

Project Solar House

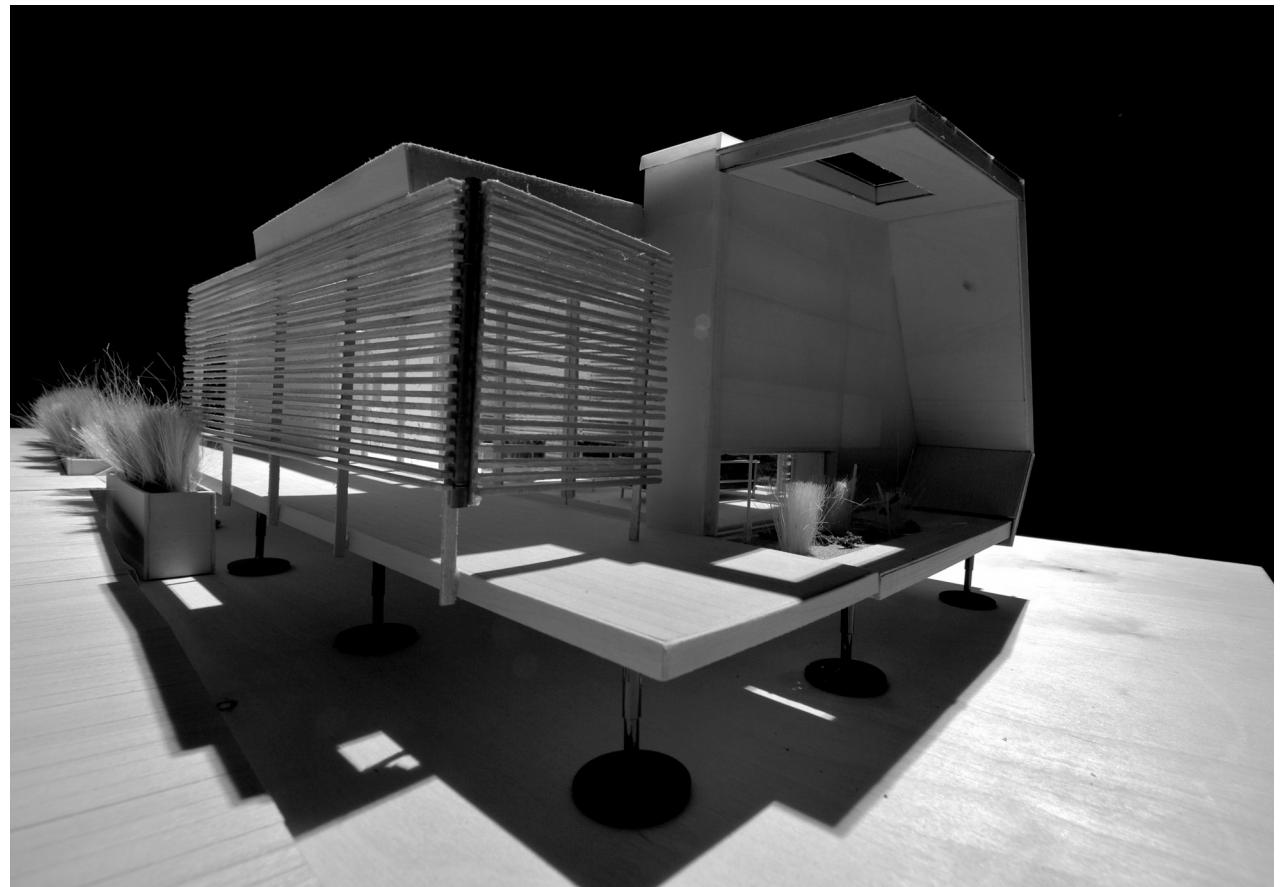
Solar House Team

Project Solar House is Kansas State University's entry to the 2007 U.S. Solar Decathlon. The Decathlon, coordinated by National Renewable Energy Laboratory (NREL) and the Department of Energy (DOE), is a selective competition that challenges university teams to design and build a small home that is powered solely by the sun. In October of this year, the competing teams will transport their homes to the National Mall in Washington, D.C. for judging and public exhibition. Competition criteria include design aesthetics, building performance, and livability. Kansas State is one of twenty teams competing this year.

A multidisciplinary team, comprised of students and faculty from the colleges of Engineering and Architecture, Planning, and Design, have conceived their entry to embody renewable energy strategies, high building performance, efficient and intelligent controls, and sustainable principles at the residential scale. As an ambassador of Kansas as a whole, Project Solar House also highlights the state's indigenous resources.

Process

From the beginning, the design of the house was seen as a collaboration between design and engineering disciplines. Students working on the project were organized into units charged with specific tasks. One of the organizational goals was to have the project be run similarly to a professional endeavor. A series of architectural studios was the backbone for the effort. Students in these studios served as liaisons to



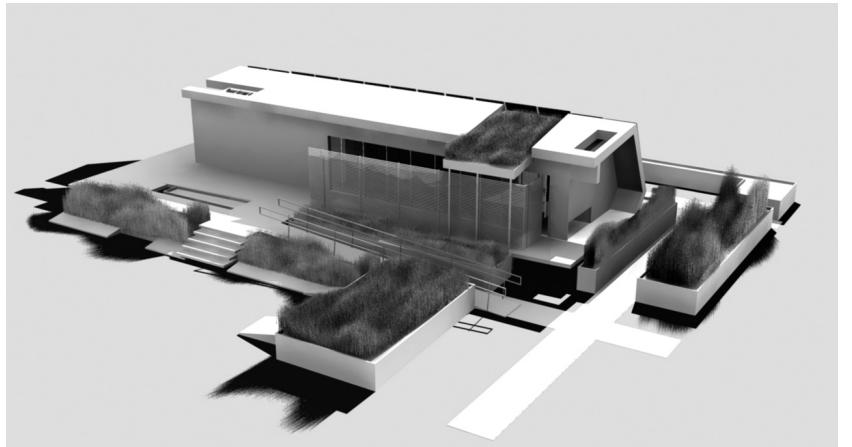
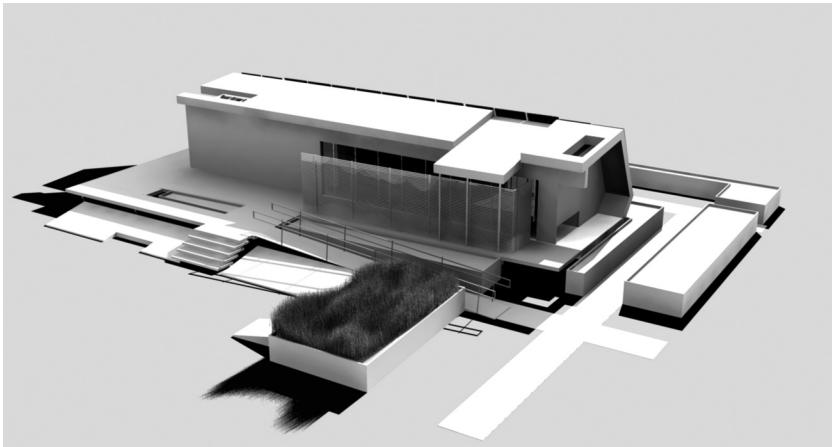
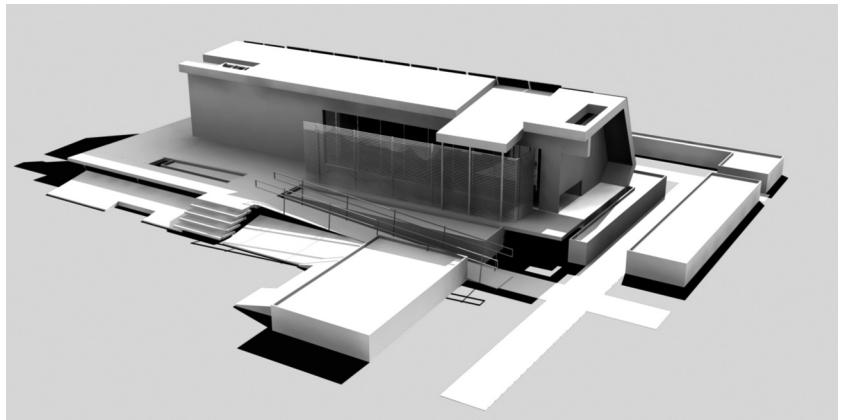
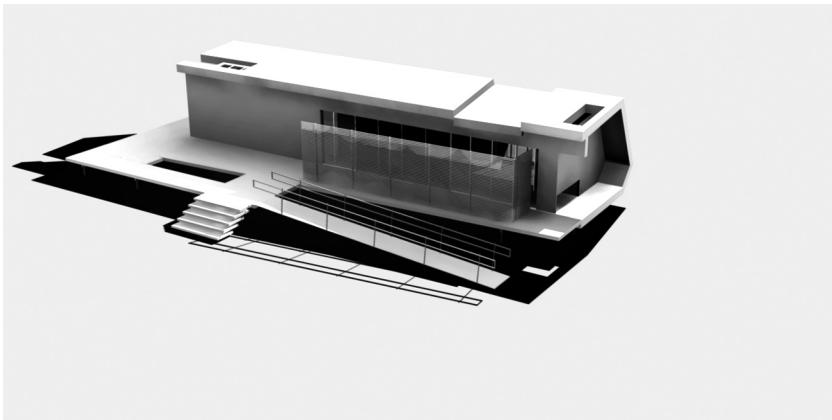
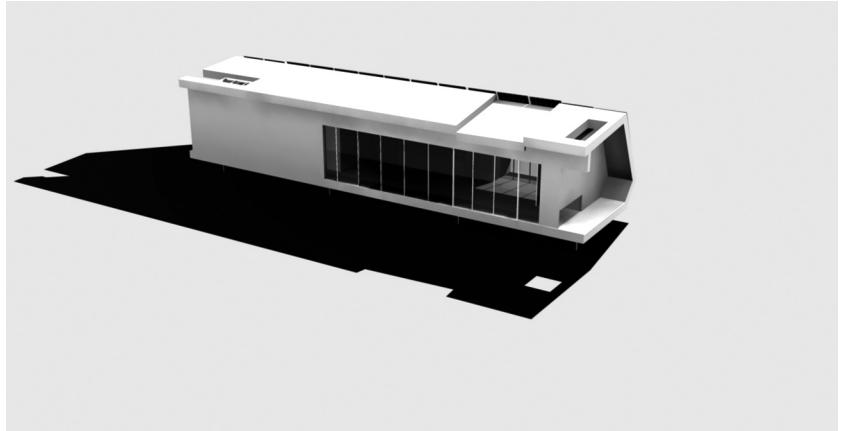
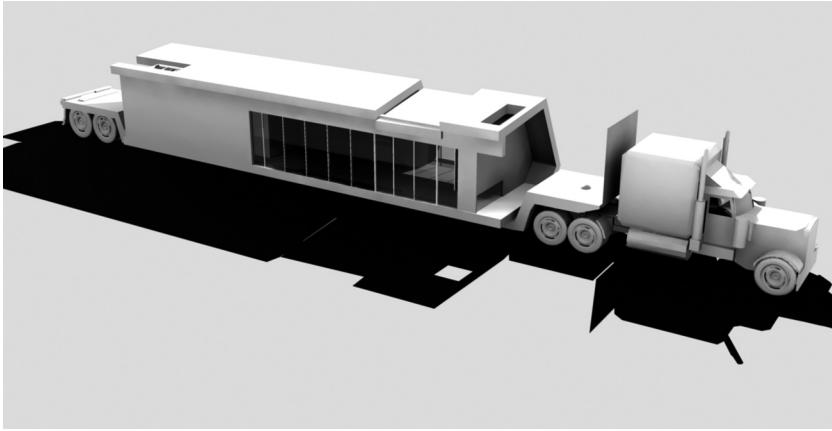
other classes and individuals working on the project. They provided criteria and brought back design recommendations and system requirements. These other classes acted as consultants, contributing to the design according to their specialization. Electrical engineering students, for example, designed the solar array for the house, and mechanical engineering students designed and constructed the HVAC system. Most students working on the project received course credit for their efforts.

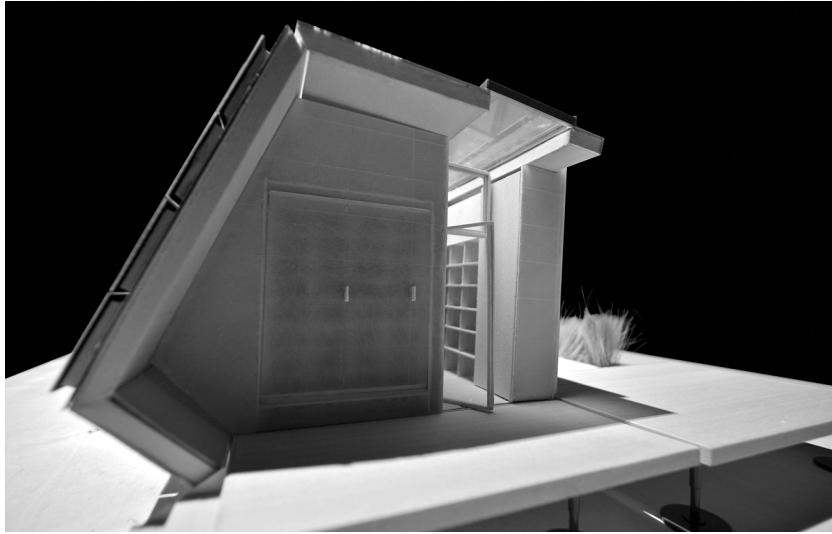
The first step in the design process was to develop a set of criteria that would guide the design of the solar home. The team identified five main points that the KSU entry should embody.

Redirect Expectations

Homes are expected to facilitate human occupation—they shelter, support, give comfort, aid in work and leisure, and at their best enrich the lives of their inhabitants. None of these aims is in itself unreasonable. The problem lies in the particular strategies

utilized to achieve them. Standard building and building design practices virtually ensure homes that are extremely energy inefficient and are ultimately unsustainable. Careful, responsible design can ensure that all of a building's requirements are met without unintended consequences. One good example is artificial lighting. Incandescent bulbs, a technology a century old, only convert 10% of the electricity they consume into visible light. The rest is lost as waste heat. Compact fluorescent bulbs are much





more efficient, delivering the same amount of light for about a quarter of the electricity.

A primary goal of the Solar Decathlon is to show that homes can provide for all the normative needs of a typical household using only energy from the sun. Project Solar House will expand this notion by challenging normative practices in every facet of home construction, operation, and inhabitation.

Look Ahead

The design should integrate new technologies that can reduce the project's need for energy, incorporate innovative building envelope strategies, and embrace and expand the applications of building integrated photovoltaics (BIPVs) and other sustainable technologies. BIPVs have the potential for wide appeal to both home-builders and owners. This is due mainly to the

fact that the solar array would not be an additional, obtrusive system, but would replace another building system, such as roofing or a façade finish. Another major new technology the entry should investigate is active controls on all energized systems.

Go Mobile

Moving, the third most stressful life event, is an almost universal phenomenon in the modern world. Forty-two million people move each year in the United States. The average individual moves 11.7 times in their lifetime--roughly once every five to six years. Rather than accepting transitory residence in permanently sited structures, inhabiting a movable home can potentially provide a much stronger sense of permanency, of stability, for its mobile inhabitants. The design should not deny the essential movability of the solar home, it should instead celebrate this condition.



Perhaps one of the biggest criticisms of mobile architecture is its lack of response to exterior conditions. Rather than obviate any potential linkage to site, Project Solar House should be crafted of an architectural language that responds to a variety of environments and celebrates exterior living.

Multiply

Perhaps the main stated goal of the Solar Decathlon is to increase the awareness of energy efficiency measures and renewable energy as a viable alternative to fossil-fueled, centralized power plants as a supplier of residential power. In *Towards a New Architecture*, Le Corbusier wrote that "a house is a machine for living," a sentiment that is more true today than it ever was. If homes were thought of as machines, like cars, then building performance would become as important as building aesthetics. As it is, lowering the energy footprint of these living ma-

chines will be a crucial component of meeting future energy demand.

Project Solar House should be considered a prototype house that combines high performance and commodious spaces. The strategies used in the solar home should possess the ability to be duplicated in existing and new home construction. A secondary consideration is the idea that the house might be marketed as a system for mass use for individuals or couples as a primary residence or a vacation home. As the home can operate off the grid, explore the potential for its use as relief housing or remote research stations.

Celebrate this Place

The project should underscore the unique resources that can be found in Kansas and synthesize the potential of this place, the geographic heart of the country. Kansas is entirely of the earth, but looks beyond the earth. It is



a place of both landscape and sky, and architecture must find itself between these two paradigms.

The first half of the 2006 spring semester was given over to a design charrette. Several proposals were developed, each with its own approach to the complex challenge of the Decathlon. These proposals were reviewed by a panel of experts from various fields, and were subsequently judged by the team as a whole, who determined which scheme would be carried forward into design development.

The remainder of the spring semester was devoted to developing the chosen design. This part of the effort was not only defined by perfecting the aesthetics of the scheme, but also the performance of the proposed building in regard to energy use. In the initial idea, for example, the south wall, ceiling, and floor were opaque and well

insulated, while the north, east, and west facades were essentially window walls. Computer simulations showed that the large glazed areas allowed a great deal of heat to be lost in winter, and so to lower the building's energy footprint, more of the envelope was subsequently insulated. The building's several skylights were also changed from clear glass to polycarbonate panels that contain aerogel, a state of the art translucent insulation that allows daylight in while resisting heat transference. These and other energy efficient measures reduced the house's projected energy demand by 42%.

The design development phase continued into the fall. During this semester, many of the engineering collaborators were activated, as well as landscape and interior design disciplines. The architecture studio made some modifications to the schematic design, including opening up some of the southern



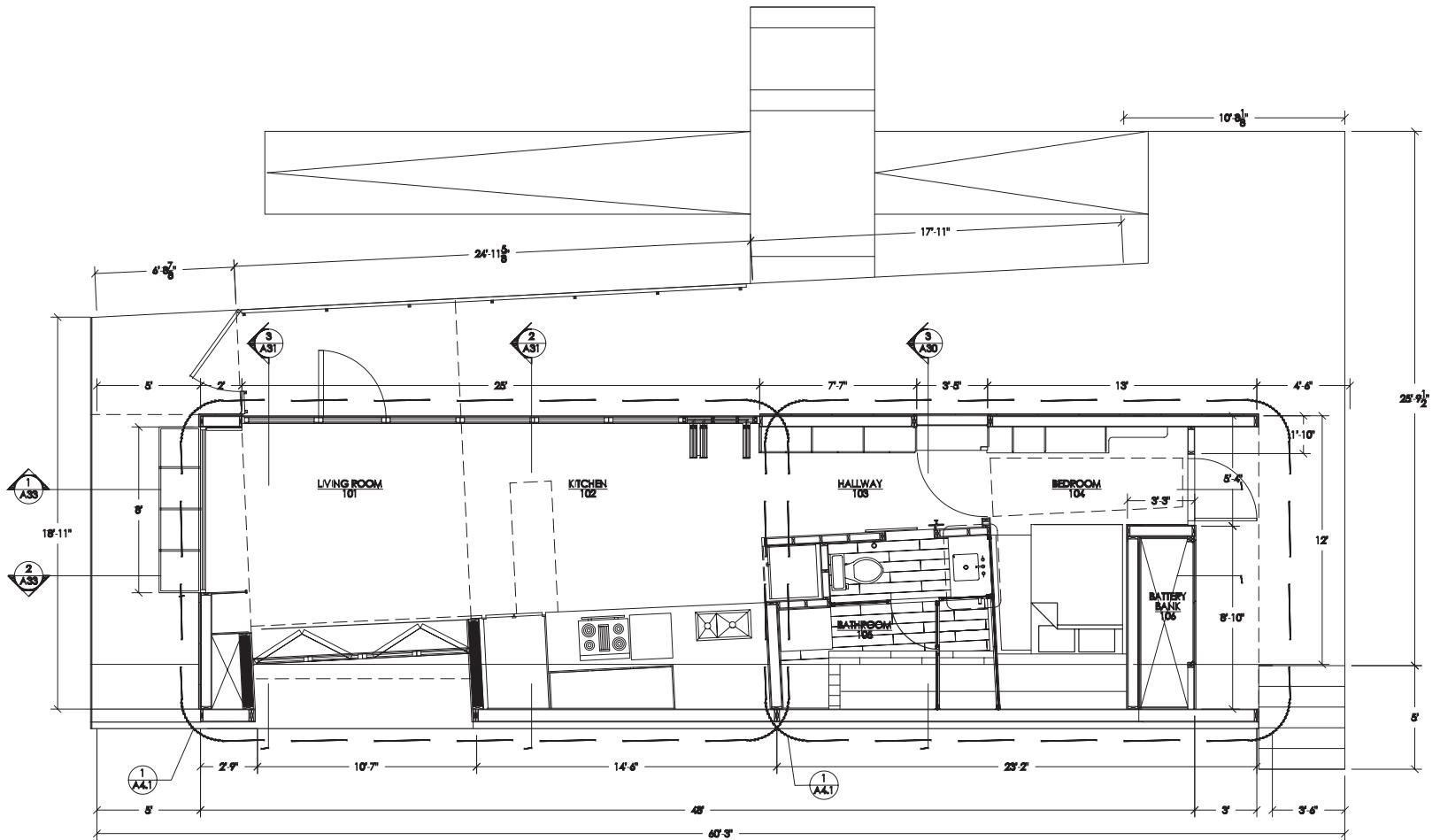
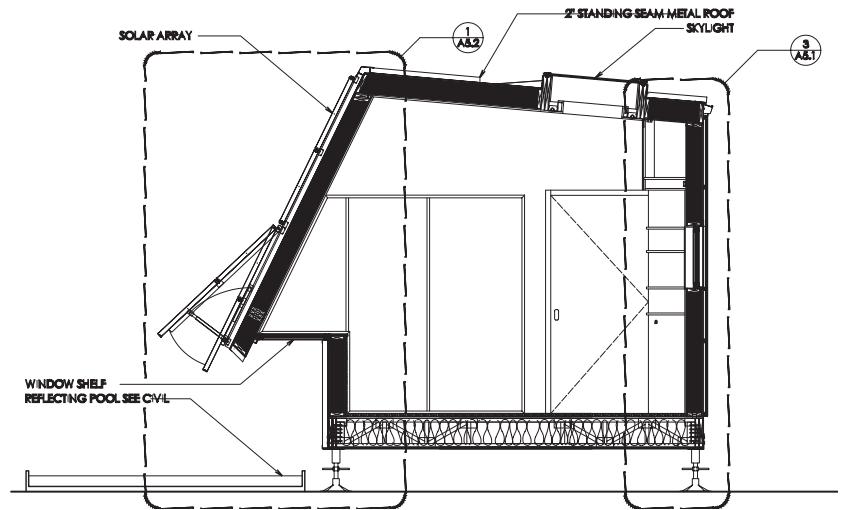
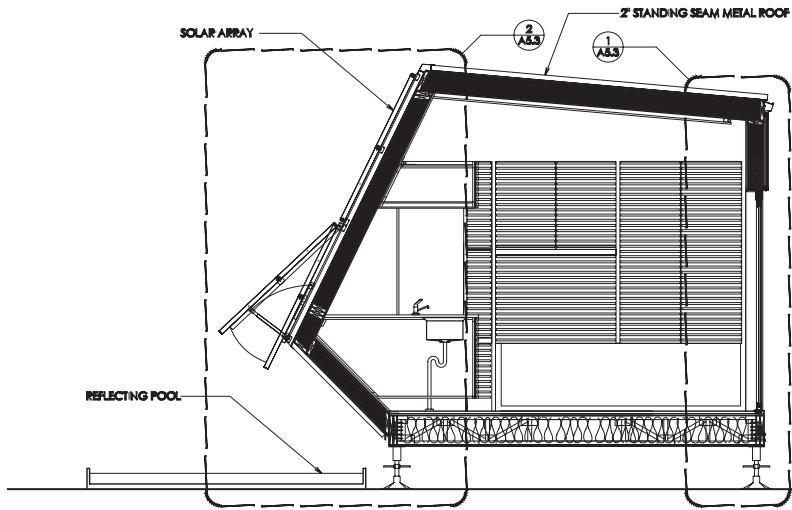
façade and adding a green roof. They detailed the building, specified materials and assemblies, and planned the procurement and construction phase of the project, which began in the spring of 2007. Construction commenced in March.

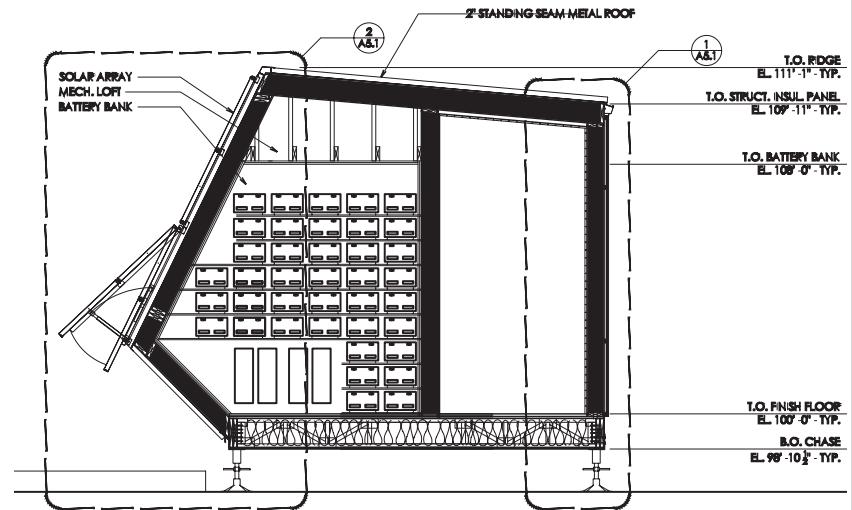
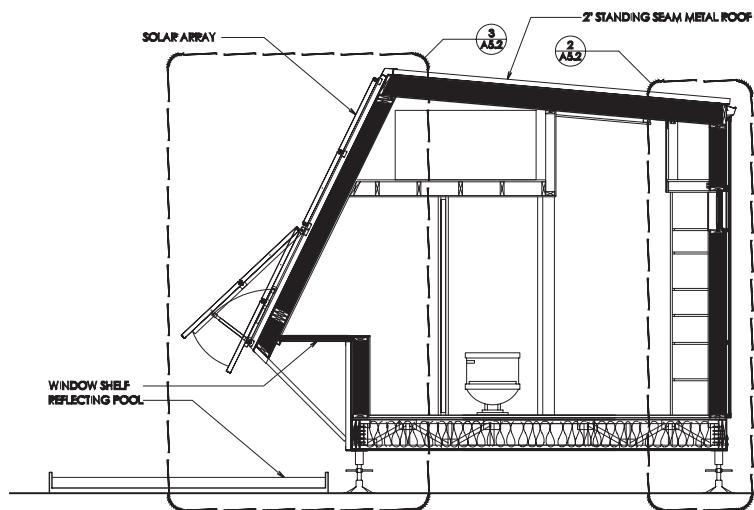
Design

The successful scheme was chosen for its approach to the points outlined above, its suitability as a competition entry, and its overall aesthetic. The scheme embraces its necessarily transportable nature. The basic parti is that of a long, rectangular volume that easily fits within shipping dimensions. It would be prebuilt and brought to the National Mall whole, ensuring the home can be quickly set up during the competition. The team researched both early and state of the art modern prefabrication techniques, visited factories, and consulted with industry experts. Though lagging behind European innovation,

the domestic premanufactured home industry has advanced considerably beyond its stereotyped beginnings in both the quality of their products and the scope of their offerings. Though the traditional stereotype of the long metal-clad trailer is still produced, many manufacturers produce housing stock that is indistinguishable from site-built construction. These homes, made in controlled factory conditions, are consistently higher in quality than conventional site-built structures and, as the homes must survive transportation sometimes for hundreds of miles, are inherently more durable. They are also built much more quickly. Kan-Build, a local home factory, can push a home through their assembly line in twelve days. The team borrowed several useful strategies from this industry to ensure the road-worthiness of the solar house.

Though its basic shape does mimic the stereotypical "trailer" the design of





the house is not limited by this basic format. The design's most recognizable feature was its highly activated, almost organic form—a long, horizontal shell with an inclined southern surface developed to absorb sunlight and act as a thermal shelter for the interior space. The south façade, not the roof, is the main source of solar collection. The sectional quality of the house is heavily influenced by the south wall, canted to the highest recommended winter azimuth angle for solar collection in Kansas. Thus, the photovoltaic array influences the interior space experientially, is integrated as the finish surface of the south façade, and is visible for public view.

To address occupation, the team performed an analysis of the process of daily home life. It was realized that creating a linear circulation flow would not only help organize space which would directly respond to human activity. One arises in the morning, dresses and cleans, eats breakfast, perhaps lounges for a few minutes, then leaves for work. In the evening, the process reverses itself. The layout of spaces

in the solar house streamlines this sequence of events, to make normative occupation as easy and uncomplicated as possible.

The home's interior space is divided into three components—public, private, and service. The public areas of the home are informal, mutable; they can be programmatically active or can transform into one large space for more specialized purposes, such as entertaining. These areas are strongly connected to expansive exterior decks, which essentially doubles the house's 800 square foot conditioned area. Glazed doors to the north and the south can be completely moved away to open the interior to the exterior. The private spaces—bedroom and bath—are more isolated. Glazing in these areas is obscured, indirect, or both. Northern vertical apertures are tucked behind the translucent polycarbonate rain screen, allowing daylight in while retaining privacy. At night, these apertures glow through the exterior surface as if a lantern. Another significant design feature in the private spaces is a horizontal light

well, which allows direct sunlight to bounce into the house from a reflecting pool set below the canted southern photovoltaic wall. The reflected light will play across the interior surface of the southern façade. These secluded spaces are separated from the public areas by a thick technology wall. The technology wall houses all of the building services—the galley kitchen, work space, mechanical system, and storage—and conceals them until they are activated. The wall is emphasized by a surface of horizontal slats made of reclaimed siding salvaged from a demolished barn.

Much thought was placed on building performance. The house's approach to energy efficiency is fourfold—reduce heat movement through the envelope; make use of passive systems, especially daylighting; utilize the most efficient energized equipment available; and incorporate a high level of control over active systems. Shading strategies are the building's first line of defense against heat gain and insulation will protect against the extremes of both winter and summer. The building shell

is extremely well-insulated. It is built of structural insulated panels (SIPs): two layers of oriented strand board that sandwich polystyrene insulation. SIPs are strong, lightweight, and are far better insulators than conventional stud framing. SIPs are much more tightly constructed, eliminating unintended drafting, and since they are constructed without studs, they defeat thermal bridging. The SIPs contribute to the structural performance of the house as well. They obviate the need for beams, columns, even ridge poles. The north and south walls are the primary structural elements, holding up the single-sloped roof. The roof SIPs span roughly ten feet without any additional support. The south wall, canted as it is away from the floor plate, transfers its load to short interior walls spaced roughly 16 feet on center.

The house takes full advantage of daylight, as noted above, to reduce and even eliminate daytime lighting load. The lighting, HVAC system, and appliances are all extremely efficient. The lighting system of the house predominantly uses fluorescent lamps, with

some LED accents. Ambient lighting utilizes traditional fluorescent tubes, powered by dimmable electronic ballasts. Task lighting uses compact fluorescent bulbs. The appliances, all the most energy efficient on the market, include a magnetic induction range, a dual drawer dishwasher, and a horizontal axis washer. Our drying needs will be met by a centrifugal dryer, which squeezes up to 95% of the water from clothing by high speed spinning rather than heat. Our final strategy is to incorporate active controls on all energized systems. Careful zoning of the program further reduces requirements for both lighting and thermal energy. The house employs occupancy and photo-sensors for lighting to ensure that no energy will be wasted where it isn't needed.

The house's response to energy efficiency extends to materiality. The design's low embodied-energy approach incorporates many building products that are natural rather than highly refined, recycled or reused, or waste-originated. Some are engineered from waste products from other processes, like oriented-strand board for the skin of the SIPs and the fiberboard and plywood substrate for cabinetry and furniture. Others are reused or recycled, like the barn siding. Countertops and the bathroom floor are made of Enviroglas, a terrazzo that uses recycled glass chips for aggregate. Yet others contribute to indoor environmental quality. The cabinet and furniture stock are made using formaldehyde free binders. All paints and stains will be environmentally benign.

The use of these products highlights alternatives to traditional construction that use abundant resources, and are low in embodied energy, interior off-gassing, and construction waste.

A team of landscape students took on the design of the site on the mall and the development of ecologically sustainable site systems. Their intent was to integrate the site design with the intent of the solar house itself. They determined to bring a sense of the Kansas landscape to Washington. As a temporary installation, all site improvements must be held off the ground below. The students designed planters made of recycled materials such as salvaged tin roofing from a local barn. Through the placement of these planters the designers proposed a site circulation route that wove through a variety of exterior spaces. Native, perennial Kansas vegetation was chosen over non-native species. The students also specified the plantings for the green roof, retention tanks to collect rainwater runoff and a grey-water treatment system, both used to irrigate site plantings.

Construction

Construction commenced in late March 2007. It is anticipated that the construction phase will conclude around the first of August. The initial component, the floor plate of the structure, was donated by Kan-Build and shipped to the construction site. The floor is designed to withstand the stresses of transportation and it provided a stable base on which to construct the house. The next step was



the assembly of the thirty-four pieces of the SIP shell. This phase began on April 6 with the erection of the north wall and was concluded 11 days later when the final roof panel was hoisted into place. The incredibly fast construction is due to the small number of components involved--thirty four panels in all--and the fact that SIPs contain structure, sheathing and insulation all at once. In normative stud construction, the structural frame is installed first, then sheathing, then insulation, and finally interior and exterior finishes. Another factor contributing to the speed of the installation is that the SIPs were factory made to fit together within an incredibly tight tolerance. The specifications were taken directly from the construction documents developed by the student design team.

In *Refabricating Architecture*, Keirnan and Timberlake comment on the many benefits to architectural design made possible by computer controlled, factory-produced components, including accuracy, precision, and quality. The one-to-one relationship between the structural drawings of the solar house and their construction is an affirmation of this new process of design.

As of this writing, the next step in the project is the installation of the two roof systems. The green roof is made waterproof by a spray-on insulation and roof system which eliminates the need for elaborate valley detailing. The remainder of the roof and the southern façade is clad in standing seam metal roofing, specified to provide frequent ridges



on which the photovoltaic panels will be clipped. Roofing, like the design and installation of the SIPs above, is a complicated procedure. The students organizing this phase of construction were responsible for product specification, negotiation with vendors, ordering the material and arranging its installation. For the roofing products, experienced professionals will be on hand to supervise and help as needed. Every student in the architecture studio is responsible for leading the development and installation of one or more building systems, expanding their sense of the limits of design as they move outside their comfort zone. Much was learned in this, as in every other phase of the project, as students came to grips with the reality that their design was

no longer just a paper project, but had to be made manifest.

Beyond the Decathlon

The solar house will continue to have utility after the competition. Even though Kansas has one of the highest potential solar harvests in the country, this potential has advanced little in the minds of the public and the construction industry. Project Solar House will be used to increase awareness of the sun as an energy source. One of the roles of the completed project will be outreach. In cooperation with the Kansas Energy Office, the team is investigating ways to utilize the project as a teaching tool after the competition. The house will also serve as a platform for research for interested faculty and students well into the future.

