

Date: November 2, 2005

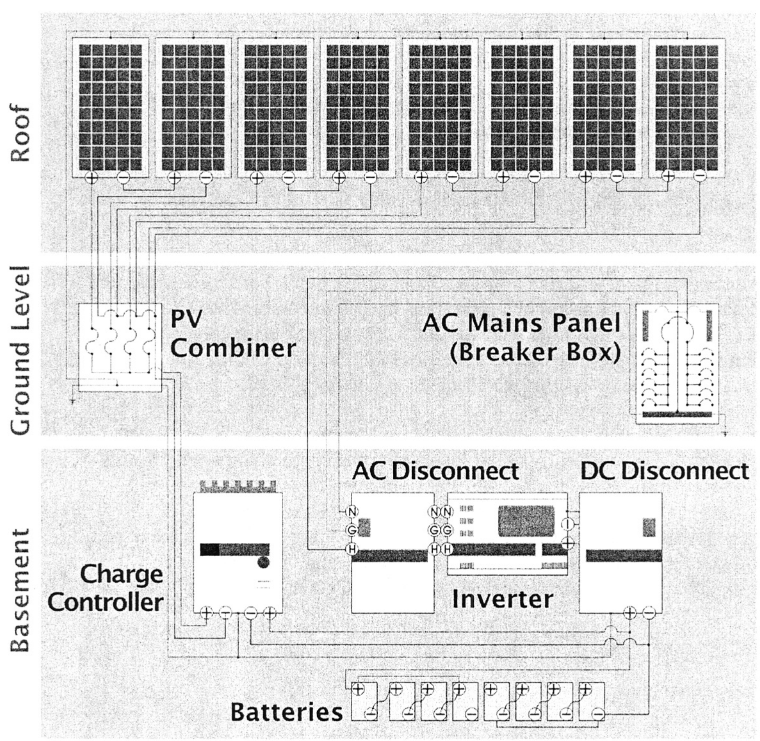
About Our House

The 2005 University Maryland Solar Decathlon Team is a multidisciplinary team of undergraduate and graduate students in the A. James Clark School of Engineering, the School of Architecture, Planning and Preservation, and various other University schools. Our team is cumulatively 100 students. In the 2005 competition, we received 8th place over all, but more importantly we received the BP Solar People's Choice Award. We were voted the best house by visitors who came to the National Mall.

Our home meets all Maryland State and Montgomery County housing code. It was designed this way so the beneficiary of our house after the competition would have a fully-functional and up-to-inspection home. Our house was donated to a non-profit community farm in Germantown, Maryland. Red Wiggler Farm (www.redwiggler.org) is a framework for adults with developmental disability to learn the importance of self-sufficiency. The Maryland house will be used as staff housing. Currently, it is temporarily seated at Red Wiggler farm awaiting its foundation.

Home Features

The photovoltaic and electrical system



Example PV System With 8 Panels

- 51 BP Solar 4175 panels in two panel series sets. Each can generate up to 175 watts of electricity. On a sunny day, our array is capable of generating 8,750 watts of electricity.
- Three OutBack Power Systems PSPV PV combiners. Each PSPV can handle 12 strings of solar panels (our panels are in series of two, so each combiner handles 24 PV panels).
- Three OutBack Power Systems MX60 charge controllers. Each MX60 is rated for 60 amps of DC output current and can be used with battery systems ranging from 12 to 60 volts. Also important, our charge controllers were Maximum Power Point Tracking (MPPT) charge controllers, meaning it is a more efficient charge controller than most.
- 40 East Penn Deka 8L16 batteries, each rated to hold 370 amp-hours at six volts (a typical car battery is rated for 12 volts, and usually holds 40 amp-hours of electricity). These batteries where arranged in five parallel sets of eight batteries in series to create a 48 volt array (six volts per battery 8=48 volt system. 370 AH/string * 5 strings = 1850 AH). This system allowed us to maintain power during the rainy week.
- OutBack Power Systems PSDC DC Disconnect. For safety, homes with PV power systems are required to have a main disconnect that separates the PV system from the rest of the home's electrical system.
- Four OutBack Power FX3648 Inverters. The inverter takes in DC electricity and makes it into AC electricity. Each inverter takes in 48 volts DC, outputs 120 volts AC at 30 amps continuously, and can handle 3600 watts continuously. We connected them in a series-parallel connection to have a possible 240 Volts and 100 Amps of service.
- The AC Disconnect is where the AC electricity created by the inverters travels into the house. When the home moves to Red Wiggler Community Farm, it will have a connection to the electrical grid also.

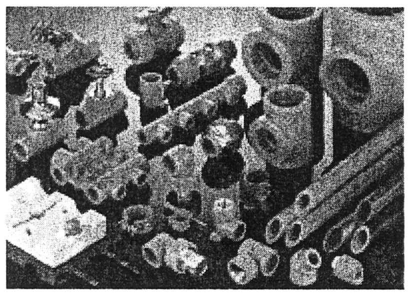
Solar Hot Water

- Apricus water heating tubes provide hot water for the house, including the hot water for the radiant floor. The tubes absorb the sun's heat in an insulating layer of air-evacuated glass. While the outside of the tubes are cool, the inside the tubes can exceed 300°F. The tubes reduce the need for an electric or gas water heater. Our system includes the capacity to heat water with stored electrical power when there is insufficient sunlight.

Plumbing

- Aquatherm Fusiotherm polypropylene pipes. This piping system consists of green polypropylene pipes and fittings that are fused together with heat. This process yields a seamless piping system with no joints to crack or break under fatigue. Polypropylene is also more environmentally-friendly than comparable home piping technologies. The most widely used pipes in homes today are made of PVC, which is a slightly flexible, white plastic. The manufacture of

PVC involves many additive chemicals used to stabilize the PVC, including heavy metals such as lead, cadmium, barium, and zinc. The installation of PVC piping also requires the use of toxic glues and primers. To install Fusiotherm piping, a heating tool is used to heat the pipe and fitting where the pipe is going to be inserted. This process takes approximately two minutes. Next, the pipes are joined together by hand and allowed to cool for approximately one minute. The joint is now fused, and the pipes are now ready for pressure. Fusiotherm fittings are available in a wide variety of sizes and types, and can be custom manufactured if needed. The pipes are certified for both hot and cold potable water, and can be manufactured for both indoor and outdoor used. Fusiotherm pipes have been in use for many years in Europe, and were just recently certified for use in the United States.



Energy Recovery Ventilation

- Stirling Technologies UltimateAir RecoupAerator 200DX ERV. This unit is the most energy-efficient and best-performing ERV available on the market. ERV devices allow exchange of air with the exterior, without losing heat or significantly altering the interior humidity. The ERV exchanges stale, indoor air for fresh, outdoor air while maintaining the home's temperature and humidity levels.

Radiant Flooring System

- Warm water circulates through cross-linked polyethylene tubes embedded in a thin, lightweight three inches layer of gypsum concrete in the floor. Heat is conducted to the concrete layer, and then transferred to the interior air by conduction and convection. Because warm air rises, this is a very efficient way to warm a house evenly without using forced air which can be a large energy sink. In addition, the concrete can hold and release heat over a longer period than wood (a principle known as thermal inertia).

Fire Protection System

- Sprinkler system that meet Montgomery and Prince George's County (both in Maryland) code. Montgomery County requires that all new residential construction have sprinkler systems, and we are the only house in the 2005 Solar Decathlon that featured a fire protection system.

Natural Ventilation

- Window placement and open floor plan allow a cross-breeze to ventilate the house. The curve of the ceiling rises toward the clerestory windows and allows rising warm air to be vented out. The house creates a natural convection for cooling.

Insulation

- Our walls and floor are insulated with non-toxic spun glass fiber. The exterior walls are framed six inches thick, rather than the usual four inches. The R value for the walls is 23. Our windows are triple-glazed, argon filled, with an R value nearly as high as the walls.

Learning Experience

The 2005 Solar Decathlon could not have come at a more opportune time, when oil and gas prices are at record highs. Consumers are searching for alternatives to the traditional forms of energy for transportation and home maintenance to alleviate the stress on their bank accounts. There have been more hybrid-fueled vehicles on the road this year than any other. Additionally, because we as a society are becoming more environmentally conscious, alternative energy production methods are becoming more and more attractive.

One major set back is cost in relation to the return on investment. Although solar energy is available now, it is not necessarily cost effective. For the solar panels on the Maryland house, each would cost consumers $1000 to produce, at a maximum, 175 Watts of power. There is also the cost for the inverter system and all the electrical systems. In order for a photovoltaic system to pay itself back, it might take up to 30 years, if not more. The payback time would, of course, depend on whether the solar power supply is being used to replace grid-supplied electricity—currently quite cheap—or natural gas, which is poised to become very expensive. The technology is not at a point that it is cost effective for everyday consumers and middle-class citizens to purchase them when renovating or building new homes. The most cost-effective systems featured in the 2005 Maryland house is the hot water tube system. A typical household spends 30 percent of its energy budget to heat water. The evacuated tubes are approximately 80 percent efficient (versus 12–15 percent for PV panels) and are nowhere near the cost of a PV system (less than $5,000 versus over $60,000).

Important issues that consumers should consider are the cost of system in terms of dollars per watt or square foot. As part of the competition rules, our house was limited to 800 square feet. Since most home owners are not limited to such a small size, they could purchase less efficient PV systems than our house, but more of them. When making decisions on the Maryland house and the PV system we used, the watt per square feet ratio was much more important that the dollar per watt ratio. To alleviate costs, consumers can use solar systems as supplemental systems.

In addition to hurdling the cost barrier, consumers must overcome the stigma that solar energy is too difficult to obtain and install, and hard to maintain. Solar energy needs more promotion and advertisement. We need to show the American public that alternative energy is available "over-the-counter" and is "user-friendly." If the government promotes the use of alternative fueling in public arenas and environmentally-friendly building techniques, alternative energy will become a part of our everyday lives.

The Solar Decathlon competition has been instrumental in promoting the availability and attractiveness of solar energy. We have received visits from politicians on Capital Hill, hundreds of news reporters, and most importantly, hundreds of thousands of everyday people who are either visiting the Washington D.C. area or live here and have heard about us. The tours that teams give to these visitors show that these display homes are no different than what they themselves live in. By connecting to the general public through this avenue, it is the best way to reach out to the public. Instead of lecturing to the public about why solar energy is "good" and how easy it is to access, we bring college students—each of whom are themselves a consumer—and their homes to show that it really is that easy. We are able to answer any questions on a personal level. The interactive aspect of this competition for the public is something that no other advertisement technique has.

We have also had the pleasure of having children visit our homes. Many teachers in this area have learned about the competition and required students to visit the competition as an assignment. Elementary level students have come in groups on field trips. These students are the future. Showing them what solar and alternative energy is on an interactive level is something that no teacher or class session can provide.

This competition is not just educational, it is also practical. Its objective is to bring solar energy to the public, and it has achieved that on many levels. Each team is required to submit information about the systems installed in their homes to the competition holders. These are then publicized on the Solar Decathlon web site. Additionally, having the "communication" and "documentation" categories of the Solar Decathlon judging requires teams, who wish to succeed, work to educate the public about alternative energy.

On another level, many of the teams have worked with sponsors who are local contactors and builders. For the Maryland team, we have worked closely with the Whiting-Turner Contracting Company and have received donations from Clark Construction and the Lennar Company. These are large builders and contractors in the local region. By partnering with them, we are not only educating ourselves about the construction industry, we are also educating them the availability of solar energy and how it appeals to the public. Many students on our team have received job offers from these companies and will eventually work with them. Hopefully, the lessons learned from this project will continue to serve these students in their careers (not to mention their employers!).

Resources and Problems

There are a variety of resources for building solar. To inspire our staff, many of the project managers visited shows and conferences across the country. We looked internally to the professors, teachers, and alumni first for help. From there, we were given contacts to outside contractors. Each step of the way, we learned and networked. Either we found the answer we wanted or we came a step closer to what we were looking for and found other sources.

Some of the major problems with designing and constructing this house were in the planning, organization, and fundraising aspects. Because the students involved are learning every step of the way, mistakes are made left and right. It is difficult to predict the future with little or no experience in real world design and construction experience, let alone learn while doing so. Also, we found that although many companies are willing to donate services and materials, money is one of the most difficult donations to receive. It is also one of the most important elements of this project. It was surprising how fast the money was spent, and how slowly it came in. Also, many of us were frustrated by the discrepancy in the university support we expected and received. We expected that the Universities would promote this project just as much as their most profitable athletic games. However, few students knew about the project, when the competition was held, or where it was held. Additionally, we along with many other teams received little support and understanding from our professors. It was assumed that this was another school project. It was hard for professors to understand the breadth of what we took on. It would be helpful if participating Universities were required to become involved and partner with the Solar Decathlon Project. It not only promotes these Universities, alternative energy, but also will alleviate the stress on already overwhelmed students.

Attracting to Home Buyers

The 2005 Maryland Solar House was one of the best-built homes in the competition in terms of craftsmanship and fit and finish. The quality of construction is impeccable and surpassed by very few of the other homes. There was a strict and high level of quality assurance during design and construction. The home was designed for lifting up and also forces coming down because it had to be transported. (Upward reinforcements are not necessary for homes that will not be transported.) The majority of the Maryland home is build from wood (60 percent sustainably harvested). It is easy to manufacture with the expertise of a few carpenters. The home was also built using traditional stud-frame construction, allowing almost any builder or contractor to make it without learning new techniques, which sets it aside from other homes in the competition. However, the design has to be changed slightly for mass production. There are many aspects of this house that were custom constructed for the competition. For example, the footers and posts that hold up the house are not necessary for a mass produced home, which ideally would have a permanent foundation. However, because this house is built to have two levels, one for storage, it lends itself to an addition of a fully functional basement if desired.

To alleviate costs on our house, home owners would not need the expensive battery bank used for the competition. The PV system would be grid-tied. Additionally, there would be no need for water tanks and other hardware used to simulate the city sewer and water. The Maryland system was oversized to make sure we were ready for any situation during the competition. Most consumers would not need to have this safeguard. For example, we would realistically only need two inverters and two charge controllers instead of four and three respectively.

The New York Times
nytimes.com

October 31, 2005
Editorial

Energy Failure

President Bush's habitual response to energy-related problems like oil dependency is to try to increase supply rather than to cut demand through energy efficiency. The imbalance is getting worse as Congress rushes to open up the Arctic National Wildlife Refuge to oil exploration. Meanwhile, the Interior Department is leasing out more fragile public land than the oil and gas companies know what to do with in the Rocky Mountain West.

The administration's conservation strategy, by contrast, consists mainly of gestures, like Treasury Secretary John Snow's pledge to ride the train to New York instead of flying the shuttle, and the Energy Department's chirpy consumer-education program featuring a cartoon villain called Energy Hog. As we learned long ago when President Gerald Ford started passing out those WIN (Whip Inflation Now) buttons, a policy that rests solely on slogans and mascots is no policy at all.

Obviously we can't expect this administration to turn on a dime and start supporting big increases in automobiles' fuel economy. But Mr. Bush has also ignored less controversial measures.

Last month, Attorney General Eliot Spitzer of New York joined with the Natural Resources Defense Council and others in a suit against the Energy Department because it has repeatedly ignored deadlines to review and strengthen efficiency standards for 22 products and appliances, including room air-conditioners and furnaces.

Congress requires periodic upgrades because technology gets better all the time. The first President George Bush strengthened 5 efficiency standards; President Bill Clinton strengthened 11. This administration hasn't strengthened any. Indeed, it tried unsuccessfully to roll back standards for central air-conditioners.

The energy savings from updated standards would not be trivial at a time when prices for oil and natural gas have zoomed. New standards for furnaces and boilers alone could save about 3 percent of the oil and 6 percent of the natural gas used to heat American homes. The electricity savings could equal the output of 40 power plants, and the value to consumers could amount to about $6,000 per household by 2020.

There's nothing inherently wrong with Energy Secretary Samuel Bodman's campaign to persuade consumers to reduce energy use voluntarily. But he should give them efficient products to work with.

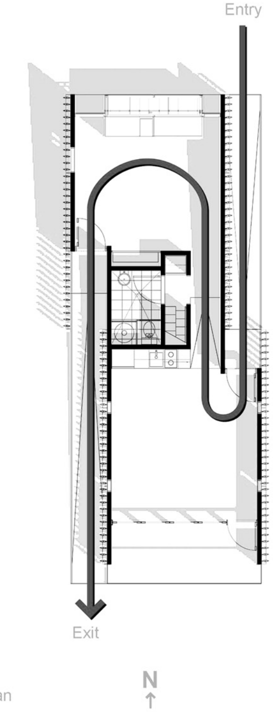

risd solar
Rhode Island School of Design | RISD Solar Abstract
United States House of Representatives
Committee on Science, Subcommittee on Energy
November 2, 2005

I. Two Ways: Interweaving Passive and Active - Efficiency and Excess

Solar houses are often characterized by the "either/or" of passive or active techniques. "Passive" systems strategically use walls, window placement and overhangs to control solar gain, where "active" systems deploy pumps, piping and mechanisms to collect, store and redistribute the sun's energy. The RISD Solar team's approach interweaves these two strategies by creating a symbiosis between the building envelope and the heating and cooling system each working in both ways. With RISD Solar, building components that are traditionally static, move (through computerized servos and biological means), while elements that are normally part of a mechanized system are visually inert (they move at the chemical and atomic level). The coordination of these two strategies allows the occupant to engage the variability of the surrounding natural environment in unique ways.

RISD's 800 square foot exhibition house is formed by the intersection of two volumes, one, which incorporates "passive" techniques and the other, which houses the "active" components.

The north-south orientation rewrites previous rules governing the layout of a solar house, which generally would stretch a building along an east-west axis. With the north-south axis, light changes throughout the day. The house, divided into four discrete domestic spaces: living|kitchen, bathroom|laundry, bedroom|office and garden|prospect, has a main circulation path which is designed to lead a large number of visitors parallel to this east-west movement. A shorter private circuit within the house ends at a secluded roof garden with an extraordinary vista (the U.S. Capital and the mall). Enclosing these spaces are multi-functioning double skin walls, roof and floors.



Floor Plan

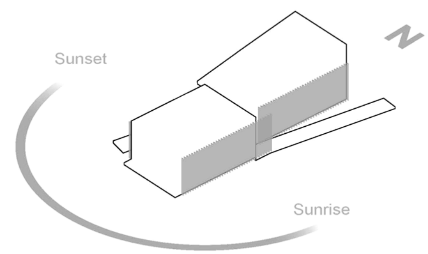
II. Heliotropic Louvers and Daylighting

Heliotropic Louvers

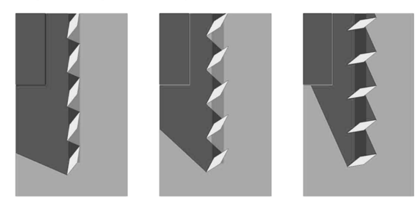
On the exterior walls of the house, a set of louvers literally moves with the sun. These vertical fins, offset from the main structure, are used to regulate the amount of sun hitting the house and to create a chimney effect of the cool air drawn up from the ground. In the summer, the louvers track the sun with their broad edge, reflecting its rays away from the building and keeping the house cool. In the winter, the louvers track the sun with their thin edge, maximizing the amount of sun hitting the house. A mapping of the solar light angles throughout the year was used to determine the movement of the louvers. The result is a house in motion, changing its character as the earth spins.

Windows and Daylight

Traditional solar homes use an excess of southern glazing in combination with thermal mass to obtain passive heating. In the RISD house, windows are carefully sized and arranged to provide a balance between the correct amount of light and well-insulated walls. To arrive at a the lighting strategy, appropriate light levels were determined based on the functions of the various spaces, then measurements were calculated and daylighting models were tested. The result is three interior spaces with distinct light effects. The south end opens to the changing light of the day with a relatively large southern glass wall. Overhangs, louvers and curtains further control the sun's rays and allow warm light to enter during the winter and keep out harsh overheated sun in the summer. The hall, which is intentionally the darkest area, brings a spot of natural light through a roof hatch that doubles as a skylight. In the bedroom/workspace, high transom windows bounce eastern morning and diffused northern light around the space while smaller windows provide isolated views. The placement of the windows is designed to avoid glare on computer and TV monitors and create a gentle glow.

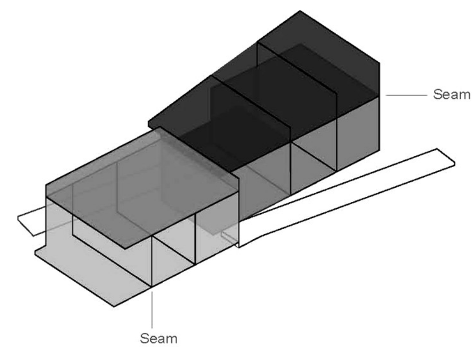


Louvers' changing angles throughout a sunny day



III. Assembly, Structure, and Well-Insulated Surfaces

Because the competition required that the house be moved from Providence, RI to Washington, DC and back, the house is designed as a modular home that is disassembled into nine individual modules. The RISD team divided their house into more modules so that they can conform to highway restrictions and still generously accommodate desired room widths. The modules are bolted together at seams, leaving most of the interior and exterior finishes intact. The exposed "expansion" joints and the strength of the plywood finishes allow the house to be moved without cracking. The entire structure was built with off-the-shelf, low-tech products enabling it to be built on site with minimal shop outsourcing and thus controlling costs. The team was careful to choose materials that met strict requirements. The materials have low embodied energy (i.e. local and recycled), do not aversely effect indoor air quality (low volatile organic compounds and non-toxic glues), do not harm the environment (no CFC's) and are renewable (plywood farmed with sustainable practices, and the use of fast growing cork). One of the primary sustainable systems used in this house is straightforward, affordable and invisible to the eye. The exterior walls, floors and roof of the structure, designed as lightweight and material efficient stressed skin panels, are filled with one of today's best performing building insulation. Between the insulation, cladding, and airspace, these walls attain an R-value (resistance to thermal transference) that is a third more than recommended by Federal Energy Code. Isonyne insulation is blown in and thereby installed to make the building "tight". This means air cannot move through unplanned openings in the floor and walls. Windows and doors also perform better than standard houses as the windows are coated with tin oxide to reflect infrared heat, double-glazed and fully gasketed. Attention to a well-insulated envelope allowed our engineers to reduce the size of their heating and cooling equipment.



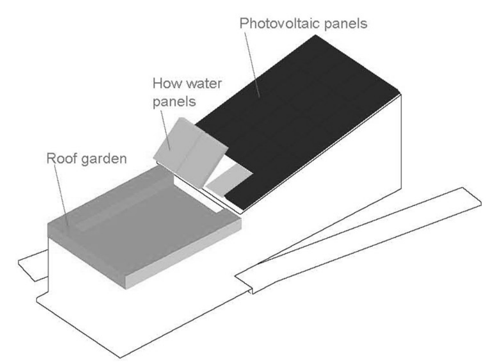
IV. Solar Surfaces and the Roof Garden

Solar Surfaces

Like the louvers and garden, the roof of the north end is covered with a second skin. The solar collecting panels shade the light colored roofing membrane, thereby helping to cool the house while also generating energy. These panels provide both the heat and electrical energy for the house and are the first component of the mechanical systems. The RISD solar team's decision was to use as few solar panels as possible in order to make room for the roof garden and reduce the cost of construction. Therefore, they used the most efficient mono-crystalline photovoltaic panels available and energy efficient appliances to reduce the total surface area of the array. The photovoltaic panels each produce 190-Watts to form a 4.6 Kilowatt system for the house. The solar hot water collectors are of the evacuated tube cylinder type, which are more efficient than flat plate collectors and allow solar heat collection in colder climates and cloudy days.

Roof Garden

The roof garden, which is made up of a series of shallow portable planters, provides many advantages. It plays an aesthetic role by extending the form of the house and creating a place of refuge. In addition, the variegated grasses and sedum, chosen because they require minimal water and maintenance, shade the house when full grown in the summer while the herbs can be used in the kitchen. The lightweight soil provides extra insulation, and absorbs water runoff. A water trough collects rainwater for irrigating the garden and use in a grey water system. The garden thus extends the usable living space of the house in area and in spirit.

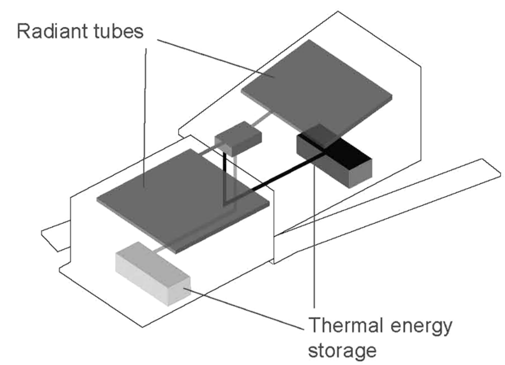


V. Building Systems: Heating, Cooling and Ventilation

The core is the most compact component of the house thereby freeing space for the living areas. Acting as the heart, it contains the hot water heating tank, the bathroom, the kitchen, the washer/dryer and access to the roof garden. Above the bathroom is our Sistine ceiling – a carefully designed and built mechanical space where the pumps, manifolds and ventilation equipment are housed. The central location of this high performance equipment minimizes duct and pipe runs, which increases efficiency. Three systems are used to maintain thermal comfort: a solar heating loop that heats both domestic hot water and the space, a cooling loop that is charged by cool night air, and an Energy Recovery Ventilator (ERV) that controls the building's supply and exhaust ventilation.

The heating and cooling systems use the principle of Thermal Energy Storage (TES). The storage is through Phase Change Materials (PCM's). The ability of the Phase Change Materials to store and release latent heat allows this material to store thermal energy in a smaller area, roughly 1/10 the area of water storage. For heating, we store solar thermal energy from the solar collectors during the day for usage during the night or days of no sun. For cooling, we use Phase Change Materials to store nighttime ambient air temperatures 60 Deg F or below for daytime cooling.

Heating and cooling are stored in two separate PCM containers, which use heat exchangers to transfer the stored heating or cooling thermal energies to radiant ceiling panels. The radiant panels are combination panels used for both heating and cooling. This is achieved through a variable speed primary/secondary pumping system located in the mechanical space. Using a hydronic variable speed pumping system allows us to use only the energy needed to heat and cool at a given time and requirement, at very low energy consumption. For comparison, a heat pump sized for the same heating and cooling loads would require 2,250 Watts of power at maximum design conditions. If that heat pump were of the newer variable speed type, the wattage range would be between 550 - 2250 Watts based on load conditions. Once our system is "charged" (i.e. has heating and cooling stored in the PCM's), our maximum wattage needed to heat and cool our



V. Building Systems (cont'd)

building (because all we are using is pumps) is 167 Watts. If we were to include the energy used by the Energy Recovery Ventilator when, or if, needed to control possible condensation, we would be at a total of 489 Watts. As we are using variable speed pumping and have variable speed control on our ERV, our maximum wattage usage is from 489 Watts down to 135 Watts based on load conditions.
Hydronic radiant cooling and heating systems can remove or add a given amount of thermal energy using less than 5% of the fan energy that would otherwise be necessary if using an all air heating and cooling system.

The advantages to our system over conventional heating and cooling technologies are:

- We are using natural ambient conditions to provide the heating and cooling for the building.

- Through the Phase Change Material Storage, we presently have the capacity to store days worth of heating and cooling strictly from environmental sources at design degree days.

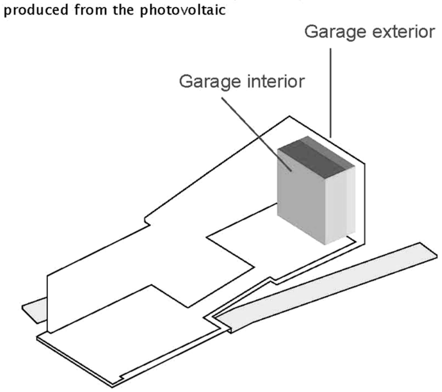
- Through the use of radiant heating and radiant cooling, we are able to provide the same heating and cooling capacity as a "conventional" system using much less energy, and at a higher comfort level to the occupants. Another advantage to this system is the effect it has on the thermal envelope heat transfer of the building. Because the heating temperature of the water is lower, the temperature difference across the thermal envelope (walls, roof etc) is also lower. This translates into less heat loss out of the building. The same works for the radiant cooling which operates at a higher cooling water temperature than a conventional system. The less temperature difference across a surface, the lower the heat transfer across that surface.

- Our system was designed to be simple, both in operation and installation.

The intent of this system is to show the potential for a building to have long term energy storage and the use of natural heating and cooling through the use of Phase Change Materials.

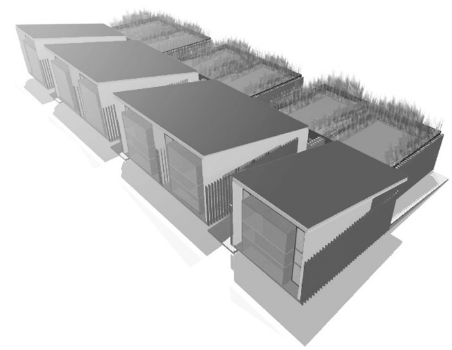
VI. Appliance Garage and Energy Star Fixtures

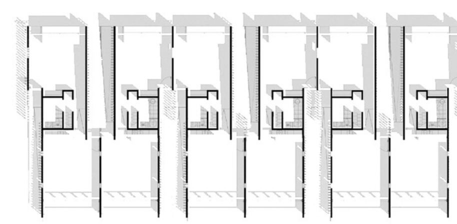
The Appliance Garage, situated at the north end of the house, is a large storage space divided into easily accessible cabinets. This cabinet is made of thin walls to conserve space and uses nanotechnology (nanopaint) to withstand the coldest side of the house. On the exterior, the Garage contains storage space and the electric equipment that converts and stores the electricity produced from the photovoltaic panels (through inverters and batteries). The interior opens up into a home office with filing cabinets, and also includes attic storage and a wardrobe. The flat screen monitor, lights and appliances are all energy efficient and energy star rated. The use of these fixtures reduces the load and the size of the photovoltaic system without compromising functionality.



VII. Planning

While RISD built only one house for the Solar Decathlon, the building layout affords site adaptability. It can be used as a freestanding house or an urban townhouse. The orientation of the building favors the north/south axis while an offset of the parts allows for adequate light throughout even if the units are clustered together or repeated. As a “townhouse”, the project responds in a unique way to the questions posed by the organizers of the Solar Decathlon. When the units come together, their displacement in section and in plan creates interstitial spaces that can become oases within the urban context. The idea of the solar village, while not a novel concept, becomes more energy efficient with the aggregation of more units. Uniting design with urban values, our solution addresses the issues of sustainability not only within the individual house, but also on a community scale.





VIII. Conclusion

Less and More

Through interweaving strategies of passive and active solar techniques, we have worked to achieve both efficiency and richness. While our wall and mechanical systems work intelligently together to create substantial efficiencies, they also allow for delightful excesses. With zero emissions, the house generates surplus energy. Each one of our techniques is integrated to create a singular design. Paramount to the project has been balancing the need for energy efficiency and production with the principles of thoughtful architectural design.

RISD Solar would not have been possible without support from the following generous sponsors:

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STATEMENT OF THE VIRGINIA TECH 2005 SOLAR DECATHLON TEAM

Bright Ideas: Winning Teams and Innovative Technologies from the 2005 Solar Decathlon

(Testimony provided to the U.S. House of Representatives' Science Committee, Subcommittee on Energy on Wednesday, November 2, 2005 by Robert Schubert, Associate Dean for Research and Outreach, College of Architecture and Urban Studies, Virginia Tech accompanied by Robert Dunay, Chair, Industrial Design Program and Joseph Wheeler, Lead Faculty Advisor, Solar Decathlon Project.)

The Virginia Tech Solar House

The Solar Decathlon of 2002 was an educational watershed challenging the relation between academia and practice and between research and its corresponding contribution to society. The knowledge derived from the 2002 competition has been integrated into the Virginia Tech house of 2005 to produce a work that combines innovative technology and daily life styles. This new project has achieved a high level of complexity expressed in an elegant simplicity. The initial theme of the *art of integration* has been realized through a design of a solar house that demonstrates a comfortable living and working environment, excellence in sustainable construction, and strong architectonic expression. The project presents forms that look to the future embodied with a sense of the sustainable and the beautiful.

Mission

The mission of the Virginia Tech Solar Decathlon Team is to inform and educate the public about issues of energy (particularly solar) and to give students energy expertise through a design-build process of innovative research and testing through application.

Our multi-disciplinary team strives to achieve the following goals:

- **To illustrate how solar energy can improve the quality of life. Solar energy is clean; it significantly reduces pollutant emissions; and solar energy is renewable, thereby increasing our nation's energy security.**
- To make the public aware of how energy is used in their daily lives, and to illustrate the energy consumption of daily activities.
- To demonstrate that market-ready technologies exist that can meet the energy requirements of our daily activities by tapping into the sun's power.
- To demonstrate that sustainable materials and technologies can comprise a beautiful structure in which to live, work, and play.
- To examine a project in a prototypical manner to develop solutions that can be reproduced and realized through manufacturing techniques with economic benefit.
- To challenge conventional practice through interdisciplinary collaboration and corporate partnerships.

Beginning of Oral Presentation of Questions to be Addressed in the Testimony

Before we address the specific questions provided, we would like to acquaint you with some of aspects of our building produced for the 2005 Solar Decathlon competition.

The Virginia Tech Solar house integrates technology and architecture. The house achieved a balance between the two as reflected by winning the juried competition elements of Architecture, Dwelling, Daylighting and tying for first place in electric lighting.

Some of the key features include:

- **efficient plan—**The house is comprised of a small (580 sq. ft.) *rectangular plan* wrapped on three sides with a *translucent skin* and covered with a hovering curved *roof* inclined toward the sun.
- **floating roof—**The particular shape of the roof, a lightweight stressed skin, folded-plate filled with foam insulation, is designed to set the solar panels at an optimum angle for energy collection and integrate the panels into the roof form.
- **north core module—**A thick linear core defines a massive north wall and houses the batteries, electrical and mechanical equipment, and service functions such as the kitchen, laundry, storage, and closets. Constructed of ex-

panded polystyrene panels that are lightweight, easily assembled, and yield a high insulation value, this module could be manufactured separately and utilized in many applications.

- **translucent wall assembly—**Two layers of aerogel filled polycarbonate panels transmit beautiful diffuse light while delivering an extremely high insulation value. There will be no need for electric lights from sunrise to sunset.
- **tunable walls—**Between the polycarbonate panels are three systems. A pair of reflective and absorptive motorized shades allow user control of light and heat transmission; linear actuated vents top and bottom provide ventilation for further thermal control; and, dimmer controlled LED lights allow the user to make the wall any color, no paint required.
- **innovative engineered systems—**our energy efficient ground source heat pumps powered by the solar electric panels provide environmental conditioning in the form of heating and cooling while delivering heat through a radiant floor that offers the best in terms of efficiency and quality. There is little air noise or movement and the ambient temperature can be kept lower saving energy.
- **transportation—**A lowboy chassis serving as the floor and foundation structure was designed to receive a detachable gooseneck and rear axels for transport. A truss on each side of the 48-foot span resists deflection while in transit and rotates down 90 degrees to create a deck surrounding the house when stationary.

In response to the specific questions:

1. Some of the main technical and other barriers to greater use of solar energy are:

- Inertia of public perception towards the status quo
- Perception of increased complexity of new system vs. conventional systems
- Conservatism of building industry and their adversity to risk
- Cost—time of return on investment
- There are few new architectural ideas relative to new technology.

Some suggestions for what might be done to overcome those barrier are:

- Increased incentives for solar installations such as tax and mortgage incentives, low interest loans, and utility credits
- Create a National Awards Program for solar design
- Encourage numerous and repetitive small-scale applications
- Regional centers that promote the use of solar energy (similar to agricultural extension programs) working in conjunction with state energy offices
- Require utilities to generate a percentage of power from solar energy
- Federal energy subsidies redirected to encourage a higher percentage of renewable energy
- In addition to a week-long competition on the Mall, re-create the solar village for a longer period in an Expo type of forum.

The Solar Decathlon Competition is an effective means to seed the potentials of solar energy in the public consciousness.

- It touches people from all walks of life and from diverse economic and social backgrounds. As witnessed in the competition of 2002 and 2005, there is widespread and growing public interest in solar energy. Integral with the competition, all aspects of the house are considered with respect to conservation of energy. Particularly the Virginia Tech house, demonstration was made that a solar dwelling can offer a desirable and rich lifestyle.
- Its competitive content activates top research universities to further their research efforts and to draw unique collaborations with industry. The competition allows partnerships to be formed. Among many corporations, Virginia Tech worked with GE Specialty Film and Sheet and Cabot Corporation to produce a wall that delivers great light and high insulation. Likewise, collaboration with California Closets has the corporation, for the first time, building cabinet prototypes from a Dow Chemical wheat board that is sustainable and non detrimental to the environment.

2. *The Solar Decathlon of 2002 provided a wealth of information in our own experience of designing and building a house as well as observing the houses from other research institutions.*

   - Our 2005 house integrates the research from the previous work and lessons learned from other houses.
   - In addition to on campus expertise, a network of manufacturers and professionals having ties to Virginia Tech was used to develop and refine ideas.
   - A student network researched a wide range of materials, processes and technologies, some of which were integrated into our design.
   - The United States Green Building Council's (USGBC) draft LEED Residential program provides us with an outline to reduce indoor air pollutants, minimize global warming, reduce waste, include recycled content, represent low embodied energy in manufacture and harvest, limit destruction to habitat, and rapidly renew.

Two of the problems we encountered were:

- An inordinate amount of time, energy and cost associated with our transportation strategy
- Percentage of time utilized to raise in-kind donations and extreme difficulty in raising cash contributions.

3. *Our house would be commercially viable:*

   - Placed within the context of commercially manufactured housing.
   - Winning the Architecture and Dwelling Awards in the competition, the Virginia Tech house demonstrated its appeal to a discriminating set of judges.
   - The Virginia Tech Solar House offers various possibilities for components that will conserve energy and improve the quality of residential building.

In conclusion, we would like to leave with this final thought:

We approach a watershed. Our lifetime has experienced an increased dependence on technology. Almost every amenity we enjoy is dependent upon centralized systems whose working and control are far removed from localized areas. A short curtailment of services sends neighborhoods and regions into temporary states of chaos. In the recent case of hurricane damage, available supplies of gasoline could not be accessed due to lack of electrical service. Whether from natural disaster or terrorist threat, large-scale technologies have exposed growing risks. We must reduce the risk of widespread technological failure by providing alternative distributed power solutions and backing up centralized systems with *grass roots* capability of generating power. With continued support and research of solar energy, this vision is achievable for the next generation.


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2005

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VIRGINIA TECH

SOLAR DECATHLON 2005

MISSION

A project that challenges the mind, stimulates the spirit, and delights the senses, the Virginia Tech Solar Decathlon has a primary mission of educating the public, while enhancing the students' educational experience through the design and construction of the most "attractive, effective, and energy-efficient" of 18 solar-powered houses built by students from universities around the world for the 2005 Department of Energy's Solar Decathlon.

Project participants will design and construct a grid-independent solar house that incorporates the best available practices of conservation and energy production as well as innovative ideas to provide an architecturally appealing and comfortable living and working environment. This task can be achieved only through a highly integrated approach, with students and faculty from the College of Architecture and Urban Studies and the College of Engineering working together.

Project participants will be motivated to learn, to innovate, and to develop teamwork, leadership, and communication skills. Our approach will not only satisfy the programmatic requirements of the competition, but also will look beyond to yield a solution that can be produced with manufactured housing techniques, that uses a high degree of recycled content in the production of the materials, and that has an overall low environmental impact. Our approach in this second Solar Decathlon will include innovative techniques that extend, improve upon, or replace techniques used in the 2002 Solar Decathlon competition.

Building this solar-powered home that fulfills the competition's criteria of "functional, comfortable, structurally sound, and appealing" makes our highly integrated approach much more than work done to satisfy a list of stringent criteria. The project challenges us to work together to solve problems, stimulates a spirit of cooperation and excitement as barriers fall to our creative insights, and delights—with its surprising components—not only us but the visitors who will tour the solar homes on Washington's Mall in October.

The team will create a home that uses innovative energy-saving technologies, and it will serve not only present but future styles of living as well. It will be a climatically adaptive building, not just designed for the presumed climate during the competition, but a solution that is adaptable for multiple climates. The house will be of long-term value, and it will balance structural integrity, function and comfort, and appeal to the viewer.

VIRGINIA TECH

S O L A R   D E C A T H L O N   2 0 0 5

THE HOUSE

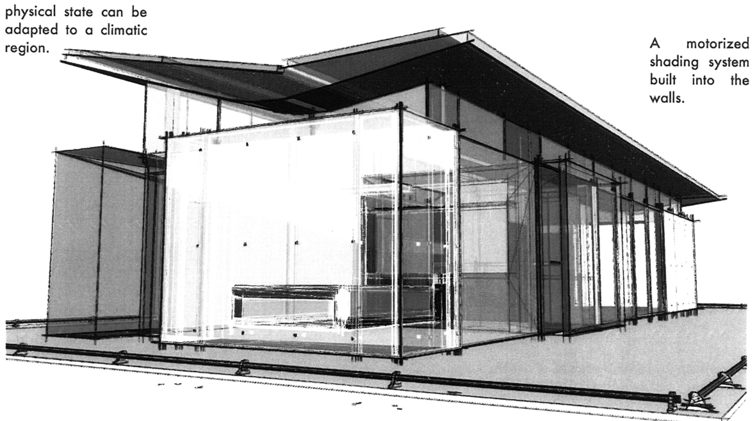
Reaching Toward the Sun

In a Solar Decathlon in which houses are, as the Department of Energy said, "Designed by People, Powered by the Sun," participants can combine imagination with knowledge and skill to produce new ways of living. Some of the innovations found in the Virginia Tech solar house are:

A wall system that is responsive to the environment. Providing enclosure of the house, it is adaptable to varying climatic conditions and regions, enhancing the double - envelope system of insulated walls. Hence, a tunable, adjustable wall, which can be refined. Its physical state can be adapted to a climatic region.

A boomerang-shaped roof that gestures toward the sun and hovers above an airy, brightly lit house is a major design element. The elegant, stressed-skin roof, which turns up toward the sun has photovoltaic panels that collect solar energy and transform it to electricity that is stored in batteries. The roof defines the spatial quality of the interior, which includes a clerestory, or raised space with windows, that provides a strong connection from the living spaces to the sun's light and provides ventilation in the summer. The necessity for the integration of photovoltaic panels, interior lighting, and ventilation - as well as the desire for beauty - influenced the form of the roof.

A motorized shading system built into the walls.



Wrap-around, translucent exterior walls on three sides. The new type of wall is made up of a thin, transparent membrane filled with a highly insulative aerogel, that achieves a high insulation value, while allowing abundant light to filter into the house. Conventional wood framing holds the walls in place.

Technical elements such as photovoltaic cells and batteries integrated into the overall composition of the house.

Radiant floor heating throughout all the rooms.

THE HOUSE

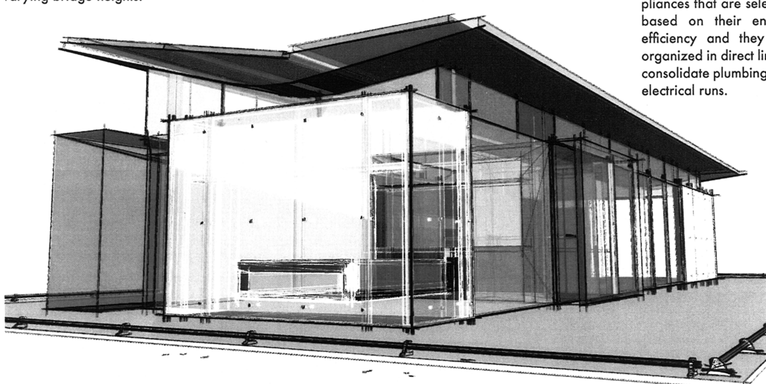
Reaching Toward the Sun

More innovations found in the Virginia Tech solar house.

An electrical closet and battery storage closet that will supply all the electrical needs of the building, powering all household needs - appliances, food prep, entertainment, wash and a small home business. The user utilizes a tablet p.c. that is inter-connected to the building control system, allowing the homeowner to convey vital signs and critical performance to the house. The homeowner can automate the controls or they can inter-act and define the way it operates and adjust it to their lifestyle.

Exterior decks that fold up to brace the house during transportation. A chassis that becomes the building foundation, which is designed to work with detachable transportation components. The chassis has a hydraulic system capability to change its ground clearance, to provide the possibility of accommodating varying bridge heights.

A kitchen made up of appliances that are selected based on their energy efficiency and they are organized in direct line to consolidate plumbing and electrical runs.



A rainwater harvesting system incorporated into the exterior decking system.

An integrated heat pump system that utilizes both active and passive techniques to environmentally condition the interior space. Passive, or non-mechanical conditioning comes from the south facing wall system that provides both heating and natural ventilation. When the building can no longer be kept comfortable with these passive techniques, the active p.v. powered heat pump takes over to provide supplemental heating and cooling as needed. The heat pump is designed to operate earth or ground coupled, to use on the mall with a water storage system.

VIRGINIA TECH

SOLAR DECATHLON 2005

Virginia Tech Students Building Solar House for Competition on the National Mall

A House Powered by the Sun

The source of power for a solar house is 93 million miles from the Earth. The sun as fuel leaves no pollution and depletes no natural resources.

A team from Virginia Tech is competing in the 2005 Solar Decathlon against 18 other teams from around the world, to build the most livable, aesthetic, and energy-efficient house completely powered by the sun. The solar house must generate enough energy to power all the needs of the house, run a small home-based business, and power a solar car. Addressing the need for alternative, sustainable energy, the Virginia Tech solar house utilizes renewable materials, truly innovative technologies and construction methods that have the goal of ultimately achieving cost-effectiveness.

The Solar Decathlon is an international, intercollegiate competition sponsored by the U.S. Department of Energy's Office of Energy Efficiency and Renewable Energy. It is designed to educate students about the ways renewable energy conserves the environment, to move the general public to think about ways they can use modern technology to conserve energy and make responsible choices about their energy use, and to speed up the development and marketing of new technology. Students begin planning, designing, and building their homes about two years before the actual competition at the 'Solar Village' on the National Mall in Washington, D.C. Virginia Tech students raised the level of their participation by having their own competition to determine the design of the house they would take to the Mall in the fall of 2005.

A crucial design criteria that the team must address is transportation of the house to Washington, D.C. for exhibition and final competition. In the 2002 competition, Virginia Tech students had to construct, then dismantle, the house, take it to the Mall by truck, and reconstruct it for the contest. This year, however, the house will be transported to the mall intact, due to a uniquely designed trailer that allows the house to fit under interstate overpasses.

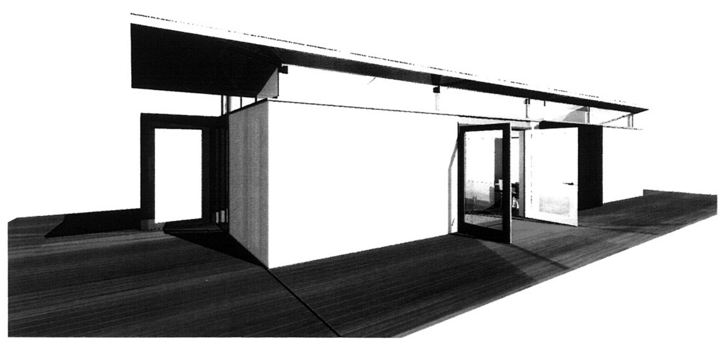
A collaborative of students and faculty from the College of Architecture and Urban Studies, (the programs of Architecture, Industrial Design, and Interior Design in the School of Architecture + Design; the departments of Building Construction and Landscape Architecture) and the College of Engineering (the departments of Civil and Environmental, Electrical and Computer, and Mechanical Engineering) form the Virginia Tech solar team. Through the design-build process of a fully self-sufficient solar house team members will experience the invaluable lessons of teamwork, collaboration and compromise. Research and technology are also emphasized throughout the process.

The Solar Decathlon project illustrates the benefits of having students and faculty work outside their own disciplines and alongside those from other fields. The range of experience it provides the students enables them to develop such things as movable walls and heated floors, a double-drop low-bay mover that may prove beneficial for moving prefabricated homes—and, of course, small, energy-efficient homes that could be useful in high-population-density areas while saving the Earth's resources. The Solar Decathlon not only gives students an intensive, hands-on course in solar housing, but also the opportunity to solve some of the problems of the world.

Once the houses are set up on the mall, experts will judge them in 10 categories: (1) Architecture, the success with which the students have incorporated "solar and energy-efficiency technologies seamlessly into the homes' designs"; (2) Dwelling, the extent to which the house is amenable to the needs of its occupants; (3) Documentation, records of the building of the house according to the design; (4) Communications, the success of the teams' web sites and tour presentations to the public; (5) Comfort Zone, the temperature and humidity control within the house; (6) Appliances, the ability to sustain refrigerators, televisions, kitchen appliances, etc.; (7) Hot Water, the ability to provide 15 gallons of water, warm enough for showering, in 10 minutes; (8) Lighting, the level of lighting and the amount of energy used by it; (9) Energy Balance, the house's ability to generate all the energy needed throughout the competition; (10) Getting Around, the amount of solar fuel the teams have left over to power electric vehicles.

The design and construction of a completely solar powered home affords students a priceless learning experience. As future builders and leaders, students will carry these important principles forth.

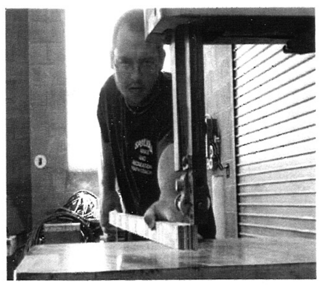
The Virginia Tech Solar Decathlon progress can be followed at http://vtsolar.arch.vt.edu, and the DOE site is found at http://www.eere.energy.gov/solardecathlon.

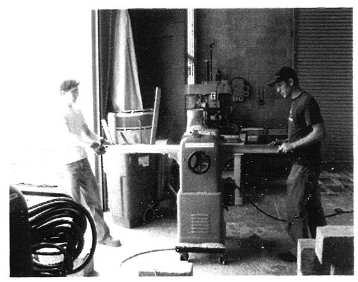


VIRGINIA TECH

SOLAR DECATHLON 2005

THE TEAM





DESIGN AND CONSTRUCTION LEADERS

Bryan Atwood	Architecture
Brett Moss	Architecture
Chip Clark	Architecture
Chuck Hoover	Architecture/Interior Design
Kyle Longbrake	Mechanical Engineering

FUNDRAISING

Joe Wheeler	Architecture
Seanene White	Architecture
Sarah Violette	Architecture

WEBMASTER

Brett Moss	Architecture

FACULTY ADVISORS

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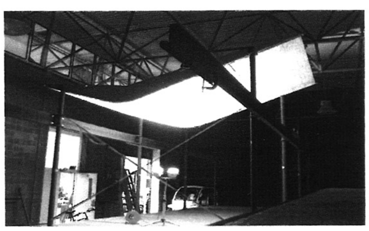
T 540-231-5607 T 540-231-2389 F 540-231-6332

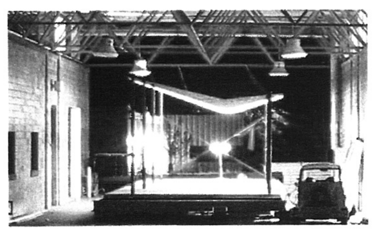
VIRGINIA TECH

SOLAR DECATHLON 2005

ABOUT THE COLLEGE OF ARCHITECTURE AND URBAN STUDIES

The College of Architecture and Urban Studies is one of the largest of its type in the nation. The CAUS is composed of two schools and the departments of landscape architecture, building construction, and art and art history. The School of Architecture + Design includes programs in architecture, industrial design and interior design. The School of Public and International Affairs includes programs in urban affairs and planning, public administration and policy, and government and international affairs. The college enrolls more than 2,000 students offering 22 degree programs taught by 160 faculty members. Additional information about the College of Architecture and Urban Studies can be found at www.caus.vt.edu





ABOUT THE COLLEGE OF ENGINEERING

The College of Engineering at Virginia Tech is internationally recognized for its excellence in 14 engineering disciplines and computer science. The college's 5,600 undergraduates benefit from an innovative curriculum that provides a "hands-on, minds-on" approach to engineering education, complementing classroom instruction with two unique design-and-build facilities and a strong Cooperative Education Program. With more than 50 research centers and numerous laboratories, the college offers its 2,000 graduate students opportunities in advanced fields of study such as biomedical engineering, state-of-the-art microelectronics, and nanotechnology. Additional information about the College Engineering can be found at www.eng.vt.edu.

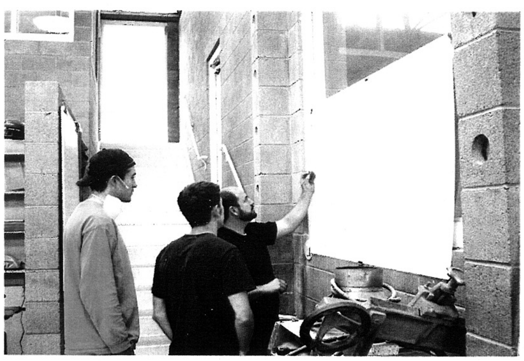
About Virginia Tech

From a modest beginning in October of 1872, Virginia Polytechnic Institute and State University, popularly known as Virginia Tech, has evolved into a comprehensive university of national and international prominence. Virginia's largest university, Virginia Tech has 25,600 students and is one of the top research institutions in the nation. It is an institution that firmly embraces a history of putting knowledge to work. That tradition is rooted in our motto, Ut Prosim: "That I may serve," and in our land-grant missions of instruction, research, and solving the problems of society through public service and outreach activities. The university offers more career options than any other Virginia university: 60 bachelor's-degree programs and 110 master's and doctoral-degree programs.

With annual research expenditures of about $268.7 million, Virginia Tech has more than 100 research centers and consistently ranks among the top institutions in industry-supported research and in the number of patents issued each year.

The university's faculty and students are involved in more than 3,500 sponsored projects in fields ranging from biotechnology to materials, from the environment and energy to food and health, and from transportation to computing information. Students and faculty who built the 2002 Solar Decathlon house conduct projects through a comprehensive research agenda around various aspects of their solar house, and those participating in this year's competition will add to the research in several areas new to their innovative house.

Virginia Tech is comprised of a Graduate School and eight colleges, two of which have students participating in the Solar Decathlon–the College of Architecture & Urban Studies (CAUS) and the College of Engineering (COE). Many of CAUS' programs are among the finest of their type in the nation. The Architecture Program in the School of Architecture + Design ranks top ten nationwide by DesignIntelligence. Regionally, the Graduate Program in Architecture was ranked among the top 10 in the South. U.S. News & World Report typically ranks the COE's undergraduate program in the top 20 among all accredited engineering schools that offer doctorates, and in the top 10 among those at public universities. The majority of the college's individual programs are also consistently ranked among the top 20 in their respective fields.



More information about Virginia Tech can be found at www.vt.edu.

Virginia Tech 1872

VIRGINIA TECH

SOLAR DECATHLON 2005

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Virginia Tech team places fourth at Solar Decathlon 2005

NATIONAL CAPITAL REGION, Oct. 17, 2005 – A house designed and built by a team of students from Virginia Tech's College of Architecture and Urban Studies and College of Engineering placed fourth overall on Friday, Oct. 14, at Solar Decathlon 2005, an international competition sponsored by the Department of Energy held on the Mall in Washington, D.C. The team also won first place category awards for "Best Architecture," "Best Dwelling," and "Best Daylight Lighting," as well as tying with another school for first place in "Best Electric Lighting." The Virginia Tech solar house was hindered only by the complete lack of sunshine for the entire Decathlon. Instead of using batteries pre-charged before the competition began to power their house, as other teams chose to do, the Virginia Tech team anticipated at least one sunny day during the competition, which would have provided the house ample solar power. Robert Schubert, College of Architecture and Urban Studies Associate Dean of Research and Outreach and one of the lead faculty advisors for the project, said, "We're proud of the team's decision to operate the Virginia Tech solar house on solar energy. We were true to the spirit of the competition, so our team can be very proud." The 18 national and international solar decathlon teams were charged with creating attractive, practical, and efficient solar homes. For more information about the Solar Decathlon, go to www.eere.energy.gov/solar_decathlon.

11/30/2005