ABSTRACT

Title of Document: INTEGRATING WASTE MANAGEMENT INTO THE ARCHITECTURAL PEDAGOGY: MODULARITY AND THE SOLAR DECATHLON

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Throughout our time in architecture school, countless hours are spent studying sustainability and environmentally friendly design. The concern will always be that these are just studies, not real life situations, and many constraints and issues can be ignored in academia. Studio culture does, however, provide a test bed for new ideas in sustainability, first realizing that it is not something that can be invented overnight but instead is born from the marriage of tradition and convention and blended with modernity. These are important issues in reducing waste on the front end of a design, not in the final stages. Bean counting such as LEED© does not lead to green design, but rather sustainability must be considered holistically from the beginning in dimensioning, material selection, and construction method. The 2007 Solar Decathlon provided an excellent case study to test this idea of sustainability through integration into studio culture, and the marriage of conventional and modern methods.

INTEGRATING WASTE MANAGEMENT INTO THE ARCHITECTURAL PEDAGOGY: MODULARITY AND THE SOLAR DECATHLON

By

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Dissertation submitted to the Faculty of the Graduate School of the
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Preface

Every two years the United States Department of Energy, in collaboration with the National Renewable Energy Laboratory and countless sponsors, holds the Solar Decathlon, an international university competition for sustainable homes powered completely by the sun. The Solar Decathlon provides an opportunity for students to design and build an 800 square foot self-sustaining house reconstruct and exhibit their homes on the National Mall over a period of three weeks.

The thesis premise: use LEAFHouse to demonstrate that, through multi-disciplinary design, a more responsible and sustainable architecture can be produced. LEAFHouse demonstrates the following five principles that, in combination with each other, work as a framework that guided the project from start to finish, and that illustrate the thesis premise brought to conclusion.

1. Use nature as inspiration and mentor.
    a. The leaf as nature's ultimate solar collector.
    b. Touching lightly on the earth.
2. Demonstrate practicality of solar technology.
    a. Using innovative and time tested active and passive technologies.
    b. Ease of integration with conventional technologies.
3. Change the design and build process.
    a. Interdisciplinary design – architecture, engineering, communications, economics, chemistry, and finance students.
    b. Intergenerational design – working with faculty, industry professionals and mentors.
4. Address the Chesapeake Bay Watershed issues.
    a. Erosion/Water Pollution – Green Wall, Grey Water Garden
    b. Humidity – Liquid Desiccant Wall
5. Raise awareness about practical solutions and environment stewardship.
    a. Integrate signage and communications materials into house experience.
    b. Public tours and presentations.

This document has been prepared as a record for the work and accomplishments of the 2007 University of Maryland Solar Decathlon Team and fulfills the requirements of the Graduate School as a Master's Thesis Document. Its purpose is to serve to assist future Decathletes and Solar Decathlon Teams through their design processes by using the LEAFHouse as a model and guide. Discussions will focus on team building and hierarchy, project organization and process (using sketches, drawings, written material, design documents, graphics, etc.) which were completed over the two year course of the project.

The majority of this information will be contained in the appendix to this document and will be cited throughout the thesis that follows. This document also serves to provide personal testaments, experiences, and lessons as to the importance of this project, not only in academia (to architecture and engineering students) but to the professional realm and the leaders of tomorrow that will mold the future of sustainability as well. The appendix to the document was completed as a collaborative effort between team leaders, and serves to portray the design process that emerged and evolved, as well as the teams' participation in the Solar Decathlon. In addition, team leaders made individual observations and chose to focus on certain aspects of the project, reflected in the first section of the document. These documents provide personal testaments to the importance of this project to not only architecture and engineering students but to the leaders of tomorrow.

Dedication

To my family, and all those along the way who have made this thesis and the extraordinary experiences associated with it possible. It was a great run!

Thank you.

Acknowledgements

I would like to acknowledge everyone who has made this thesis possible. Over the past one and a half years that I have worked on this project, there have been too many people involved to count, let alone mention. I will make no attempt to start to mention names because without a doubt, someone would be mistakenly left off the list. Without the hard work of so many dedicated people, the LEAFHouse would not have been possible and our accomplishments would never have been reached. This thesis is to serve as a record of those accomplishments and off the dedication of so many to this project.

Thank you.

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Chapter 1: LEED and Sustainability

History[1]

In 1994, in part due to the increasing concern about the environmentally unfriendliness of the modern built environment, the National Resources Defense Council (NRDC) established a steering committee to study the way structures were designed and built in the hope of establishing a rating system for sustainable design. In turn the steering committee established a task force, which included non-profit public agencies, government officials, architects, engineers, as well as developers, contractors, builders, and industry manufacturers to help advise them during the process. In 1998, after four years of study, the United States Green Building Council (USGBC) established the Leadership in Energy and Environmental Design (LEED) Green Building Rating System.

The overall goal of the new LEED rating system was to provide a checklist of standards for environmentally friendly design and construction. It was created to accomplish the following:

- Define green building by establishing a common standard of measurement
- Promote integrated, whole-building design practices
- Recognize environmental leadership in the building industry
- Stimulate green competition
- Raise consumer awareness of green building benefits
- Transform the building market

[1] United States Green Building Council. www.usgbc.org.

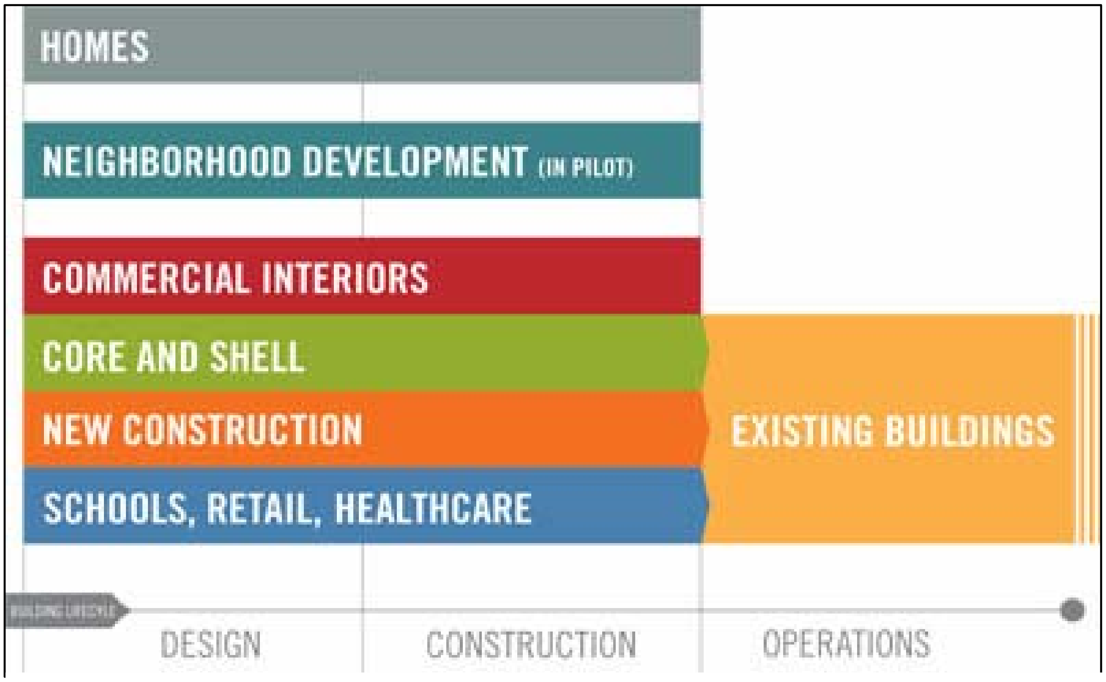


Figure 1. LEED Rating Systems [USGBC]

In addition, its purpose was to "encourage and accelerate global adoption of sustainable green building and development practices through the creation and implementation of universally understood and accepted tools and performance criteria." In 1996, there was only one rating standard that was established that dealt solely with new construction. Since that time, however, eight more ratings areas have been established dealing with the realms of existing buildings, commercial interiors, core and shell, schools, retail, healthcare, residential homes, and neighborhood development. Each one of these ratings areas have had the LEED system specifically adapted to its needs and functions, so that each system is tailor made to fit with a specific typology or condition. The USGBC realized very early on that no one ratings system could account for the vast array of difference in each of the nine areas, and as such, they are constantly tweaking the existing ratings, as well as establishing new areas as additional situations arise in this country. In addition to the growth of the ratings system itself, the USGBC and the LEED system have seen rapid growth in their staff and technical advising committees. Since its inception in 1998, the USGBC has increased its capacity from one committee of six volunteers, to twenty committees of over two-hundred volunteers in 2006.

Today, the LEED system has become the "nationally accepted benchmark for the design, construction and operation of high performance green buildings." The rating system gives designers, owners, and operators the needed tools to positively impact their building's performance and environmental impact. In creating the LEED system, the USGBC wanted to promote a "whole-building approach to sustainability by recognizing performance in five key areas of human and environmental health. These five major subcategories of each rating system show at the top of the previous page include (1):

- Sustainable site development
- Water savings
- Energy efficiency
- Materials selection
- Indoor environmental quality

In addition, points are subjectively awarded for added innovation within the design and/or construction of the building and site.

Within each of these areas is a series of itemized lists with the United States Green Building Council has deemed important for a sustainable, environmentally friendly building. The USGBC has in turn assigned a specific point value to each of the items in the category, and to the category as a whole. With the aid of industry professionals and consultants, an architect, engineer, contractor, or owner can go through the list and determine which items, if any, from each category they think they can fit/afford into their building and site. If an item or strategy is employed in the design, then full points are awarded for that item. When the points are tallied, the project can receive a LEED rating on four distinct levels: LEED Certified (26-32 pts), LEED Silver (33-38 pts), LEED Gold (39-51 pts), or LEED Platinum (52-69 pts). The higher the score, the more environmentally friendly and sustainable the design is considered by the USGBC, and public recognition or even government grants can be awarded to the project.

LEED: Here and Now[2]

LEED accreditation has become a very important aspect in the modern built environment, not only in the United States, but around the world, as it pushes to "provide independent, third-party verification that a building project meets the highest green building and performance measures. All certified projects receive a LEED plaque, which is the nationally recognized symbol demonstrating that a building is environmentally responsible, profitable and a healthy place to live and work." Many government agencies, such as the Department of Defense and the Department of Agriculture, have mandated LEED accreditation on all of their projects. Many state and local jurisdictions are also requiring certification at some level for any public-owned or publicly funded project. Additionally, LEED based projects are currently underway in forty-one countries around the world, including Mexico, Canada, and India.

Many professionals, from architects and engineers, to real estate agents and facility managers, are becoming LEED certified in order to better understand what

[2] United States Green Building Council. www.usgbc.org.

role they each play in the development of the ideas surrounding sustainability, with each recognizing that through LEED accreditation and certification, buildings and environments are created which have(1):

- Lower operating costs and increased asset value.
- Reduce waste sent to landfills.
- Conserve energy and water.
- Healthier and safer for occupants.
- Reduce harmful greenhouse gas emissions.
- Qualify for tax rebates, zoning allowances and other incentives in hundreds of cities.
- Demonstrate an owner's commitment to environmental stewardship and social responsibility.

It is our responsibility as architects and designers to be stewards and guardians for nature and our surroundings and to conceptualize, design, specify, and detail in such a way as to enhance our environment and quality of life. For many years we relied on technology and energy to make our buildings comfortable and habitable, and we have suffered for it. Good design is environmentally friendly design, a design that minimizes its impact on the surrounding environment, both natural, and man-made. The LEED rating system has come a long way in its ten years of existence to try to tackle this daunting task, and it will continue to develop to better address the most critical issues at hand in the future as our ideas about being “green” and “sustainable” continue to be molded and adapted.

Project Checklist

Sustainable Sites — 14 Possible Points

Prereq 1	**Construction Activity Pollution Prevention**	Required
Credit 1	**Site Selection**	1
Credit 2	**Development Density & Community Connectivity**	1
Credit 3	**Brownfield Redevelopment**	1
Credit 4.1	**Alternative Transportation**, Public Transportation Access	1
Credit 4.2	**Alternative Transportation**, Bicycle Storage & Changing Rooms	1
Credit 4.3	**Alternative Transportation**, Low Emitting & Fuel Efficient Vehicles	1
Credit 4.4	**Alternative Transportation**, Parking Capacity	1
Credit 5.1	**Site Development**, Protect or Restore Habitat	1
Credit 5.2	**Site Development**, Maximize Open Space	1
Credit 6.1	**Stormwater Design**, Quantity Control	1
Credit 6.2	**Stormwater Design**, Quality Control	1
Credit 7.1	**Heat Island Effect**, Non-Roof	1
Credit 7.2	**Heat Island Effect**, Roof	1
Credit 8	**Light Pollution Reduction**	1

Water Efficiency — 5 Possible Points

Credit 1.1	**Water Efficient Landscaping**, Reduce by 50%	1
Credit 1.2	**Water Efficient Landscaping**, No Potable Use or No Irrigation	1
Credit 2	**Innovative Wastewater Technologies**	1
Credit 3.1	**Water Use Reduction**, 20% Reduction	1
Credit 3.2	**Water Use Reduction**, 30% Reduction	1

Energy & Atmosphere — 17 Possible Points

Prereq 1	**Fundamental Commissioning of the Building Energy Systems**	Required
Prereq 2	**Minimum Energy Performance**	Required
Prereq 3	**Fundamental Refrigerant Management**	Required
Credit 1	**Optimize Energy Performance** (2 points mandatory for LEED for New Construction projects registered after June 26, 2007)	1–10
Credit 2	**On-Site Renewable Energy**	1–3
Credit 3	**Enhanced Commissioning**	1
Credit 4	**Enhanced Refrigerant Management**	1
Credit 5	**Measurement & Verification**	1
Credit 6	**Green Power**	1

Materials & Resources — 13 Possible Points

Prereq 1	**Storage & Collection of Recyclables**	Required
Credit 1.1	**Building Reuse**, Maintain 75% of Existing Walls, Floors & Roof	1
Credit 1.2	**Building Reuse**, Maintain 95% of Existing Walls, Floors & Roof	1

LEED for New Construction Version 2.2 9
October 2005 - Revised EA section for projects registered after June 26, 2007

Figure 2. LEED Certification Checklist for New Construction, Page 1. [USGBC]

Credit 1.3	**Building Reuse**, Maintain 50% of Interior Non-Structural Elements	1
Credit 2.1	**Construction Waste Management**, Divert 50% from Disposal	1
Credit 2.2	**Construction Waste Management**, Divert 75% from Disposal	1
Credit 3.1	**Materials Reuse**, 5%	1
Credit 3.2	**Materials Reuse**, 10%	1
Credit 4.1	**Recycled Content**, 10% (post-consumer + 1/2 pre-consumer)	1
Credit 4.2	**Recycled Content**, 20% (post-consumer + 1/2 pre-consumer)	1
Credit 5.1	**Regional Materials**, 10% Extracted, Processed & Manufactured Regionally	1
Credit 5.2	**Regional Materials**, 20% Extracted, Processed & Manufactured Regionally	1
Credit 6	**Rapidly Renewable Materials**	1
Credit 7	**Certified Wood**	1

Indoor Environmental Quality — 15 Possible Points

Prereq 1	**Minimum IAQ Performance**	Required
Prereq 2	**Environmental Tobacco Smoke (ETS) Control**	Required
Credit 1	**Outdoor Air Delivery Monitoring**	1
Credit 2	**Increased Ventilation**	1
Credit 3.1	**Construction IAQ Management Plan**, During Construction	1
Credit 3.2	**Construction IAQ Management Plan**, Before Occupancy	1
Credit 4.1	**Low-Emitting Materials**, Adhesives & Sealants	1
Credit 4.2	**Low-Emitting Materials**, Paints & Coatings	1
Credit 4.3	**Low-Emitting Materials**, Carpet Systems	1
Credit 4.4	**Low-Emitting Materials**, Composite Wood & Agrifiber Products	1
Credit 5	**Indoor Chemical & Pollutant Source Control**	1
Credit 6.1	**Controllability of Systems**, Lighting	1
Credit 6.2	**Controllability of Systems**, Thermal Comfort	1
Credit 7.1	**Thermal Comfort**, Design	1
Credit 7.2	**Thermal Comfort**, Verification	1
Credit 8.1	**Daylight & Views**, Daylight 75% of Spaces	1
Credit 8.2	**Daylight & Views**, Views for 90% of Spaces	1

Innovation & Design Process — 5 Possible Points

Credit 1.1	**Innovation in Design**	1
Credit 1.2	**Innovation in Design**	1
Credit 1.3	**Innovation in Design**	1
Credit 1.4	**Innovation in Design**	1
Credit 2	**LEED Accredited Professional**	1

Project Totals — 69 Possible Points

Certified 26–32 points Silver 33–38 points Gold 39–51 points Platinum 52–69 points

LEED for New Construction Version 2.2 10
October 2005 - Revised EA section for projects registered after June 26, 2007

Figure 3. LEED Certification Checklist for New Construction, Page 2. [USGBC]

Chapter 2: The Solar Decathlon and Sustainability

The Guidelines

In the spring of 2006, University of Maryland graduate architecture students embarked on the initial conceptions for their school's entry into the 2007 Solar Decathlon. These studies were carried out by a studio of approximately six graduate students, led by three faculty advisors from the architecture and engineering departments. During this spring semester, each student first conceptualized their own project, and then each of the six designs was reviewed. Following the review, students were paired up in teams of two according to likenesses in their original design concepts, project parti, or goals. Each of these three teams was then given the task to design what they believed to be the most suitable entry into the Solar Decathlon.

At the conclusion of the spring semester, the three distinct designs were presented to the faculty. These three designs can be found in the appendix to this document. In addition, professionals and tradesman who would be involved with the house were brought in to assess each of the designs and weigh in on the pros and cons of each concept from every possible angle, including heating loads, transportation, constructability, and market appeal. Notes were attached to each scheme to highlight the positive aspects of the design, and at the end, these notes were collected in order to draw out the best of each of the three schemes into what would hopefully be an all-inclusive final scheme.

From these notes, and over the following summer and fall semester, during countless collaborative meetings, brainstorming sessions, and workgroups, the team slowly began to create an image or brand for their decathlon entry. By the end of this tedious yet eye opening process, the team had created five guiding principles that would serve as the basic guidelines for the house as the project moved forward from conception to construction. The guidelines were to be used to shepherd the team to use LEAFHouse to demonstrate that, through multi-disciplinary design, a more responsible and sustainable architecture can be produced, and are as follows:

1. Use nature as inspiration and mentor.
    c. The leaf as nature's ultimate solar collector.
    d. Touching lightly on the earth.
2. Demonstrate practicality of solar technology.
    e. Using innovative and time tested active and passive technologies.
    f. Ease of integration with conventional technologies.
3. Change the design and build process.
    g. Interdisciplinary design – architecture, engineering, communications, economics, chemistry, and finance students.
    h. Intergenerational design – working with faculty, industry professionals and mentors.
4. Address the Chesapeake Bay Watershed issues.
    i. Erosion/Water Pollution – Green Wall, Grey Water Garden
    j. Humidity – Liquid Desiccant Wall
5. Raise awareness about practical solutions and environment stewardship.
    k. Integrate signage and communications materials into house experience.
    l. Public tours and presentations.

The Design

The design of the LEAFHouse and its components gained its most momentum during the fall 2006 semester. Following the five guidelines listed above, the team set out to design a sustainably-minded house through the collaborative efforts of its interdisciplinary team. This was initially done through the use and incorporation of solar technologies in the house. It was deemed that the most sustainable way to do this was to integrate these new technologies with conventional methods so as to lessen the need for extreme innovation. In addition, incorporating designs specially suited for the regional characteristics of the Chesapeake Bay Watershed helped the team mold an idea about sustainability in our local region. However, due to many of the constraints placed on the competition by the Department of Energy, the Park Service, and other government agencies, many oddities were developed in the plans of many of the houses. At one point, LEED certification for the house was even considered, but it was determined that the house did not quite fit into any of the ratings categories, and that, in fact, the LEED rating system simply did not accomplish all of the goals for sustainability that the team had in mind for this house.

One of the most important constraints put on the competition was an eight-hundred square foot allowance for all of the houses. This included all conditioned space, as well as any device that was used to shade on the exterior of the house. Also included in this allowance was anything technology that used solar power, such as solar powered site lights. In addition, each house had a strict eighteen foot height limit and solar envelope drawn over their “lot” on the National Mall so that no house could shade or block the sun from its neighboring houses. This height limit had a tremendous impact on the quality and size of interior spaces in all of the houses on the Mall.

Early in the design process, however, the team had gone away from the flat-roof box concept with tilted photovoltaic panels and instead decided on a house with a much more volumetric interior with a sloped roof that would better integrate the PV panels into the design. After many studies, the minimum PV angle that was needed was determined, and this provided yet another constraint onto the design of the house. Due to such constraints that were placed on the team early on during the design

Figure 4. Cutting of FSC 2”x6” Studs for Wall Framing [LEAFHouse Team]

development process, it was quickly found during the construction documents phase that many of the dimensions the team had back themselves into a corner with were not anywhere near what is considered to be conventional framing dimensions for available materials.

Due to this fact, the team had forced themselves into odd dimensions and a tremendous amount of wasted materials during the construction process. Every attempt was made to use sustainable materials, and in many instances, such as our Forest Stewardship Council (FSC) 2”x6” studs, environmentally friendly products were ordered to try to offset the amount of waste generated. For instance, due to the needed angle of the sloped roof for the PV array and the eighteen foot height limit, the team had forced themselves into a finish ceiling height in the flat roof portions of approximately 7'-1", which was only one inch above the minimum allowable clearance by code. This ceiling height in turn lead to a framed wall height of approximately 7'-3" and a stud height of 6'-10 ½". The only studs available on the

Figure 5. View of Waste Piles on Site. [LEAFHouse Team]

market come in eight foot lengths, so the team had to settle for cutting and losing over twelve inches from each of the over two-hundred studs used in the framing of the house. Additionally, early on the house had been set at the odd roof framing dimension of 2'-9" on center for the rafters. While this may not at first seem significant, normal roof sheathing is designed to be installed on sixteen inch or twenty-four inch on-center dimensions. Although oriented-strand board (OSB) sheathing, which is considered to be a sustainable product made of waste materials, was used on the roof, there was tremendous waste of materials during the sheathing process because of the odd framing dimensions. This material could not be used for anything else on the project, so it was all discarded into a waste dumpster for removal.

There were quite a few counterintuitive items and methods that were present in the LEAFHouse design, many simply because the team had chosen to stick with them because it was too late in the process to rethink, revisit, and redesign and detail the issues. Structurally Insulated Panels (SIPS) were discarded as a possible sustainable idea early on because the design was simply not far enough along to produce the needed shop drawings for the manufacturer. Additionally, the SIPS panels would not have provided the necessary flexibility that the team had to have with a prototype building such as the one they were designing. The team saw many items go and many items stay throughout the design process, with each part having some sort of impact on the overall sustainability of the design and construction of the project.

Chapter 3: Sustainability Lessons

As was previously stated in the abstract to this document, countless hours are spent studying sustainability and environmentally friendly design during architecture school, including the USGBC LEED rating system mentioned in earlier sections. While these studies are extremely valuable and helpful in molding students' ideas concerning sustainability and green design, the concern will always be that these are just studies, not real life situations, and many constraints and issues can be ignored in academia that affect sustainability in the real world. Studio culture does, however, provide an excellent test bed for new ideas in sustainability, first realizing that it is not something that can be invented overnight but instead is born from the marriage of tradition and convention and blended with modernity. These are important issues in reducing waste on the front end of a design, not in the final stages. Bean counting such as the LEED rating system does not lead to green design, but rather sustainability must be considered holistically from the beginning in dimensioning, material selection, and construction method. The 2007 Solar Decathlon provided an excellent case study to test this idea of sustainability through integration into studio culture, and the marriage of conventional and modern methods.

As mentioned in the previous section concerning some of the design guidelines and aspects surrounding LEAFHouse, faculty advisors decided early on to use the LEAFHouse project for research in ideas about methods for sustainable design and construction. This was not something that was stipulated by the Solar Decathlon regulations or even actively encouraged by the competition coordinators, as it was something that is very difficult to measure in a competition such as this. It was also realized early on that the LEED rating system did not quite fit into this project, and that was something that needed to be addressed within the design, detailing, and construction of the house. In a way, LEAFHouse stood as a critique of how sustainability is currently viewed and practiced in this country.

Sustainability today, as it is most often viewed through the LEED process, almost works backwards with in the design. A building can achieve high LEED certification without ever severely impacting the design, construction materials and methods, and materials selection. As was shown in the LEED checklist at the end of Chapter 1, LEED points can be achieved in such areas as access to public transportation, and the inclusion of bike racks. Points are also awarded for recycling programs, and the use of low-flush toilets and other water reduction devices. While these areas and means are undoubtedly important to reducing the negative impact of buildings on the environment, they do not impact the design of the building, and many are not actually designed and incorporated into the structure from the beginning of the project, but merely specified in the project manual for finishes. Where LEED fell short was not only in the lack of holistic approach, but also in the point values assigned to various categories.

Sustainability is something that needs to be viewed from the ground up, not the top down. In order to be truly successful on all scales of a building, it is something that has to be incorporated into the every phase of a project, starting with the original proposal and design guidelines and ending with the construction documents and project manual. In a well established firm that has been building their ideas surrounding sustainability for years, this may be something that has already been introduced into the design process and culture of the firm, taking their sustainability levels far beyond those “minimum requirements” contained in the LEED rating system. Based on years of design experience, many more factors are known that can be included in the process concerning proper dimension of materials and the like. In an academic setting, such as the one surrounding the design and construction of the LEAFHouse, this information and its related “constraints” are not known by students. Therefore, many items that could be designed and constructed on such a project require much more materials and/or generate much more waste than they would otherwise if conventional means and methods were studied and explored in more depth in the studio culture, and more resources were made available to students to investigate those items.

Through the collaborative design environment that was used for LEAFHouse, many items were constructed to be as sustainable as possible. For instance, the design team was in constant contact with the engineering team when it came to the efficiency of the exterior envelope, something that is not specifically addressed and covered in the LEED process. The structure and envelope of a building is very important to its overall efficiency and life-span. The design team was constantly modifying glazing sizes and types, as well as wall thicknesses and insulation depth and values to try to achieve as optimal and efficient shell to LEAFHouse as was possible with the constraints on the project. For instance, the north skylight ridge was changed from clear, double-pane glazing to Nanogel filled polycarbonate panels due to the fact that the energy model showed that clear glazing would adversely affect the heating load so dramatically that it would offset the benefits of the natural daylight coming through the opening.

In addition to working with the energy modeling team on the exterior shell of the building, the design team also worked with the structural consultants to ensure that the “optimal energy envelope” would mesh effectively with the needs and structural requirement of the building. All of these collaborations occurred very early on during the design process so that every angle would be considered and all important aspects would be incorporated from the very beginning.

As the design and construction process continued through the spring 2007 semester, the team gained more experience with conventional construction materials and methods and more adept at designing around these aspects to create an efficient structure. As was mentioned in earlier sections, the roof framing was designed early on in the process based on a 2’-9” on center rafter dimension, a dimension that was completely unsuitable for available sheathing dimensions without wasted a significant amount of material. While the team had accepted and embraced this aspect of the design, concluding that there just was not enough time to revisit the entire issue, they were not content with the waste of material. Because of this, the design and construction teams decided to incorporate blocking in the rafter bays where the sheets of roof sheathing would hit. This blocking allowed the sheathing to be run continuously across the roof without custom cutting, greatly reducing waste of material. Here again, is an instance of where the LEED system does not account for such an issue. LEAFHouse had a recycling program for construction waste, which is included in LEED credits, but they were not content with simply falling back on that option. Instead, they were proactive in changing what they could within the design system such that less material had to be ordered, less waste was generated, and less recycling was needed.

Another such instance where the lack of conventional knowledge in the pedagogy impacted the design was in dealing with the exterior decks. The team also had to deal with competition regulations in this realm, mainly with the angles of the solar envelope on the site, which limited the reach of the decks on the site. During the design phase, however, the team had no idea of the sizing of traditional deck framing lumber, and instead, the decks were sized to the needs of the structure, mainly when dealing with the north deck.

The north deck covered the large battery bank for LEAFHouse, and the batteries needed to be protected from the weather as much as possible to prevent corrosion on the terminals. Because of the racking system the team had chosen to move the batteries under the deck, it was determined that the deck needed to be approximately 12'-6" in length from the face of the house. While this was optimal for the protection of the batteries, it was not optimal for the use of material and the economy of funds available for the project. If the 12'-6" length for deck framing was maintained, it would mean the team would have to purchase 14' material and cut 18" off the end of each board. This would increase the overall cost of the material package, as well as increase the need for waste disposal of this material, since pressure-treated lumber cannot be recycled. The design and construction team quickly realized this issue based on their previously experiences on the project, and changed the deck dimension to 12' so that no material would be wasted in the construction of the beams for this deck. While this resolution led the batteries to be more exposed to the elements, it did save the team materials cost, as well as the disposal fee and environmental impacts that the treated lumber would have in a landfill. Again, we see an issue of going beyond the call of LEED demonstrated through the critical thinking of the LEAFHouse team.

It was about at this stage that the design and construction teams became much savvier as to the efficient use of conventional building materials and methods. For the remainder of the project, the teams were constantly collaborating on design issues to make sure that no issue such as the one previously mentioned was overlooked again. Every attempt was made to design within the constraints of the material that could be order so that both material and funds were used as effectively and efficiently as possible with minimal waste generated. This was not something that the team has learned in the classroom, in the studio, or from the LEED guidelines brochure. It was something that they had learned from the real-life situation of not only designing a structure/detail, but also seeing that detail through construction and observing how efficiently it was assembled, including labor time and material usage/waste. This was not a simple progression that happened overnight, but instead happened over months of collaborative efforts. While the LEED rating system currently does no incorporate such efficiency ratings into its accreditation, the architectural pedagogy could be changed so that such ground-up efficiencies permeate through the studio culture, lessening the learning curve for the students for projects such as LEAFHouse, as well as their future careers and dealings with sustainability issues.

Conclusions: The Future

To further the sustainable nature of the LEAFHouse, the team began looking at the issue of modularity in the spring of 2007, which can be found in the appendix to this document. In doing this study, the team was trying to look at how the house could be designed more efficiently using the traditional 16" and 24" on center dimensions to which the majority of building materials are designed to work with. This aspect of the design was to focus on reducing waste as much as possible through the efficient use of a broad spectrum of building materials by minimizing cuts that would have to be made on site and materials that would have to be discarded and recycled. Recycling is always an effective way at mitigating the waste that has been generated, but it is much better to reduce the issue of waste on the front end so that recycling is not even needed. The design was also based on the fact that the entire structure could be efficiently built of parts in a factory that were assembled on site, or that the house could be built conventionally but without the traditional waste that is present on the majority of construction site. Either method was equally suited to the more rationalized plan of the house and was sustainable in its effective use of materials.

The future of the architectural profession depends on its ability to adapt to the changing ideas surround the practice. While those already in the profession serve to help mold and incorporate these new ideas, it is the modern students and the academic environment which provide the most influence and pressure on the established realms to change. Sustainability and green design are one of the realms on which students today will have a tremendous impact on architecture in the future.

While students may work in constraint free studio environments, it is this lack of limits which allows ideas to form, grow, and become established principles of architecture. Studio culture provides a perfect test bed for new ideas in sustainability. However, real life constraints cannot always be ignored in the pedagogy. In order to fully understand and utilize the materials and methods which are still to come, students must first realize the conventional materials and methods which they have to deal with presently. When these methods are fully studied and understood, new ways of applying them will undoubtedly form. Sustainability, as it was demonstrated through the LEAFHouse project, is not something that can be started from scratch and be born anew overnight. Traditional know-how is vital in this discovery process, first realizing that sustainability is not something that can be invented overnight but instead is born from the marriage of tradition and convention and blended with modernity to use all the tools we have at hand in the most effective and efficient way as possible. Sustainability is not simply the bean counting that is represented and has been discussed in previous sections concerning the present state of the LEED rating system. Instead, it is a holistic issue deeply rooted in regional characteristics and traditional know-how. The growth of the knowledge of the LEAFHouse teams demonstrates the effectiveness a ground-up, collaborative approach to design has on the sustainability of the project, considering not only "green" material selection, but also proper dimensioning, material selection, and construction methods.

The LEAFHouse and the 2007 Solar Decathlon provided an excellent case study to test this idea of sustainability through integration into studio culture and the marriage of conventional and modern methods to use our tools most effectively, in the end proving that we still have far to go in our development of sustainable practice, but also showing that we have come along way in our notions of what being "sustainable" really means.

Appendices

The Solar Decathlon

Introduction

The Solar Decathlon is a design-build competition sponsored by the Department of Energy and the National Renewable Energy Lab. Proposals from twenty universities from around the world are accepted as part of this international competition to design and build an 800 sq. ft. completely solar-powered house. The competition takes place on the National Mall in Washington D.C. and consists of ten contests in which the teams partake while open to the public for tours.

Figure 6. Solar Village on the National Mall [Richard King]

The goals of the competition are to "challenge the student competitors to think in new ways about energy and how it impacts our everyday lives," as well as to "provide students with a way to show and tell the world what they have learned," and to "push research and development of energy efficiency and energy production technologies in order to encourage all of us to act responsibly when making energy choices" (http://www.solardecathlon.org/purpose.html).

The universities chosen to compete in the 2007 Solar Decathlon were:

Carnegie Mellon University

Technische Universitat Darmstadt

Cornell University

Texas A&M University

Georgia Institute of Technology

Universidad Politecnica de Madrid

Kansas State University/University of Kansas

Universidad de Puerto Rico

Lawrence Technological University

University of Colorado at Boulder

Massachusetts Institute of Technology

University of Cincinnati

New York Institute of Technology

University of Illinois at Urbana-Champaign

Penn State

University of Maryland

Santa Clara University

University of Missouri-Rolla

Team Montreal

University of Texas at Austin

Figure 7. Universities chosen to compete in the Solar Decathlon.

After being chosen to participate in the 2007 Solar Decathlon, the twenty universities were asked to choose a site for their house along Decathlete Way on the National Mall. The site orientation served as a basis for beginning design of the house.

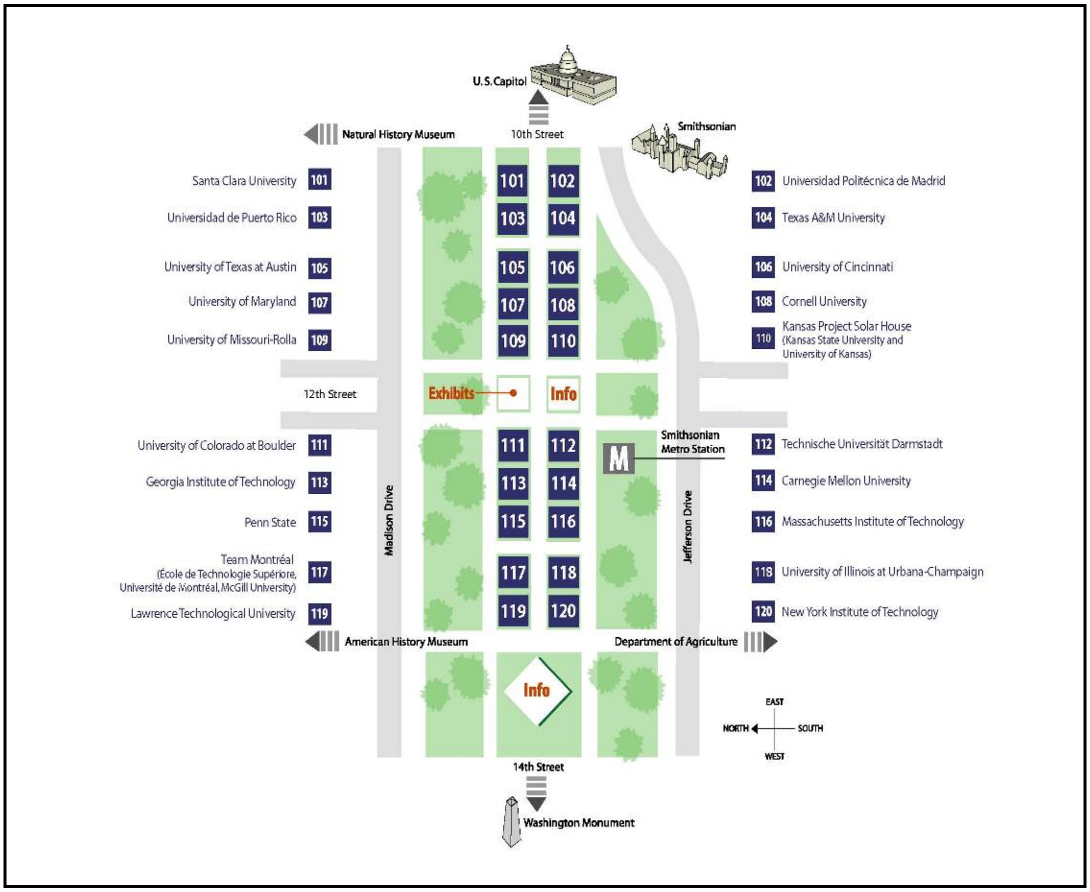


Figure 8. Chosen sites of houses on the National Mall.   [www.solardecathlon.org]

In addition to choosing a site, teams were also asked to use the Rules and Regulations established by the DOE and NREL as a set of guidelines for designing the houses and as a means for beginning to strategize about each of the ten contests. These contests include both subjective and objective contests ranging from architecture and engineering to hot water and energy balance and were judged on a series of criteria established in the Rules and Regulations. The criteria are as follows:

Solar Decathlon - The Ten Contests

Contest 1 – Architecture: To be architecturally sound, a home's design must not only satisfy human comfort needs, it must also be well organized and visually pleasing both inside and out. The Architecture contest is intended to demonstrate that solar-powered, energy-efficient homes can be designed to meet enduring architectural standards. A jury of architects will judge each entry on the overall aesthetics and the successful design and integration of the solar, energy-efficiency, and other technical features of the house. The jury will evaluate the houses early in the week of contests and will not be influenced by the objectively measured performances of the houses.

Contest 2 – Engineering: Although architects are critical collaborators in the engineering design of well-integrated high performance homes, engineers and other technical experts possess unique skills that are required to design, specify, install, and maintain the house's systems. A jury of technical experts in the residential building industry will judge each entry on the functionality, efficiency, innovation, robustness, and economic value of the house's building envelope, environmental control, mechanical, electrical, and plumbing systems.

Contest 3 – Market Viability: An important objective of the Solar Decathlon is to prove that homes containing solar and energy-efficient design and technologies are market ready and belong in the world's diverse neighborhoods. Experts from the building industry will compose the jury for this contest. Judging will take place early in the week of contests and will not be influenced by the objectively measured technical performance of the houses.

Contest 4 – Communications: The Solar Decathlon is a competition and a public event. The Communications contest challenges teams to communicate their experiences in this project to a general audience. Through Web sites and public tours, the teams will share the knowledge they have acquired. Their experiences and their houses will serve as living demonstrations of the viability of solar energy and energy efficiency technologies in the home. Panels of judges with expertise in communications and public relations will award points based on subjective evaluations of the teams' Web sites and house tours.

Contest 5 – Comfort Zone: Well-designed houses provide a safe and comfortable indoor environment for occupants through heating, cooling, humidity, and ventilation controls. In this contest, the teams will be evaluated objectively on their ability to maintain temperature and relative humidity within prescribed set points. Other aspects of indoor environmental quality will be evaluated in Contest 2: Engineering.

(http://www.solardecathlon.org/pdfs/sd07_rules_regs.pdf)

Figure 9. Ten contents with descriptions. [www.solardecathlon.org]

Solar Decathlon - The Ten Contests

Contest 6 – Appliances: A house is not a home without kitchen appliances, laundry facilities, and electronics such as personal computers and TV/video players. This contest requires the teams to demonstrate that their houses can provide the necessary energy to effectively operate appliances and electronics. The teams will store food in their refrigerators and freezers, host a dinner party, wash dishes, and do laundry during the week of contests. The teams will also be required to operate their personal computers and TV/video players a set number of hours each day. All points for this contest will be awarded based on task completion and objective performance evaluations of the required appliances and electronics.

Contest 7 – Hot Water: This contest demonstrates that the teams' houses can provide all of the energy necessary to heat water for domestic uses. Teams will receive points for performing tests that simulate the average time and temperature requirements for two showers each day of the contest week. Twice per day, teams will have to deliver 15 gallons (56.8 liters) of hot water (at least 110ºF [43.3ºC]) in no more than 10 minutes.

Contest 8 – Lighting: Sunlight, moonlight, and electric light all contribute to the livability and environment of a dwelling, inside and out. Lighting systems should be designed to minimize energy use by maximizing the contribution of daylighting and by using controls to minimize the use of electric illumination. This contest evaluates the quantity and quality of the lighting in the houses both day and night. Points will be awarded on a team's ability to provide acceptable lighting levels for specified durations. A jury of lighting experts will award points on the basis of subjective evaluations of the teams' lighting system designs.

Contest 9 – Energy Balance: is to produce as much or more energy than the house consumes over a defined period of time to demonstrate that the house and its systems function sustainably. Points will be awarded based on each team's ability to use their solar electric systems to produce as much electrical energy as they require during the contest week.

Contest 10 – Getting Around: Because the amount of energy households use to meet their personal transportation needs is so significant, this contest is designed to demonstrate that a house itself can be used to provide that energy. The contest evaluates how much "extra" energy the houses can generate to provide transportation for the teams in street-legal, commercially available electric vehicles, which will be provided by the organizers. All points for this contest will be awarded based on objective evaluation—the more miles the teams drive, the more points they get.

(The complete document of Rules and Regulations can be found on the Solar Decathlon website at: http://www.solardecathlon.org/pdfs/sd07_rules_regs.pdf)

Figure 10. Ten contests with descriptions (cont.'d) [www.solardecathlon.org]

Using these criteria as a framework for designing, the twenty chosen universities spent approximately two years designing and building their solar-powered houses, and then transported them to the National Mall in October of 2007 where they were completed and open for public tours. The ten contests were judged over the course of a week and subjective contest winners were announced each day. Final scores and standings were announced on the last day of the competition in an Awards Ceremony in which all teams were congratulated on their concerted efforts and outstanding achievements over the course of the project.

In order to accomplish the goals set forth by the Solar Decathlon, teams developed their own organization, strategies and ideals for designing and delivering a solar-powered house; aesthetically pleasing and functional, using available, off the shelf technologies as well as new and innovative means by which to live sustainably and energy efficiently.

Pre-Design

Introduction

Design of the University of Maryland 2007 Solar Decathlon entry began in January of 2006 in a graduate level studio. The goal of the studio was to design and detail the house to the level of Design Development Documents; the first set of deliverables judged by NREL. Before these deliverables could be completed, the studio, comprised of graduate students, faculty advisors, industry mentors and members of the 2005 Solar Decathlon Team, established principles, goals, and intentions for the house, separate from those set forth by the competition. These goals and intentions consisted of both individual and team goals and intentions as well as goals and intentions for the house ranging from discussions about how to tell the story of the house and communicate the message to the public, to the desire to have the design of the house reflect the principles established by the team. A means for making design development and competition decisions was developed by way of a team organization consisting of a flat hierarchy of students from a variety of disciplines within the university.

Team Organization

The team consists of a cadre of eager, intelligent, insightful, committed students from disciplines including architecture; mechanical, electrical, structural, environmental, computer, and aerospace engineering; computer science; economics; accounting; English; journalism; communication; finance; chemistry; physics; neuroscience; geography; and landscape architecture. The group of faculty, professional colleagues and mentors represents an equally broad spectrum of knowledge and expertise.

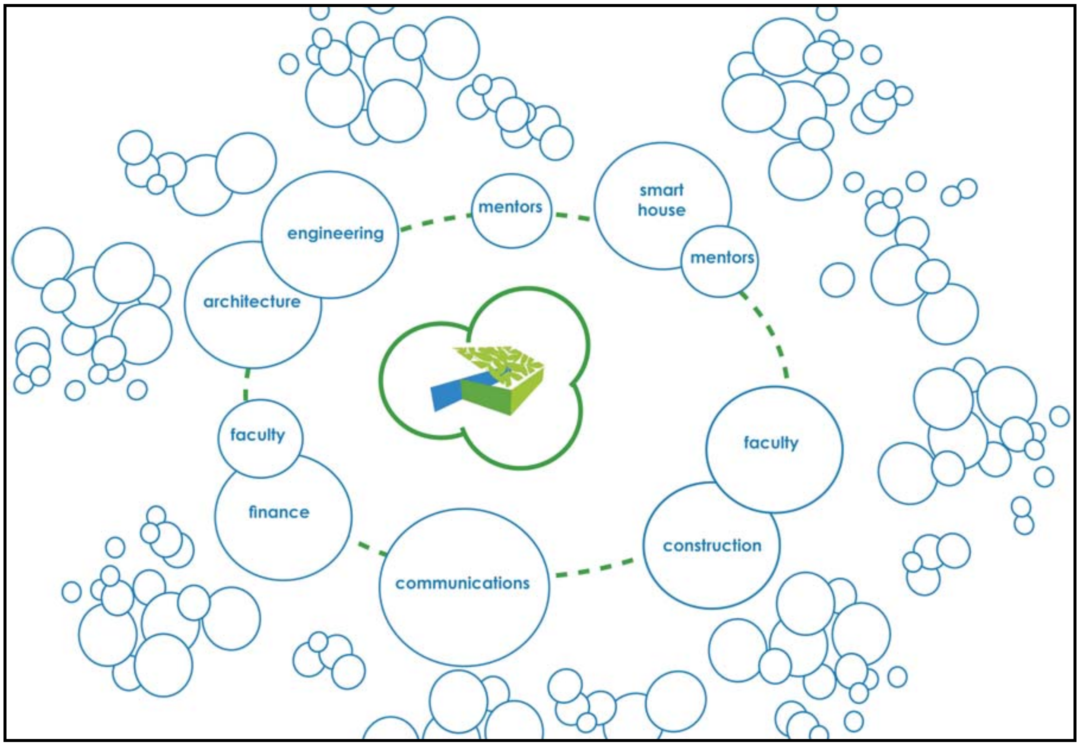


Figure 11. Bubble Diagram of Team Organization. [LEAFHouse Team]

The organizational structure is a matrix of interdependencies with clear leadership, but not a traditional hierarchy. This fosters communication and collaboration, rather than emphasizing individuals. Everyone involved in the project, from students to professionals, has the benefit of learning from each other. From the beginning of the project, the team established the importance of having architecture and engineering students work together on different aspects of the project. In fact, one of the goals set forth by the team was to change the means by which we design, encouraging a number of disciplines to collaborate from conception to completion, working alongside each other rather than separately.

Figure 12. The team at the Green Building Institute in Jessup, Maryland. [Gardner]

The University of Maryland entry was created through interdisciplinary teamwork, resulting in an integrated whole in which architecture and engineering elements complement and complete each other. The architecture is intricately linked with the systems and the systems reflect the diagrams, thoughts and intentions of the team as a whole.

Team Intentions

The Maryland Team viewed the Solar Decathlon as an opportunity to ask, and answer, questions about the way we live. How do our actions affect the environment and impact the future? What makes a "house" a "home?" What do the Vitruvian ideals of firmness, commodity and delight mean for the 21st century? How do we integrate technology into our lifestyle? These inquiries led to an exploration of the very nature and meaning of the form and use of the house, its place in society, and its relationship to the natural environment.

The team began by studying the way that we “dwell”, establishing intentions, strategies and tactics for changing the way we “dwell”. Diagrams were made to reflect the ideals of dwelling, provoking a thought process for designing the house that reflected the way we *should* “dwell” in the 21st century.

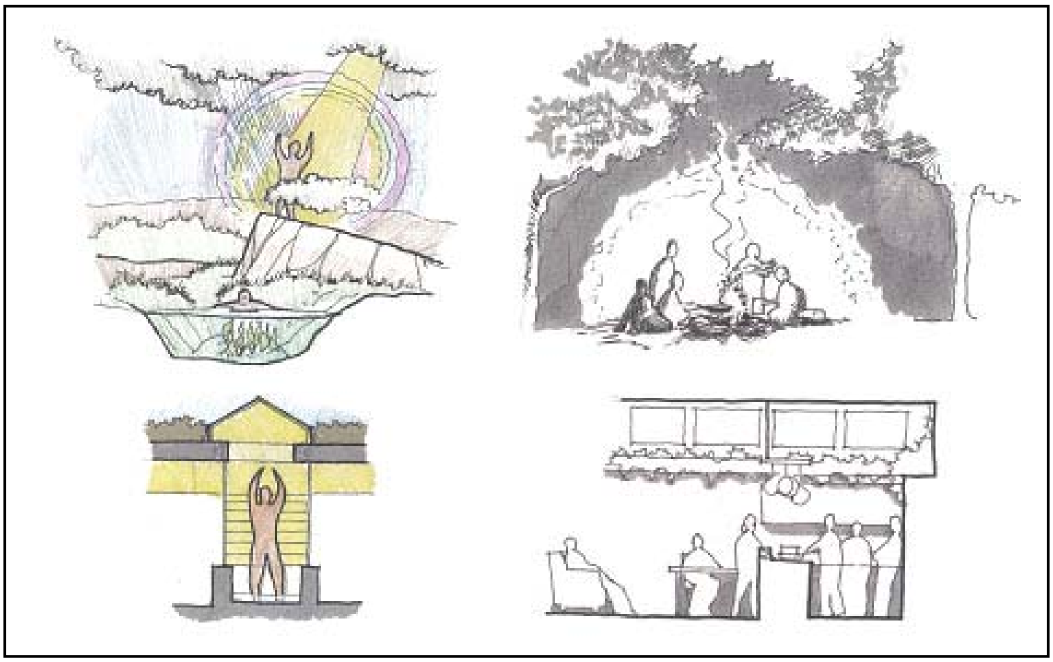


Figure 13. Diagrams examining the way we dwell versus the way we *should* dwell. [Mike Binder]

Figure 14. Intentions, Strategies and Tactics brainstorming session. [Amy Gardner]

The intentions established for the house ranged from minimal impact on the landscape, to the re-establishment of a connection to nature, both visually and experientially. Strategies and tactics were developed to ensure the reality of the intentions. These included designing in such a way to minimize the footprint of the house on the site, locating the house thoughtfully on the site and designing with a "complete life-cycle mentality" – suggesting the use of recycled materials, and materials that are easily recyclable and sustainable.

The goals of the team became to demonstrate that through multidisciplinary design, a more responsible and sustainable architecture can be produced. The following five principles became the framework that guided the project from start to finish - use nature as inspiration and mentor, demonstrate the practicality of solar technology, change the design and build process, address the Chesapeake Bay Watershed issues, and raise awareness about practical solutions and environmental stewardship.

Five design principles were also established as a result of team meetings and collaboration which the team used as a checklist which students used to begin the design process. These principles acted as the conclusions that students made about the design of the house; that the house be livable, transformable, bio-inspired, connected to nature and sustainable.

House/Team Branding

Based on the 5 principles of design, the team had multiple brainstorming sessions on what the name of the house would be. The team wanted the name to be one which relayed a strong message to the public, and a name that also mimicked the design intentions of the house.

Several brainstorming sessions were held with communications mentor, Peter Kelley, to determine the target market and target region of the house, in addition to the brand, or label for the house. The name LEAFHouse was widely accepted by the team, in that it held true to the goals and intentions set forth by the team; nature as an inspiration, and was clearly able to portray the message of the team: that through interdisciplinary, sustainable and environmentally friendly design, we can accomplish the ultimate goal of "Leading Everyone to an Abundant Future."

Target Market/Target Region

Figure 15. Communications mentor, Peter Kelley [Gardner]

In addition to giving the house an identity, the team also defined a target market and a target region. After several brainstorming sessions identifying the goals and missions of the team, they defined the target market as early adopting baby boomers. This market can be characterized as empty nesters looking to downsize. They are easily adopting of sustainable and solar technologies and want to incorporate these innovations into their house in a way that is integrated yet also affordable. The target region was determined as a result of the team's building location, competition site and anticipated final resting place. Thus the team wanted the house to fit in aesthetically and systematically to the Chesapeake Bay region. The Chesapeake Bay watershed encompasses much of the east coast and is plagued by issues that the team found important to address through the design of the house. Some of these pertinent issues included water usage, erosion and humidity.

The team also discussed the ways which the LEAFHouse message and story could be relayed to the public in order to gain support and interest in the project as well as educate the local public about the issues found in the Chesapeake Bay region to improve the conditions of both the natural and built environment.

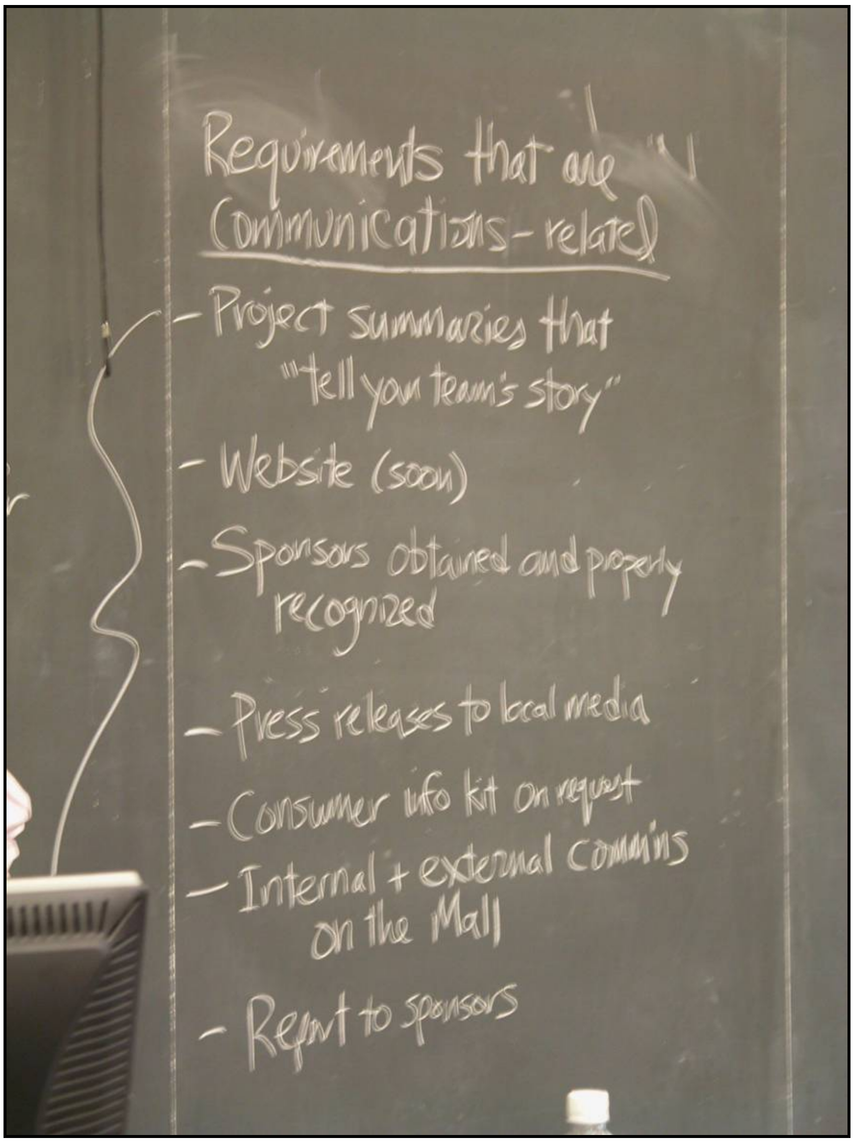


Figure 16. Potential Communications Strategies [Gardner]

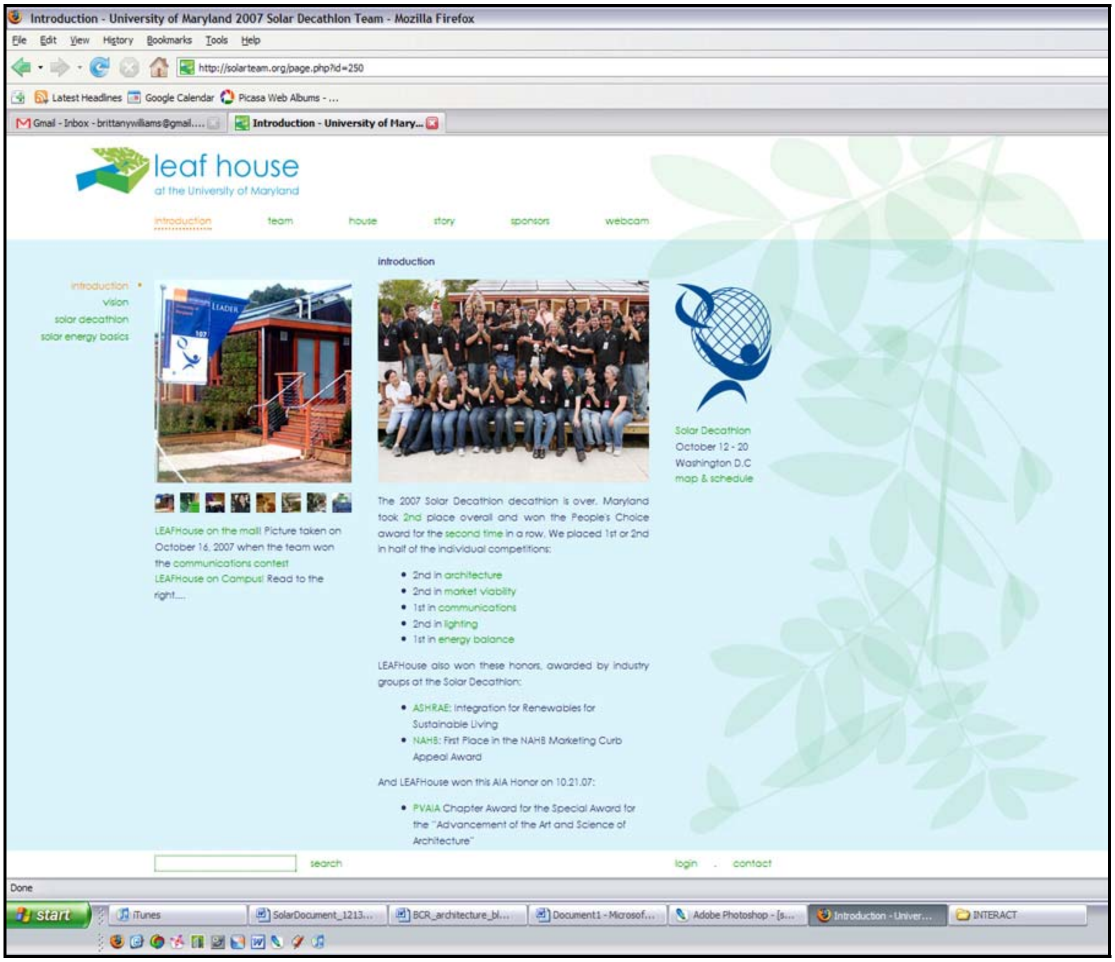


Figure 17: LEAFHouse Team Website [www.solarteam.org]

Public Outreach

The team saw it as their mission not only to build an innovative and sustainable house, but also to educate the public about their journey and the things they learned along the way. This mission was achieved in many ways including face to face meetings and presentations with professionals and local organizations, the team's website, and celebratory events. All of these methods were equally important as the team saw spreading the word of the project as worthwhile and educational as building the house itself.

In order to tell the story of LEAFHouse, the team developed a website that was updated every week, showing the progress of the team. The website outlined the development of design and construction through a Photo Journal that contained images and text. The website also contained information for consumers about different aspects of LEAFHouse as well as information about how the public can apply technology and solar techniques to their own home. A webcam provided live feed of construction and meetings on site. Another portion of the website contained extensive information recognizing sponsors. This section showed the donations and services as well as guided the public in how they could implement these technologies and materials into their own lives. The website was an interactive and important part of the team and its outreach mission.

In order to spread the mission of LEAFHouse to as many people as possible, the team also made presentations to local organizations and professional practices. Through these presentations, the team hoped to gain support and raise awareness of the issues the team chose to address as well as learn from these organizations.

Through the process of design and construction, the team held events to promote the house, fundraise and celebrate the progress. In fall 2006, the team held an event to promote the house called Equinox. Held at Community Forklift, a second hand construction materials exchange, the team unveiled the house design and solicited support from the trades people, professionals and other members of the public in attendance.

Several months later to kick off the start of construction, the team hosted another event called Ground Raising. Members of the university, professionals and the media all gathered at the School of Architecture, Planning and Preservation to celebrate the start of construction on LEAFHouse.

To celebrate the nearing of construction completion in September 2007, the team held an event just before moving the house for the competition. The event showcased the house and also gave an opportunity for the team to speak about their goals and wishes. University President Dr. C. D. Mote and Maryland State Senators were in attendance as well as students, team members, local media and the Mighty Sound of Maryland marching band.

Figure 18: Photographs of LEAFHouse Team Events [Gaddam]

Speaker's Bureau Speaking Events

* Baltimore Green Week / EcoFestival 2006, 2007
* AIA Chesapeake Bay Presentation
* Women in Engineering, University of Maryland
* Art Farm at Red Wiggler 2006, 2007
* Greater DC Tour of Solar Homes, 2006
* Marks Thomas Green Futures Presentation
* Society of Women Engineers / INCOSE
* College Park Rotary Club
* County Engineers Association of Maryland Conference
* Green Building Institute Workshop
* Regional Leadership Conference on Green Building
* University Park Historic Preservation Group
* OPX
* IEEE Adcom
* American Association of University Women
* CSBA May Green Happy Hour
* Stampfest, University of Maryland
* Baltimore Building Congress and Exchange
* Urbanite Beyond Sustainability Presentation
* Bradley Hills Presbyterian Church
* Baltimore Engineers' Club
* DCAIA Design DC 2006
* UMD Master of Real Estate Development Program Presentation
* Bonstra/Haresign
* Emerging Engineers, University of Maryland
* William McDonough and Partners
* Architecture 170: Introduction to Architecture course, UMD
* University 100: Introduction to the University, UMD
* UMD Sustainability Lecture Series 2007
* Council of Scientific Society Presidents, Washington, DC

Figure 19: LEAFHouse Team Speaker's Bureau Events

Design

<u>Precedents</u>

Precedents which reflected the goals and intentions of the LEAFHouse were chosen and analyzed by the graduate studio. A sample of these precedents included Michelle Kaufman's Glidehouse, Flatpak, and Farnsworth House. All of the precedents studied were houses of a comparable size to LEAFHouse. The team studied the houses looking at treatments of programmatic layout, connection to nature, transformability and a variety of other aspects.

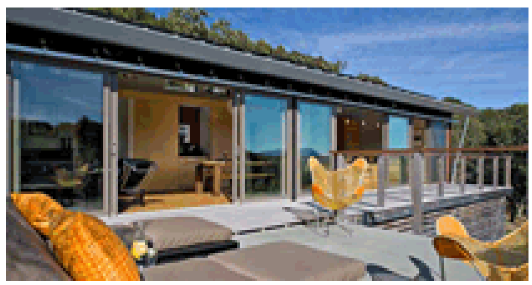


Figure 20. Michelle Kaufman GlideHouse, exterior.

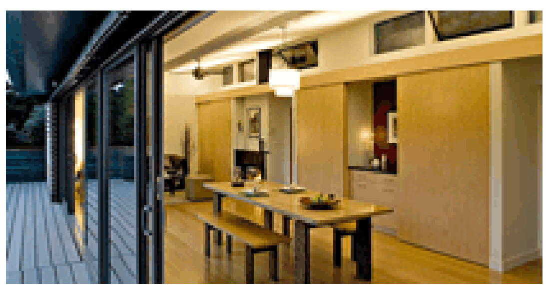


Figure 21. Michelle Kaufman GlideHouse, interior.

Figure 22. Michelle Kaufman GlideHouse, exterior.

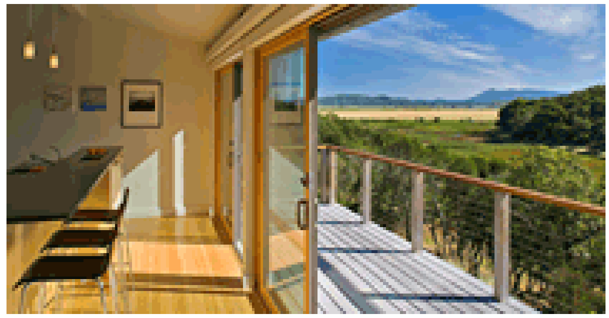


Figure 23. Michelle Kaufman GlideHouse, interior. [http://www.mkd-arc.com/homes/glidehouse/tour/tour.php]

In Michelle Kaurfman's GlideHouse, the team examined the house's connection to nature as well as the basic programmatic layout. The house is relatively open and takes advantage of the connection to the exterior. Along the south side of the house, there are layers of sliding glass doors and panels that allow for a seamless connection to the outside.

Figure 24. Charlie Lazor Flatpak House. http://www.treehugger.com/files/2005/01/flatpak_house.php

Through an examination of the Flatpak House, the team explored the modularity of the design. The team also observed the way that the pieces of the houses were put together both on site and ahead of time. This exploration ultimately led the team to explore partnering with a modular home builder or panelizing the house itself.

Figure 25. Mies van der Rohe Farnsworth House.

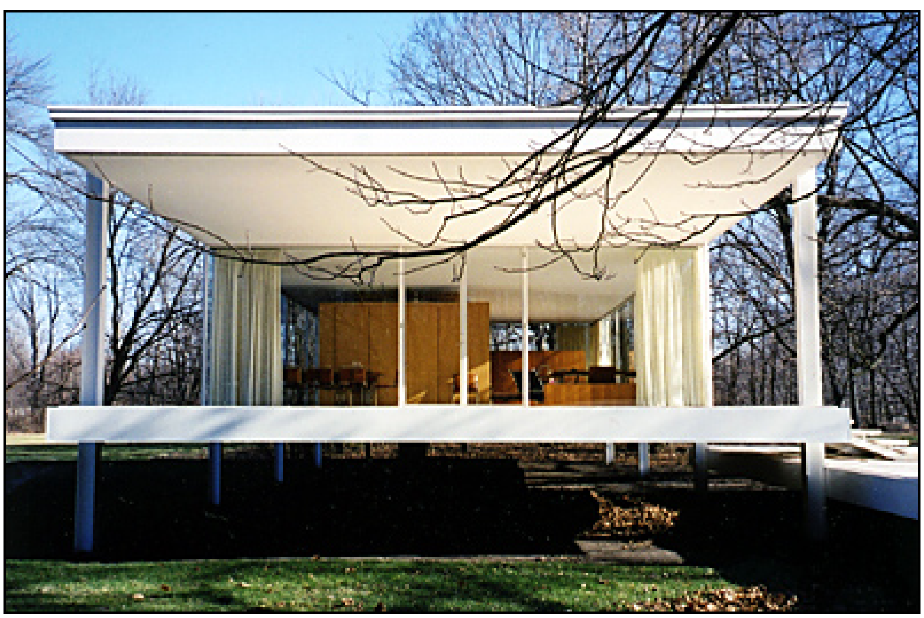


Figure 26. Mies van der Rohe Farnsworth House.

Figure 27. Mies van der Rohe Farnsworth House. http://www.farnsworthhouse.org/photos.htm

The team also examined the Farnsworth House. Through diagrams and research the team observed an open layout as well as strong visual connection to the exterior. This precedent provided an example of architecture touching lightly on the earth. The house also contains overlapping spaces which the team could apply to their own design.

The precedent studies done in preparation for designing the solar house were exhaustive and informative. Through observation and analysis, the team created a catalogue of ideas and techniques directly and indirectly applicable to LEAFHouse.

Three Schemes

Based on precedent studies and earlier established principles, students worked individually on a scheme and were then paired based on similar ideas about the design of the house. From this came three different schemes for the solar house which were then discussed, determining which features best represent the goals of LEAFHouse, and finding a way to incorporate them all into the final design of the house.

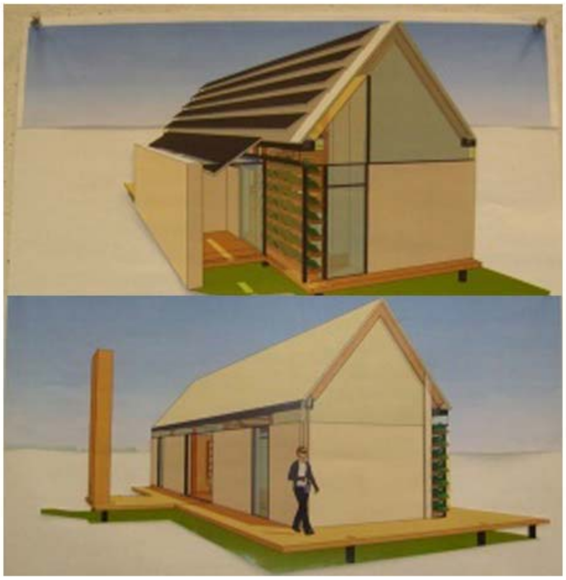
The three schemes that were developed were:

Courtyard House

The design of the courtyard house focused on using multiple modules to create outdoor spaces. The bathroom module was connected to a green wall water filtration system and to the kitchen, creating a bio-mechanical core. This linear core divided the entry court from the private bedroom deck. The interior design also stressed openness and modularity. A pergola extending from the roof helped emphasize the horizontality of the roof.

Figure 28. Scheme 1: Courtyard House [Mike Binder and Huijun Shang]

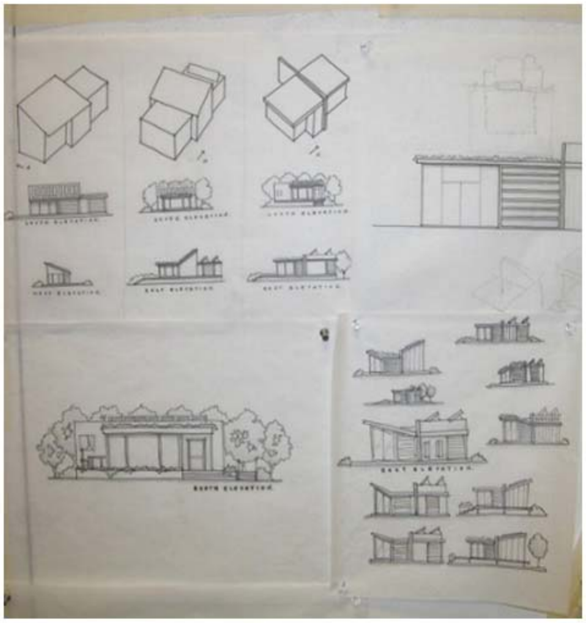
Icon House



The design concept featured a symmetric gabled roof, very iconic in residential architecture. The plan stressed flexible use of interior space and a simple, straightforward bar parti. The south façade incorporated a green wall to moderate temperature and connect the residents to the natural world.

Figure 29. Scheme 2: Icon House [Debbie Bauer, Devin Kimmel, Jef Zaborski]

Pavilion in the Landscape



The group's design for the pavilion in the landscape was centered on the vision of touching lightly on the earth; the south pavilion essentially being a glass box, housing the public areas of the house. The north pavilion was a much more solid box housing the private parts of the program. The two were united by a thick wall that housed much of the mechanical equipment. This wall created a strong datum that extended the house into the landscape, becoming an object in the landscape.

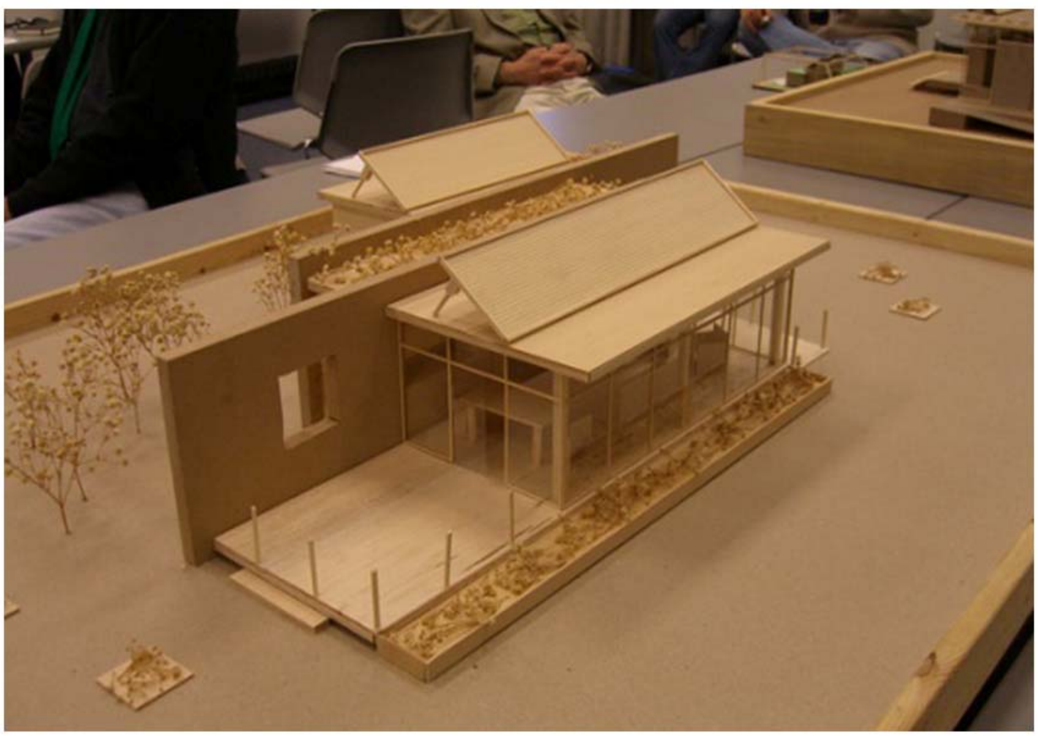


Figure 30. Scheme 3: Pavilion in the Landscape. [Kim Singleton, Brittany Williams]

After the three schemes were developed, students, mentors, and industry professionals analyzed the house designs, and chose different elements that they believed should be present in the final house design. The students then took these design elements and principles and developed a diagram which encompassed all of those ideas. The parti which resulted embraced the five design principles developed at the beginning of the semester. These principles were expanded upon and became a set of goals for the team in the detailing and completion of the house.

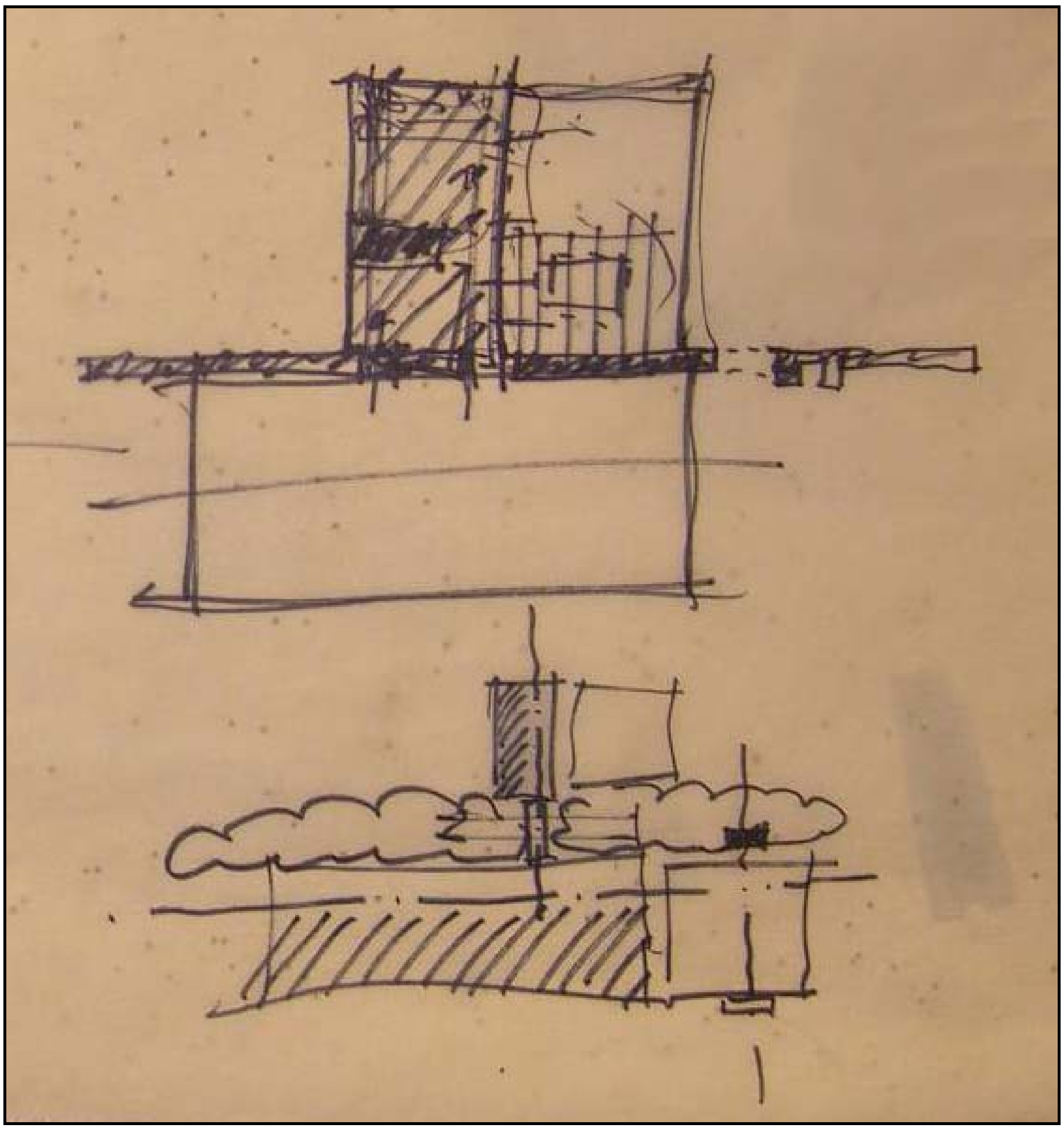


Figure 31. Parti for the final design of the house. [LEAFHouse Team]

Design Development Documents

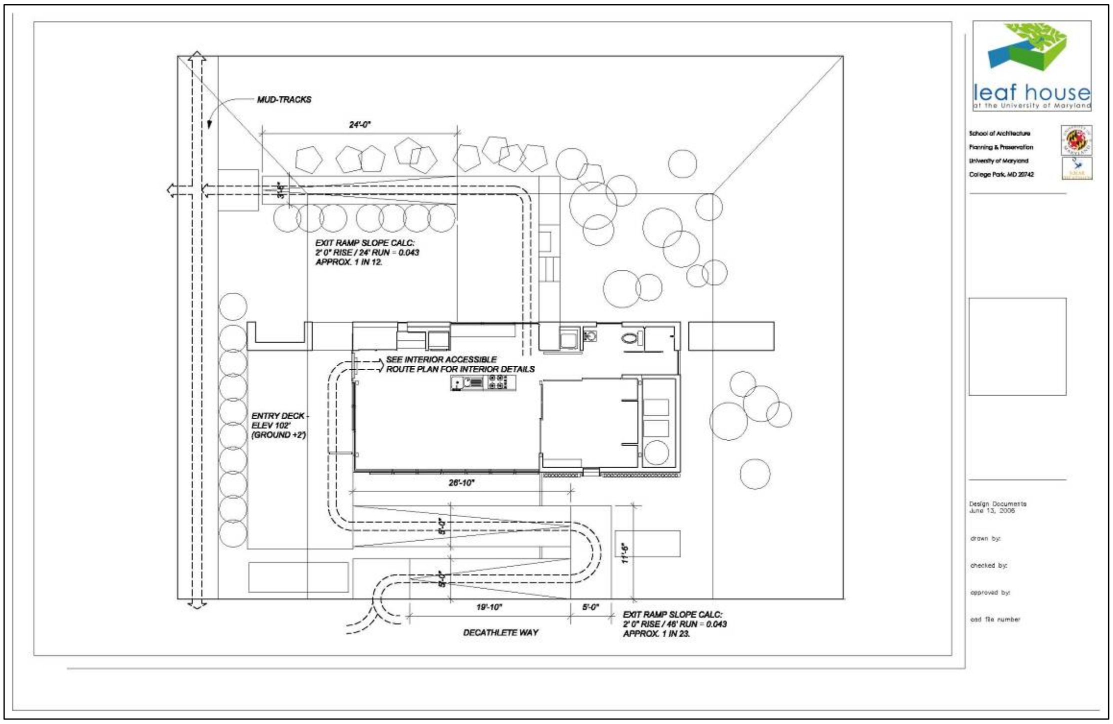


Figure 32. Site Plan. [LEAFHouse Team]

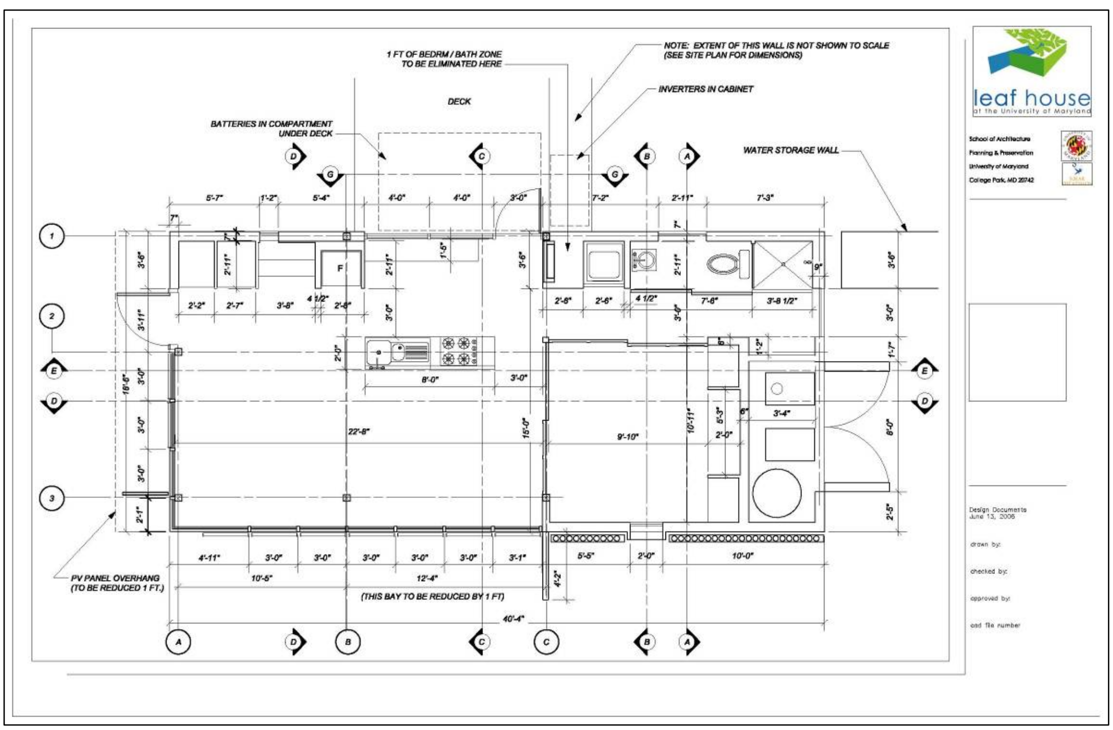


Figure 33. Floor Plan. [LEAFHouse Team]

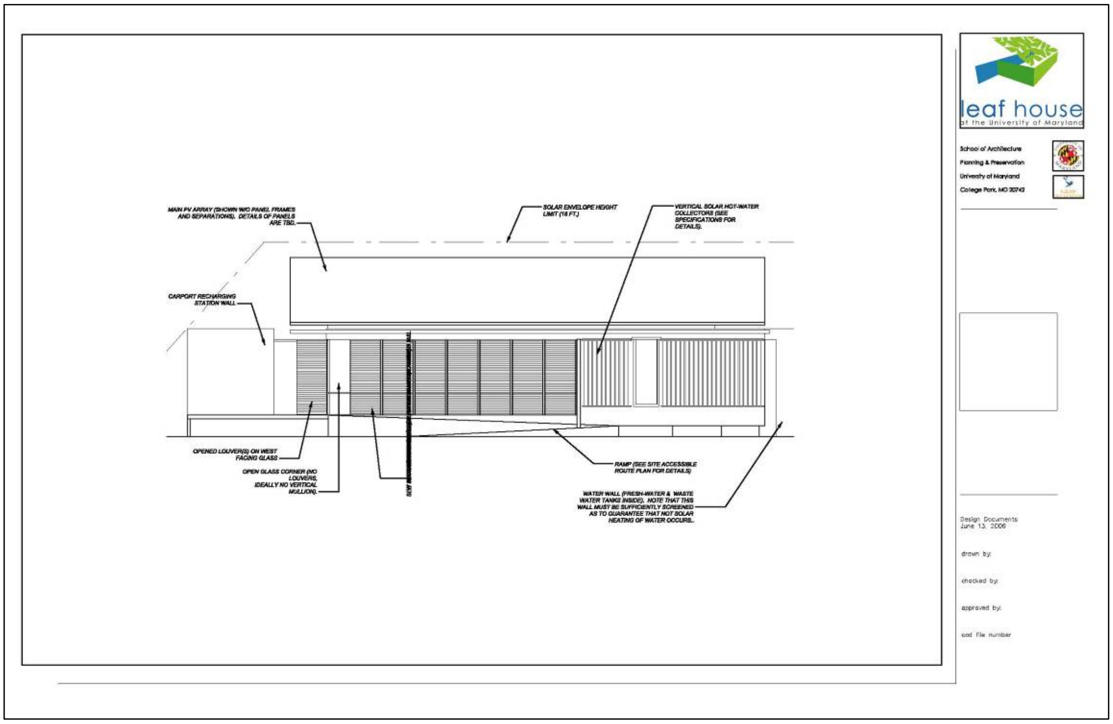


Figure 34. South Elevation. [LEAFHouse Team]

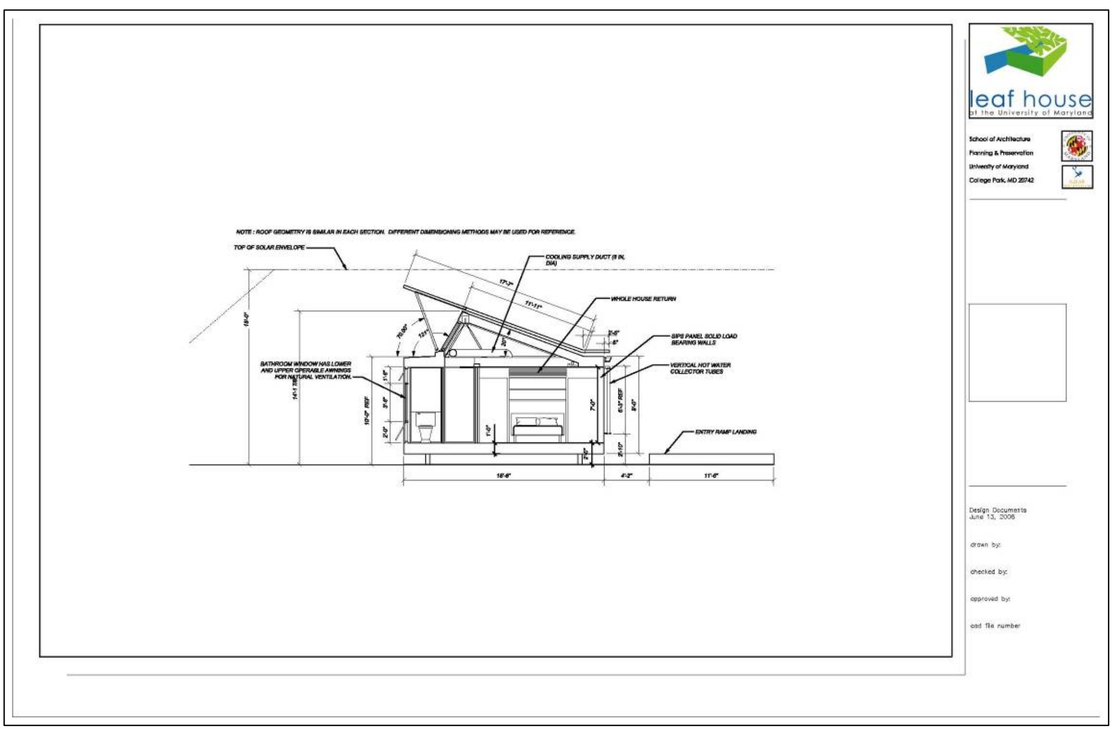


Figure 35. Transverse Section. [LEAFHouse Team]

Construction Documents

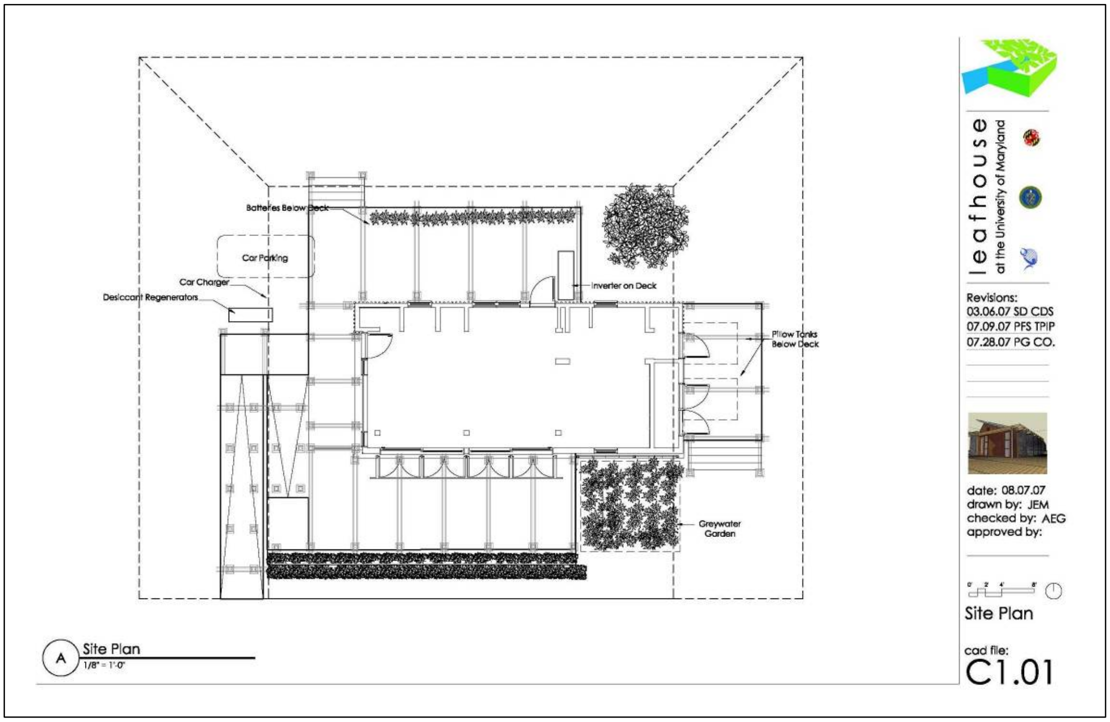


Figure 36. Site Plan. [LEAFHouse Team]

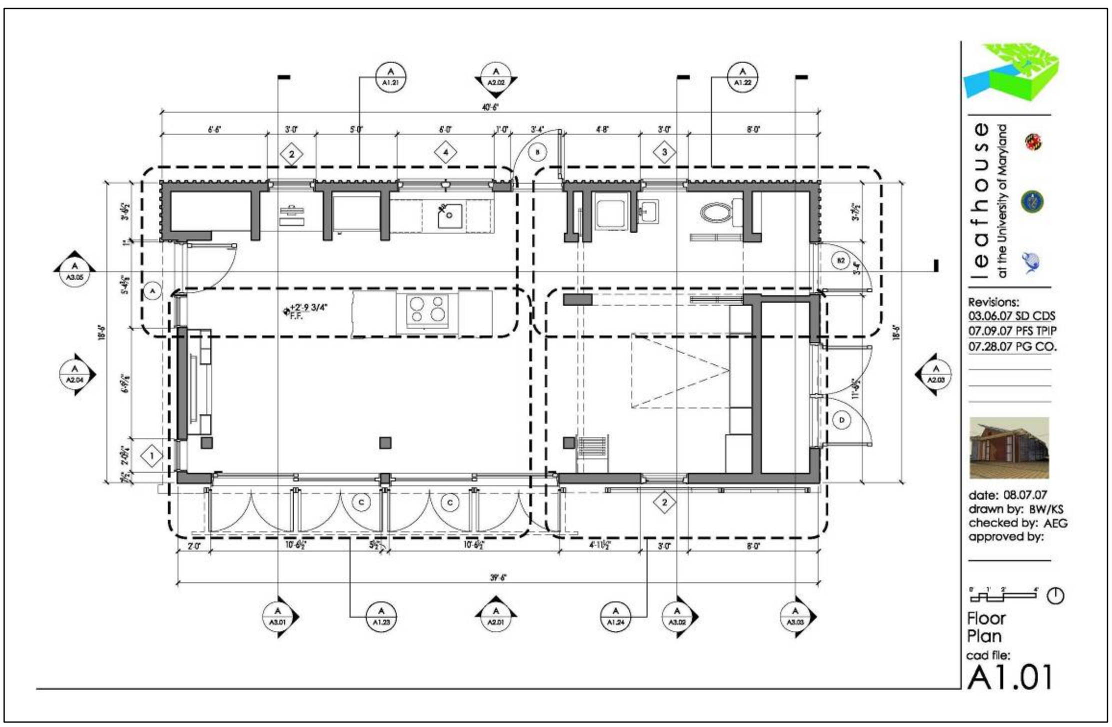


Figure 37. Floor Plan. [LEAFHouse Team]

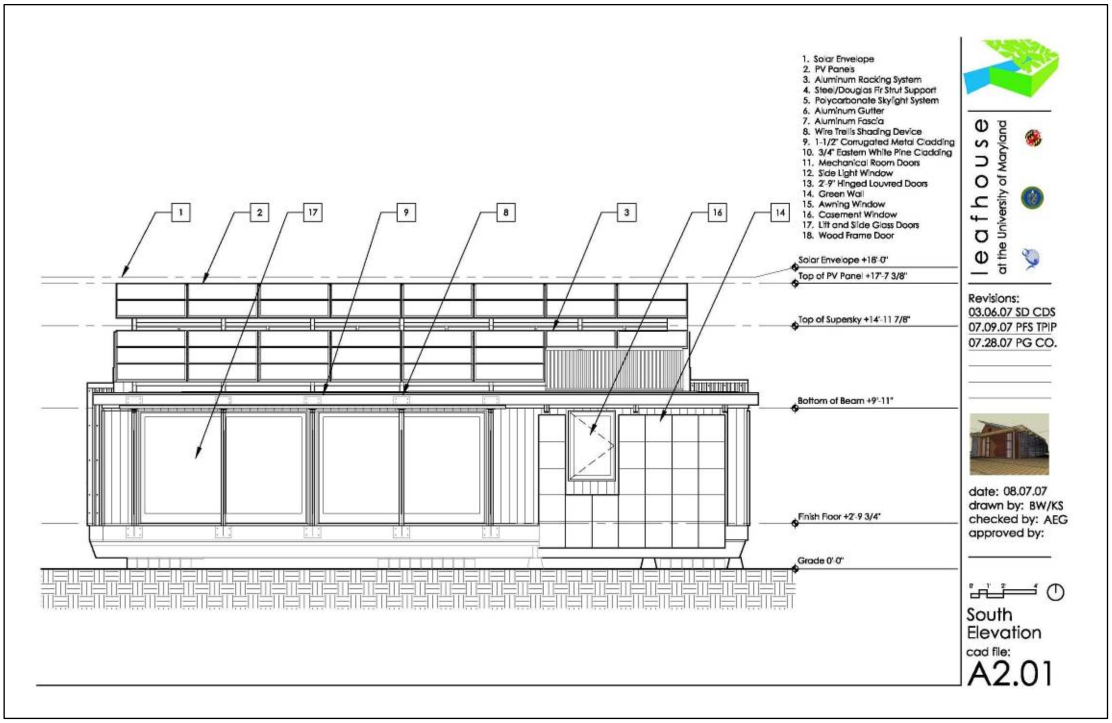


Figure 38. South Elevation. [LEAFHouse Team]

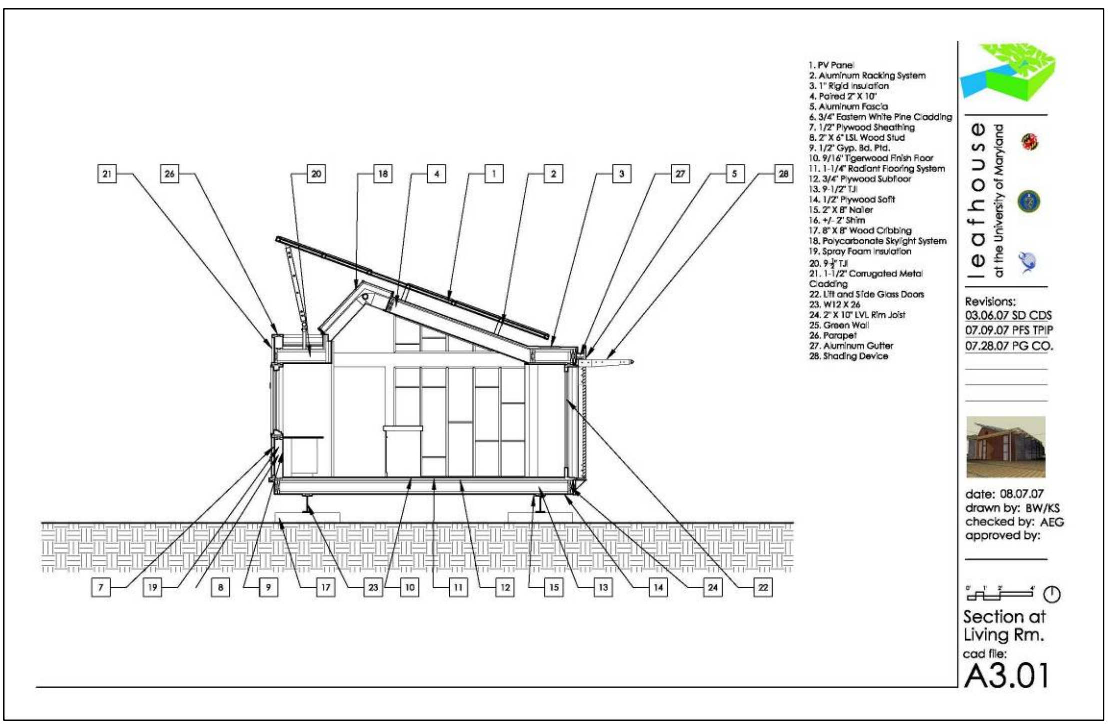


Figure 39. Transverse Section. [LEAFHouse Team]

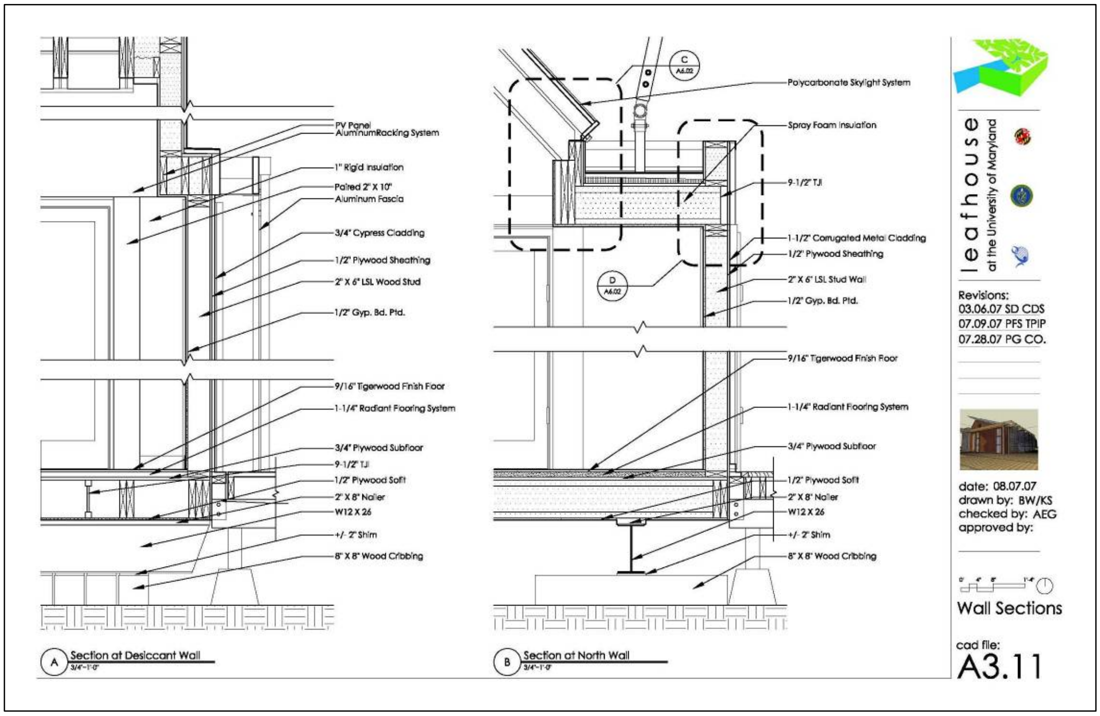


Figure 40. Wall Sections. [LEAFHouse Team]

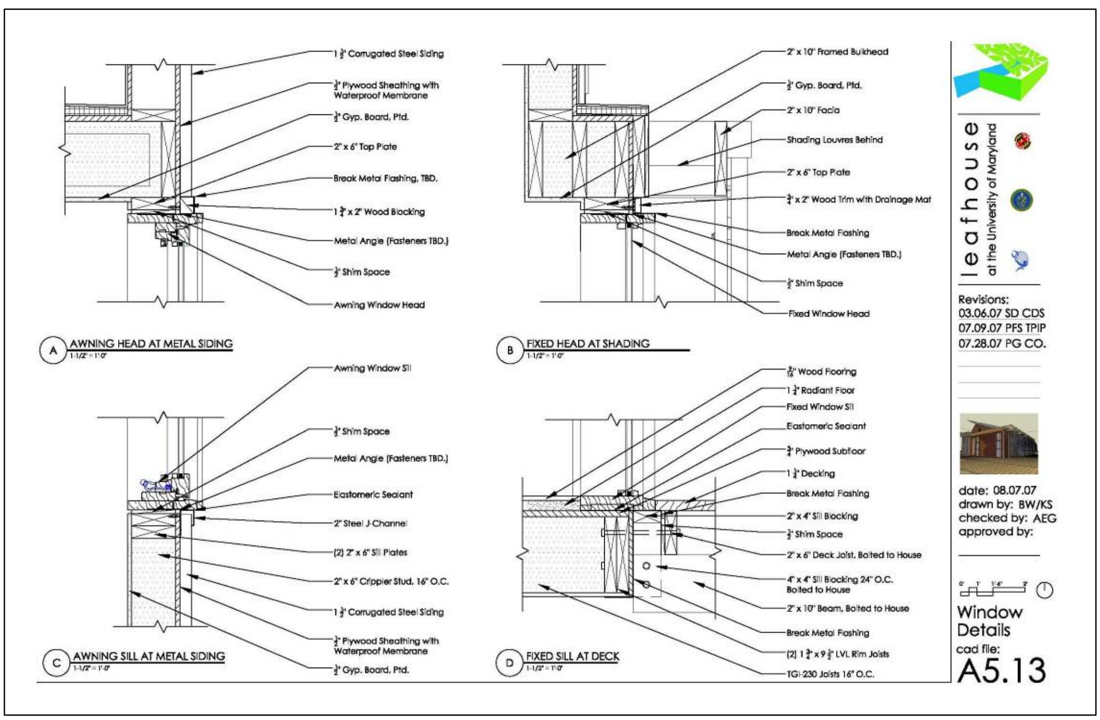


Figure 41. Details. [LEAFHouse Team]

Shop Drawings

Throughout the entire two year design process, the team worked towards compiling, detailing, and describing drawings in packages that were sent out to the various manufacturers and trades people. Over the course of ten months, packages and shop drawings were sent out for everything from the roof and exterior finishes of the house, to insulation, interior casework, and finishes.

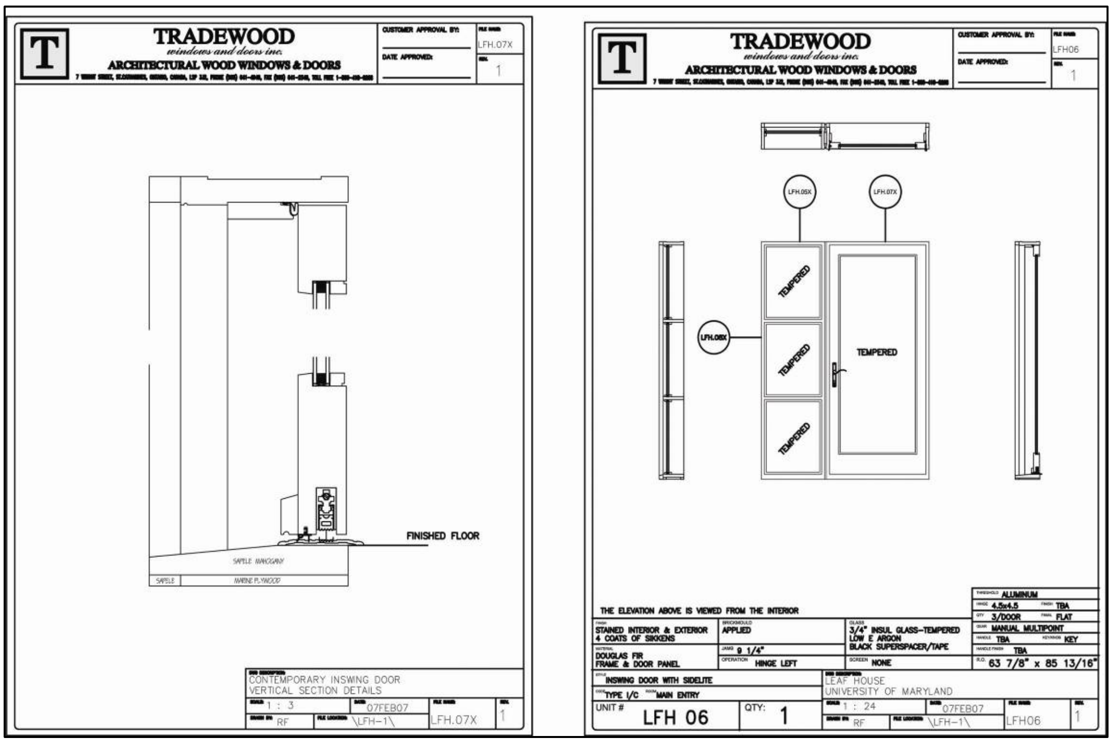


Figure 42. Tradewood Shop Drawings. [Tradewood]

Packages changed as design decisions changed, and everything continually had to be re-detailed and re-checked to ensure it was correct. At these critical times, it was vital that the entire team was involved and collaborated to ensure that each team member was aware of the changes being made and how those changed affected the work of each composite team. Clear and concise discussions were had with mentors, suppliers and suppliers/manufacturers, and the process continued for weeks depending on the depth of detail and precision necessary for that part or system.

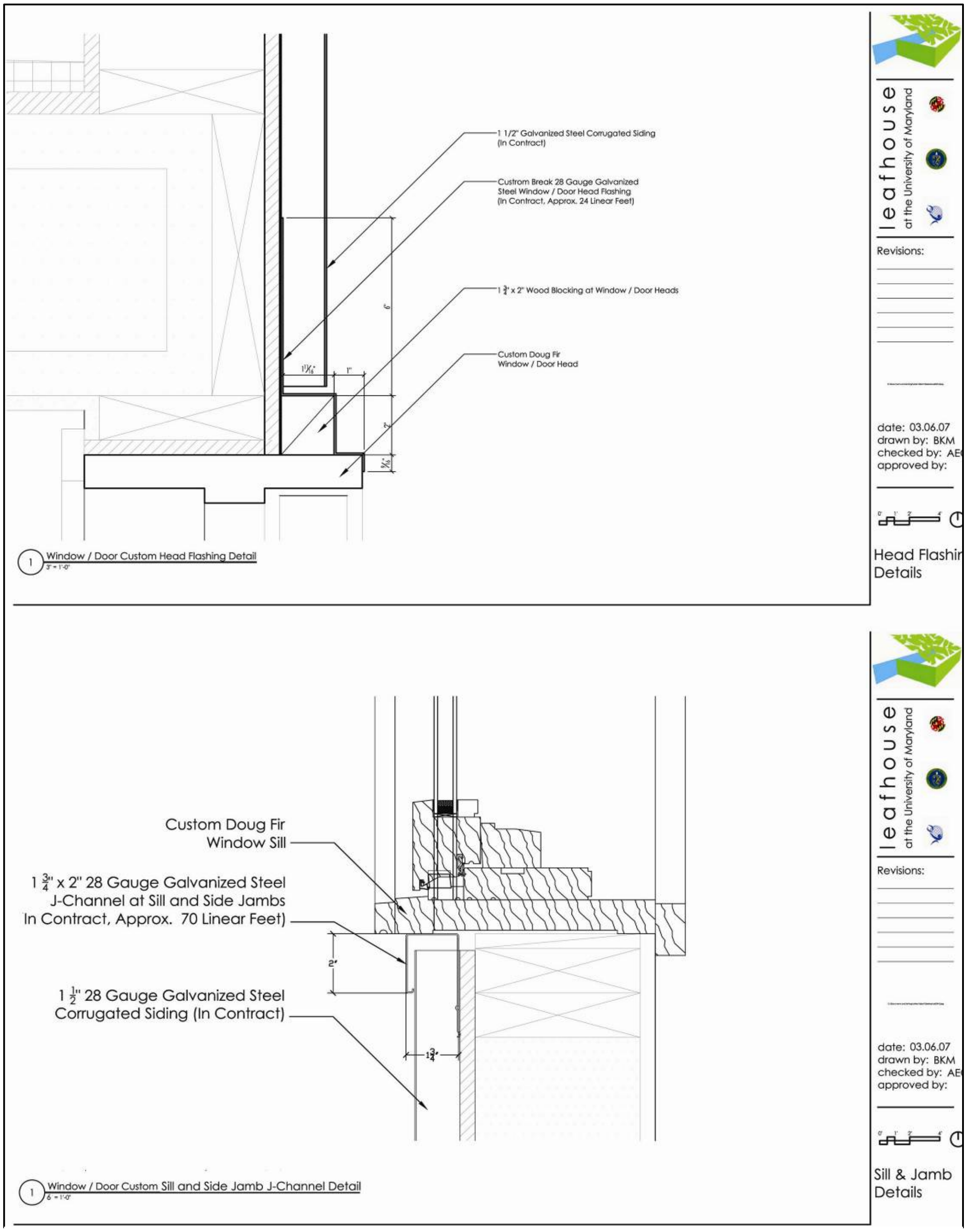


Figure 43. ATAS Siding Detail Shop Drawings [LEAFHouse Team]

The process of completing the shop drawing became a back and forth between the team and the manufacturers. This learning process had an effect on the schedule, of course; however, the team gained valuable experience and expertise in this realm in their dealings with all of the various manufacturers, as each subsequent package, as a result became more and more succinct and well described than the previous

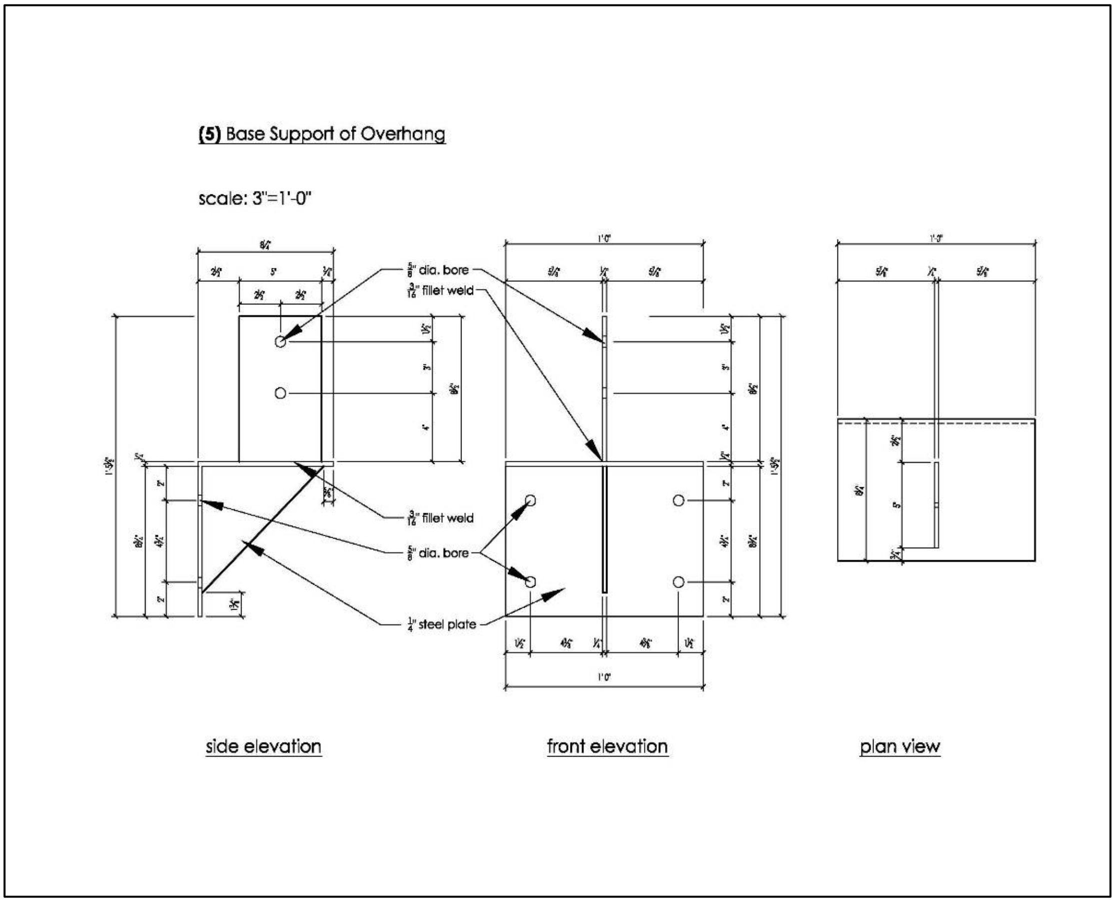


Figure 44. Shop Drawings for South Overhang Supports.   [LEAFHouse Team]

The Design

Figure 45: Aerial View of Plan [LEAFHouse Team]

Figure 46: View of South Façade. [Williams]

Figure 47: Interior Space looking at the living room and kitchen. [Photo by Amy Gardner]

Figure 48. Perspective of southern green wall. [Photo by Amy Gardner]

Figure 49. Perspective of southern wall of glass and louvers. [Photo by Amy Gardner]

Figure 50. Perspective of eastern elevation. [Photo by Amy Gardner]

leaf house
at the University of Maryland

Architecture Design and Implementation

"**L**eading **E**veryone to an **A**bundant **F**uture."

School of Architecture, Planning and Preservation and the A. James Clark School of Engineering

The design of LEAFHouse is a marriage of interdisciplinary team work, resulting in an integrated whole in which architecture and engineering elements work in accord with and compliment each other. The architecture cannot be discussed without the inclusion of other systems and ideals. The overall design strategy is born from three central principles: the intent to connect to the natural world; to create a home that is transformable at many scales, and that in order to Lead Everyone to An Abundant Future, energy efficiency is understood as a central form-giver.

Engineering Integration

The LEAFHouse design process is founded on the premise that architectural and engineering design inform each another, with the focus of integrating emerging technologies with time-tested passive techniques.

The engineering features became integral parts of the design that informed both broad ranging architectural concepts as well as details. A liquid desiccant wall is a focal point in the living room and melds both architectural and engineering design through the interaction of the equipment, casework and space. A similar synchronicity between architecture and engineering exists in the design of the roof. The roof was explicitly designed with a structural strategy that simultaneously provides a daylit spine that illuminates and organizes the space and and structure. The solar panels and evacuated hot water tubes soar above the roof on an extruded aluminum racking system that follows the slope of the roof. The PV panels become a second skin that cantilevers over the skylight system and is grounded by a delicate steel and wood strut system. Other integrated systems can be found throughout the house.

Nature as Inspiration

LEAFHouse strives to work in tandem with nature. By studying and working with nature, the team has incorporated both passive design strategies as well as innovative bio inspired elements into the house. These features range in scale from small details to overarching ideas that informed the design.

LEAFHouse is modeled after a leaf both in function and in appearance. As nature's ultimate solar collector, the architecture and engineering aspects come together to approximate the leaf. Architecturally, portions of the house are designed so that the skin reveals the structure of the house itself. On the interior, the finish material is pulled away at the ridge of the roof to reveal alternating paired rafters sandwiching a steel knife plate system that connect to a delicate steel pipe. The steel pipe runs the length of the house and is framed by a translucent skylight that sits above. This skylight highlights the structural and architectural feature of the house and also provides diffuse light through out the house. This feature alludes to the veins of a leaf.

Organizational Strategies

As a response to solar orientation and programmatic challenges, LEAFHouse is divided into a public and private zone. These zones are articulated architecturally through differing fenestrations and through exterior skins. The two major use zones are

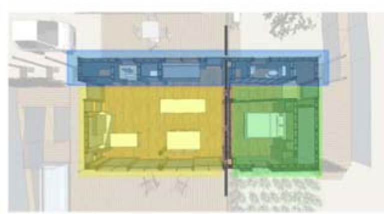


Figure 51. Architecture Brief Contest Report. [LEAFHouse Team]

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Architecture Design and Implementation

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then tied together with a biomechanical zone that runs along the north portion of the house. This zone houses much of the mechanical equipment of the house and is a solid bar with volumes carved away to create different areas of use within. The house is thus conceived in layers, from the organization of spaces to the concept of the roof. The north and east zones are the "bio-mechanical layer", nestling the "living zones" in their embrace and rendering them largely free of fixed walls.

The roof structure is another example of layering: LEAFHouse roof design draws from the concept of tropical "double" roofs, which encourage air flow between the house roof and the upper roof, thereby passively cooling the house roof as well as the back of the PV panels. It also shades the lower roof, deflecting radiant energy gain. The PV array is the upper canopy, -- an aesthetically pleasing grid that can support a variety of PV configurations, solar thermal systems, or can be used as a trellis/shading system when extended past the boundaries of the house proper.

Transformability

Transformability is integral in the design of LEAFHouse. The design is flexible, to expand based on the needs of the inhabitant; needs that may change from day to day, seasonally, or over a period of years. Moveable panels within the house allow transformability of the spaces to provide the most efficient use of the spaces. These translucent moveable panels, while closed, create intimate spaces. Yet they can be configured in many different ways that allow the space to take on different qualities depending on the activities occurring in the house. This transformability is not limited to within the interior of the house and extends to the exterior as well. Large sliding glass doors that line the south public portion of the house can open up and users can take advantage of the deck area and surrounding site. At an even smaller scale, the house design includes many transformable features that aid in the ideals of living. Interior walls that serve double as tall pullout cabinets, a Murphy bed and a nesting dining room table that can allow for expansion are all ways that LEAFHouse can adapt to the needs of the user.

The house is also transformable at the scale of the community. LEAFHouse is designed to be extended into expanded models and communities, by virtue of adding modules or aggregating into larger building types. These various models and communities encompass a variety of densities and lifestyles from apartment complexes to single family homes.

Connection to Nature

Seen as an extension of the house, the site design follows the intentions of the architecture and engineering concepts. The south side of the house is the more public of the several outdoor "rooms".. A large spacious deck with strong physical and visual connections to the interior create a place to socialize and call the front porch. The north side of the house is more private and intimate. A landscaping, including a full sized tree, create carefully framed views from in the house as well as sculpt outdoor spaces. The north side of the house is also a place where the site and engineering concepts come together. The desiccant regenerators, solar power inverter, and condenser all help to shape the exterior spaces and extend the logic of the interior spatial organization.

The house and site are conceived as a system in other ways, as well. They are linked through the water management systems. Rain- and grey water gardens join the house to the landscape. One of the most important features of the landscape is the "building integrated storm water management system" -- a vertical rain garden on the south side of the house. This green wall of plants is not only aesthetic, but it also filters water run off from the roof. This green wall joins the house to the grey water garden located adjacent.

Materiality

Aside from the especially innovative items in the house, LEAFHouse is built with time-tested, readily available materials used in innovative ways. From sustainably harvested local woods to recycled corrugated metal siding, the materials in the house were chosen for their beauty, ease in construction, and environmental appeal.

Figure 52. Architecture Brief Contest Report (cont.'d) [LEAFHouse Team]

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Communication and Outreach

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A robust communications and outreach program is critical for the Solar Decathlon to have the impact it deserves at a critical moment for the development of U.S. solar energy. As the "hometown team," we have taken on several tasks meant to magnify the impact not only of our entry in the contest, but of all the teams' efforts. Our communications and outreach program is showcasing the contest's broader goals, as well as the LEAF House, in the Washington, D.C. media market and in Congress—and in the Maryland State Legislature, the major research university that hosts us, and our community of suppliers and supporters.

Public events

As the "hometown team," we are organizing a Lobby Week from Sept. 10-14 during which team members will meet with Members of Congress and staff members to describe the Solar Decathlon and educate them about the value of solar energy. During that week, on Sept. 11, we will also provide a pre-Mall tour of our entry for members of the Maryland State Legislature, in the form of a "send-off party." Then on Thursday, Oct. 18, after closing hour on the Mall, we will hold a VIP reception for major donors and suppliers, university leaders, and congressional staff, featuring a "100-mile dinner" that will consist of Maryland food and beverages all obtained within 100 miles of the National Mall, and prepared at the house.

We previously held a well-attended opening kickoff party last fall at the Community Forklift, a local supplier of recycled building materials; and, a "ground-raising" ceremony to launch construction this spring. Both were covered by local newspapers, radio, and TV.

Media outreach

The above events have been promoted to local media as opportunities to cover the students' community service, the novel features of solar houses and the LEAF House in particular, and the broader goals of energy independence and reducing pollution. Our most recent media "hit" was a feature in July on the evening news program of the local CBS affiliate, WUSA-TV, mentioning our "edible" soy insulation, the interior dessicant waterfall, and other elements, and interviewing several team members and mentors. We have partnered with a local green PR firm, Kelley Campaigns (the DC representative of the RenewComm renewable energy communications practice), to obtain professional coaching and University of Maryland communications interns who produce press materials and call the media on our behalf.

Printed materials

Our commitment to a broader impact is shown by our flyer for the Mall, which includes a postcard for house visitors to mail to their member of Congress in support of solar energy—and a tearoff slip to let us know they sent the postcard, and make other pledges to energy savings at their own homes. (It also collects their email address for follow-up.)

The color flyer shows an exploded view of the house and explains the main systems, as well as illustrating other LEAF House configurations as an urban villa, a townhouse, a garden flat, or larger solar homes of up to 2,400 square feet. It is being printed at cost by a local union printer on recycled stock that is Rainforest Alliance- and FSC- certified.

Figure 53. Communication Brief Contest Report. [LEAFHouse Team]

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Communication and Outreach

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Video interview series

A series of short videos of team members are appearing on our website and on YouTube from Labor Day through the contest period. The video shorts portray team members' motivations, explain their favorite house features, and describe breakthroughs during the process of design, construction, and outreach. Team volunteers are editing the videos into slightly longer versions to be shown on the television in the Maryland house while it is on the Mall, to take every opportunity to entertain and educate visitors about the people behind the house and unique features that might not be readily apparent.

House interpretation

Interpretive signage features "nutrition labeling" in the style of shipping labels attached to the various items in the house, showing their energy savings and respective payback periods, as well as a running series of signs on the deck (to make the most of waiting time), and the house walls and fixtures. In addition, house visitors will be invited to use their cell phones to hear a recorded message at any time, day or night, explaining the Decathlon and the Maryland entry, for those who miss one of our regularly organized tours or prefer a self-guided tour.

House tours

We are coordinating tour guide recruitment efforts on campus with the leaders of the University of Maryland "First Year Book" program, who this year have asked that all freshmen read the book *Ravaging Tide*, by local author and organizer Mike Tidwell, about the potential impacts of climate change and sea-level rise on America's coastlines. (Maryland is the second state most at risk, after Louisiana.) Fresh from reading the book, freshmen are being invited to form a team of tour guides to be extensively trained to give tours on the Mall and supplement the core team of house builders. Additional campus visibility efforts have been coordinated through a class of undergraduate communications students who took on the Maryland entry as a semester-long project in planning a promotion campaign.

Speakers bureau

We have recruited and provided message and media training to a panel of knowledgeable team members and mentors who can represent the goals of solar power and sustainability to the Washington media and in group presentations. Their names and contact information appear on our website as a solar house speakers bureau, and bookings are being obtained.

House furnishing

A "retro metro" look has been selected for our house furnishings and incidental items to illustrate its appeal to the initial target audience we identified for the initial 800-square foot model of LEAF House: downsizing baby boomers, and affluent twenty- or thirty-somethings buying their first home or just starting their family. Further marketing materials are adopting this look and feel, as well, to make the house as appealing as possible to its core target market.

Team branding and messaging

The leaf motif of the Maryland team's logo and house name connotes nature's perfect solar collector, the leaf—as well as being an acronym for the number one project goal that emerged early during our branding process, namely, "Leading Everyone to an Abundant Future." The leaf is used in our logo and throughout our house and materials. Message-rich team T-shirts convey the bright future of "pure energy" from the sun, and tour guide uniform shirts are made from a sustainable bamboo fabric that is soft to the touch. Support from the University's First Year Book program has enabled all our tour guides to wear these shirts on the Mall, and help us convey the Decathlon's messages to the widest possible audience.

Figure 54. Communication Brief Contest Report (cont.'d) [LEAFHouse Team]

leaf house
at the University of Maryland

Engineering Design and Implementation

"**L**eading **E**veryone to an **A**bundant **F**uture."

School of Architecture, Planning and Preservation and the A. James Clark School of Engineering

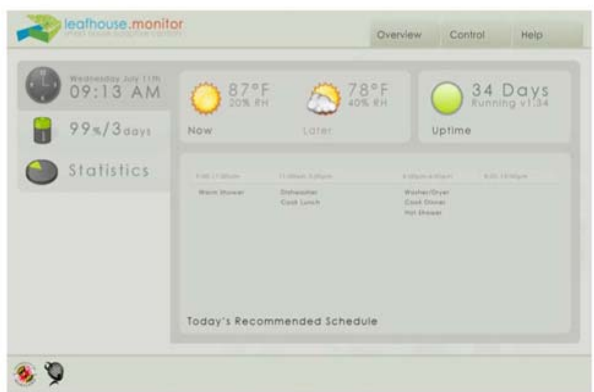
In an effort to fuse sustainability and livability, the University of Maryland LEAFHouse utilizes a wide range of unique engineering techniques. With its blending of biological sensitivity and cutting-edge technology LEAFHouse creates a living experience like no other. The LEAF House was designed not only to cater to its inhabitants but also to minimize the footprint on its own environment. Through the hard work of many, the LEAFHouse is proud to present unique methods of powering, heating, and controlling your home.

Building Envelope

The building's skin is made up of wood, glass, vegetation, and corrugated metal applied to 2x6 wood stud walls filled with soy based spray foam insulation. There is a twenty-two foot, four-panel sliding glass door system which allows the sun and the environment to enter the household. There is also a translucent polycarbonate skylight running the full length of the ridge of the house in order to provide diffuse light into the house.

Indoor Environmental Control

One of the most unique aspects of the LEAFHouse is the application of its desiccant dehumidification. In order to decrease the normal electrical load associated with traditional dehumidifiers , LEAFHouse utilizes a liquid desiccant dehumidifier. This system uses very little electricity and is a highlight of the indoor décor. The desiccant that is used in the LEAF House is a Calcium Chloride solution that is a safe, odorless chemical that naturally absorbs moisture. When moisture is absorbed from the air, the compound heats up and is pumped to a reservoir near the roof of the house. Here it releases its heat and regenerates around 170 F (76.6 C). The desiccant dehumidification system is located in the living room of the house and is the focal point of the room.



In order to control the environment of the house, the LEAFHouse is equipped with a Smart House Adaptive Control System. This system gives the occupants the ability to interact with the house and track the house's conditions from a web based interface. The conditions can be viewed in real time and adjustments can be made in order to optimize energy use, humidity, light, and water consumption. SHAC allows the house to be maintained efficiently and economically through its automated control system that performs tasks and monitors the house based on collected data.

Figure 55. Engineering Brief Contest Report. [LEAFHouse Team]

leaf house
at the University of Maryland

Engineering Design and Implementation

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Mechanical

The LEAF House uses radiant heating to control the temperature in the house. It has heating panels in the floor in order to take advantage of heat rising. This system uses PEX tubing imbedded into MDF panels. This system enables efficient heating of the house at a low cost and takes advantage of thermodynamics to control the living environment.

The house is cooled by a ductless mini-split system. This system is set up as an auxiliary heat pump, which utilizes refrigerant lines and a fan to cool or heat the air. It will be set for 74 degrees Fahrenheit, causing it to heat or cool the air when necessary. The ductless mini-split system is run off of ozone friendly refrigerant, R410a. There will be two fans, one on the west facing wall of the mechanical wall and the other is on the south facing wall of the kitchen.

Electrical

The key to the success of LEAFHouse lies in the photovoltaic cells that convert solar energy into electricity. To make LEAFHouse fully self-sustainable the design maximizes the effectiveness of the solar arrays. Thirty-four solar panels are arranged across the entirety of the roof in three independent circuits. The panels on the east side form one circuit, the panels in the middle form another, and the panels on the west form the third circuit. The division of panels maximizes power production during sunrise and sunset when the intensity of light on one side of the roof will be much higher than the far side.

The design calls for thirty-four panels, each rated to produce a maximum output power of 205 watts. Each panel weighs 31 pounds and produces a maximum open circuit voltage of 68.7 Volts. The panels are rated for an overall efficiency of 17% making them sufficient for LEAFHouse's needs and budget requirements.

Batteries and Inverters comprise two other key elements to the electrical system. LEAF House has 48 twelve volt batteries stored under the deck that are capable of powering everything in the house for four full days. The sealed lead acid batteries are divided into groups of four, connected in series, to produce a total voltage of 48 volts, thereby maximizing the efficiency of the inverters. Thirteen of these groups of four are wired together in parallel strings to increase the amount of current that can be drawn by the system at any time. LEAFHouse's have a low hydrogen leakage and can each steadily produce 250 Amps for 20 hours.

PV cells and batteries produce and store electricity as direct current, but almost all appliances are designed to run on alternating current. LEAFHouse uses four Flexware 100 power inverters to provide the appliances with usable alternating current. The inverters are compatible with fully off-grid systems as well as grid integrated systems.

Plumbing

The plumbing of the LEAF House is oriented around the green wall. Rainwater is collected and re-circulated through a series is vertical and horizontal rain gardens. These gardens filter and retain the grey water which reduces the waste produced by the LEAF House.

LEAFHouse is focused and committed to the retention and collection of rainwater and greywater on site. Greywater from the house is used for irrigation in a grey water garden. Run off from the roof is plumbed in to the vertical green wall, a prominent feature on the house's south façade.

Figure 56. Engineering Brief Contest Report (cont.'d) [LEAFHouse Team]

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Electric Lighting and Daylighting Quality

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While using clean, environmentally-friendly solar power is important, it is as equally important to ensure the use of the energy is productive and efficient. LEAFHouse blends architecture and engineering to maximize the light afforded its inhabitants with creative use of glazing, energy efficient fixtures and an innovative twist to traditional electric light dimming systems.

The house lighting is an integral part of LEAFHouse's design and the architectural intent. Programmatic function, solar orientation and volumetrics of inhabitable space all contribute to LEAFHouse's marriage of functionality and aesthetics. A public area requires considerable light, and LEAFHouse is provided with large expanses of glass that wrap around the house and afford gorgeous views. Private areas need lower levels of light, and use smaller windows to offer more privacy. The north-south orientation of the house allows for superior energy gain with larger south-facing windows in the living spaces, paired with smaller north-facing windows in the biomechanical zone minimizing energy loss. Solar gain through the south-facing doors is controlled with shutters that are specially louvered to provide ideal shading during the summer while allowing maximum light and heat gain during the winter. An exterior overhang helps boost the efficiency of the louvered doors. Though the smaller north-facing windows reduce the available daylight in the northern zone of the house, an innovative roof-ridge skylight allows diffuse sunshine to filter through its highly insulative, nanogel-filled panes.

SHAC, LEAFHouse's smart house system continually monitors interior lighting levels and responds to environmental conditions b balancing electric lighting with natural light. This system helps control energy usage and enhance the user's experience in the house. Homeowners can individually control dimming levels according to who is in the house, what time of day it is and what type of activitiy they are engaging in. There are more than a dozen Lutron SeeTouch® multifunction button stations designed to control lighting functions and levels in all of the places one would expect to find a traditional switch as well as a central control system located at the house's workstation computer. SHAC's web-based interface also allows remote control of LEAFHouse's lighting system.

Electric light is produced using two of the most efficient sources available on the market: fluorescent and LED lighting. The strict environmental sustainability requirements of the Team is reflected in the use of Philips Alto II low-mercury fluorescent lamps, and the ceiling plane becomes an oversized reflector for a series of Elliptipar fluorescent fixtures. Local task lighting is supplied using LED lamps mounted inside low-voltage recess lighting fixtures that are carefully aligned within the grid of the house. To illuminate LEAFHouse's

Figure 57. Lighting Brief Contest Report. [LEAFHouse Team]

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at the University of Maryland

Electric Lighting and Daylighting Quality

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mechanical features, flat-panel LED fixtures are utilized in the liquid desiccant wall and the mechanical room. Wall mounted low-voltage fixtures are retrofitted with LED lamps on the exterior to provide lighting at the entrance, north, and east doors, while miniature LED downlights emphasize the south overhang and provide additional lighting at the two large doors. LED fixtures around the site provide a welcome entrance to guests while highlighting the beautiful landscaping. All of the fixtures are wired to a Lutron Grafik Eye® 3000, a centralized dimming and switching system that permits flexible lighting control as well as delicate finely-tuned adjustment. This system is divided into three dimming controllers with six zones each, for a total of 18 zones of lighting for the house.

The Solar Decathlon is not just about the team with the largest photovoltaic array, but the team that can use the power given by their solar panels the most wisely. By bringing the sun's energy, electric light and the house design into harmony, LEAFHouse blends nature and technology into an efficient piece of architecture.

Figure 58. Lighting Brief Contest Report (cont.'d) [LEAFHouse Team]

leaf house
at the University of Maryland

Market Appeal

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Defined Target Market

The target market for LEAFHouse is the present population of green-thinking baby-boomers—the early adopters considering downsizing or a second home—to the future, when LEAFHouse can be replicated and combined to form larger, multi-family dwellings. LEAFHouse will make it clear that everyone can live in a solar house like this one. LEAFHouse is leading everyone to an abundant future by showing the way—solving tomorrow's problems, today.

Everyday Livability

Everyday tasks are able to be performed efficiently and in a home built of firmness, commodity, and delight. Simple circulation paths, relationships of rooms, and transformable spaces allow inhabitants easy movement and multiple options for the use of spaces. Abundant natural light and an electric light control system provide ample light for activities of all types, from socializing to cooking to working. Spaces integrated with the landscape connect the inside to the outside as well as the reverse. The kitchen is the hearth of the home, while the north mechanical "bar" provides a clear zone of services allowing the living spaces to be as open and spacious as possible.

Lighting receives special attention in LEAFHouse. Lighting control is a very important part of energy usage in the United States. By incorporating several Lutron Grafik Eye® systems, the homeowner can have the choice between many different levels of lighting in the house. Instead of having only two choices – on/off – the resident can control dimming levels according to who is in the house, what time of day it is, and what type of activity they are engaging in.

The house can be operated and maintained efficiently and economically, due to the overall organizational strategy of "service and served" spaces; the management of comfort zone and total electric loads; and to the SHAC system. A "cost to compare" website provides a figure of 750 kWh/month listed as a monthly electricity use for a typical home. If that home had the LEAFHouse PV capacity, it would produce a surplus, in addition to paying for its utility bill. The Smart House / Adaptive Controls System (SHAC) offers the owner a management system for "simple living", with an emphasis on the efficient use of energy.

Americans are growing increasingly concerned about the impact their excessive energy consumption is having on the environment and on their energy bills. Most people, however, lack the time and technical knowledge necessary to monitor and control their homes effectively, to achieve both comfort and efficiency. The SHAC system is being developed to provide this service with an automation package that efficiently manages resources in the house such as lighting, air conditioning, etc. It automatically explores strategies for reducing consumption, especially during those days when solar income is limited. Over time, it builds a profile of house performance and resident preferences in order to optimize the balance between energy conservation and comfort. SHAC provides a user-friendly graphic interface to help people become aware of their energy consumption patterns and strategies to reduce waste. SHAC also monitors the operation of the house systems, detects problems that impact reliability and efficiency, reports these problems to the residents and to the technicians who help service and maintain the house.

Figure 59. Market Viability Brief Contest Report. [LEAFHouse Team]

leaf house
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Market Appeal

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Video interview series

A series of short videos of team members are appearing on our website and on YouTube from Labor Day through the contest period. The video shorts portray team members' motivations, explain their favorite house features, and describe breakthroughs during the process of design, construction, and outreach. Team volunteers are editing the videos into slightly longer versions to be shown on the television in the Maryland house while it is on the Mall, to take every opportunity to entertain and educate visitors about the people behind the house and unique features that might not be readily apparent.

House interpretation

Interpretive signage features "nutrition labeling" in the style of shipping labels attached to the various items in the house, showing their energy savings and respective payback periods, as well as a running series of signs on the deck (to make the most of waiting time), and the house walls and fixtures. In addition, house visitors will be invited to use their cell phones to hear a recorded message at any time, day or night, explaining the Decathlon and the Maryland entry, for those who miss one of our regularly organized tours or prefer a self-guided tour.

House tours

We are coordinating tour guide recruitment efforts on campus with the leaders of the University of Maryland "First Year Book" program, who this year have asked that all freshmen read the book *Ravaging Tide*, by local author and organizer Mike Tidwell, about the potential impacts of climate change and sea-level rise on America's coastlines. (Maryland is the second state most at risk, after Louisiana.) Fresh from reading the book, freshmen are being invited to form a team of tour guides to be extensively trained to give tours on the Mall and supplement the core team of house builders. Additional campus visibility efforts have been coordinated through a class of undergraduate communications students who took on the Maryland entry as a semester-long project in planning a promotion campaign.

Speakers bureau

We have recruited and provided message and media training to a panel of knowledgeable team members and mentors who can represent the goals of solar power and sustainability to the Washington media and in group presentations. Their names and contact information appear on our website as a solar house speakers bureau, and bookings are being obtained.

House furnishing

A "retro metro" look has been selected for our house furnishings and incidental items to illustrate its appeal to the initial target audience we identified for the initial 800-square foot model of LEAF House: downsizing baby boomers, and affluent twenty- or thirty-somethings buying their first home or just starting their family. Further marketing materials are adopting this look and feel, as well, to make the house as appealing as possible to its core target market.

Team branding and messaging

The leaf motif of the Maryland team's logo and house name connotes nature's perfect solar collector, the leaf—as well as being an acronym for the number one project goal that emerged early during our branding process, namely, "Leading Everyone to an Abundant Future." The leaf is used in our logo and throughout our house and materials. Message-rich team T-shirts convey the bright future of "pure energy" from the sun, and tour guide uniform shirts are made from a sustainable bamboo fabric that is soft to the touch. Support from the University's First Year Book program has enabled all our tour guides to wear these shirts on the Mall, and help us convey the Decathlon's messages to the widest possible audience.

Figure 60. Market Viability Brief Contest Report. [LEAFHouse Team]

leaf house
at the University of Maryland

Website

"**L**eading **E**veryone to an **A**bundant **F**uture."

School of Architecture, Planning and Preservation and the A. James Clark School of Engineering

In "leading everyone to an abundant future," as our mantra states, education is extremely important in achieving this goal. The LEAF House team website http://www.solarteam.org is one of the many communications tools used to reach visitors of all ages, solar interest levels, and experiences with sustainable technology. LEAF House uses the website not only as a way to educate the public, but also allows those who are interested to follow our process and learn alongside with us.

Website Organization
The website is organized in easy to interpret and quick to access sections. It is deliberately designed to distribute all the information the LEAF House team intends for the public to a variety of audiences. They include:

- Home
- About
- House
- Updates
- Sponsor
- Webcam

Home
The home page contains a brief description of the Solar Decathlon competition and the goals, history, and mission statement of the LEAF House team. This page is intended for new visitors to the site to gain a broad understanding of the Solar Decathlon and the LEAF House team. For repeat visitors, special feature links allow them to go directly to new LEAF House updates since their last visit. The feature links are available through the website for easy navigation throughout.

About
The website is a way for the LEAF House team to distinguish our team from others, but much more important than winning the Communication Competition, LEAF House wants to achieve the Competition overall goal to education the public and promote the understanding and use of solar and sustainable technology in their personal or professional lives. The "About" section features our team, courses offered, the unique process LEAF House team used, and basic solar references. The LEAF House team includes the students, advisors, and the dedicated mentors all highlighted on the website. To foster collaboration between students from various departments on campus and encourage and reward students for their interest in the project, LEAF House offered academic credit as mentioned in the courses and detailed in the process sections. The About section includes team members' reflections on what they have gained from working on LEAFHouse. The basic solar references section is a collection of website links for visitors to learn about alternative technology, how they can install it in their homes, and various incentives from their local government. It is not intended to answer all questions that visitors may have, but to guide them toward reliable sources of information on sustainability.

House
Sections following the "About" section are all unique to the LEAF House team. The "House" section contains information about our construction process. As our team works toward house construction, details about the current construction stage are revealed to allow visitors to follow our progress. This section also describes the basic

Figure 61. Website Brief Contest Report. [LEAFHouse Team]

leaf house
at the University of Maryland

Website

"**L**eading **E**veryone to an **A**bundant **F**uture."

School of Architecture, Planning and Preservation and the A. James Clark School of Engineering

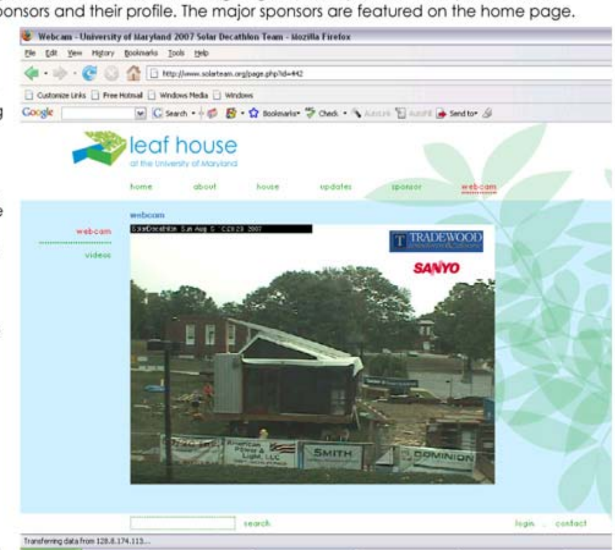
technology employed in the LEAF House. Additionally, it includes an interactive map that not only visualizes the house interior, exterior, and construction stages but also allows users to learn more about the materials and technologies used along with LEAF House sponsors who contributed those items. Sponsor recognition rewards those corporations or individuals who are interested in promoting sustainability and directs visitors local to the Maryland, Virginia, and DC area to local corporations who can help bring sustainability into their lives.

Updates

As mentioned in the introduction, in an effort to educate and entertain visitors, the "Update" section contains a picture gallery, construction videos, and press information related to the LEAF House team. The picture gallery captures our everyday endeavors whether it is team design meetings during the initial design phase, house construction during the final stages, or public speaking events throughout the entire process. Sprinkled in the picture gallery are out-take photos of the team members at their best. This section brings out the personal side of the team and the project. The entire updates section is easy to understand, entertaining to visit through and is great for visitors of all ages.

Sponsor

LEAF House would not be possible without the generous donations that our sponsors have provided. Whether it is monetary, material, or services and regardless of the amount of the giving all of our sponsors are important to us. This section is updated daily with our sponsors and their profile. The major sponsors are featured on the home page. For those interested in sponsoring our team, the sponsor kit and levels of giving sections provide all the information they would need to make the decision to join our team in leading everyone to an abundant future.



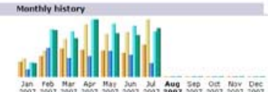
Webcam

The last major section of the website is the webcam page. This page is unique to few teams in the Competition. It provides the ultimate up to the minute progress report. In educating the public it is paramount that the information is correct, relevant as well as engaging. This is a key goal that the LEAF House website team has maintained.

Statistics

Internally, the LEAF House team has been monitoring information on visitor statistics. Currently, the website has 82,341 hits and 7,964 unique visitors as of August 5, 2007. This translates to approximately 45 unique visitors per day and approximately 10 page views per unique visitor per view. These statistics indicate that our website continued to attract new visitors, and for those news visitors our website has been engaging enough for them to return. This is additionally supported by the corresponding graph showing increases in unique visitors since the website came live in January of 2007.

Monthly history



Month	Unique visitors	Number of visits	Pages	Hits	Bandwidth
Jan 2007	974	1145	16646	34066	835.24 MB
Feb 2007	1317	1705	67983	111749	2.83 GB
Mar 2007	1793	2415	44513	106555	2.30 GB
Apr 2007	1715	3369	48330	134689	3.44 GB
May 2007	1675	2761	60463	124440	2.64 GB
Jun 2007	1523	2887	51717	121139	2.52 GB
Jul 2007	2039	3666	31807	107124	2.93 GB
Aug 2007	0	0	0	0	0
Sep 2007	0	0	0	0	0
Oct 2007	0	0	0	0	0
Nov 2007	0	0	0	0	0
Dec 2007	0	0	0	0	0
Total	11036	17946	321459	739762	17.47 GB

Figure 62. Website Brief Contest Report. [LEAFHouse Team]

LEAFHouse Larger

From the conceptual stages of LEAFHouse, the team wanted to make the design of the house such that it could be incorporated into larger units or homes as well as communities. The team believed that the 800 sq. ft. house stipulated by the competition, although sustainably designed with green materials, was not sustainable as far as the global community and environment was concerned. This therefore, became one of the teams' guiding principles. The competition houses were designed to stand alone as a single family dwelling on a private lot, a situation that has the potential to lead to suburban sprawl and the overtaking of green fields throughout the United States. The systems and materials of the house may be sustainable and green, but the one-off prototype houses were not. The LEAFHouse team thought of the house in a different way in terms of master planning, in which densities could be increased and sprawl could be reduced.

Figure 63. Early discussions on LEAFHouse communities. [LEAFHouse Team]

In the spring of 2006 the team set out to formulate ways to incorporate LEAFHouse into larger communities. Many of these early concepts were straightforward, simply using the basic LEAFHouse module and plan, and incorporating them in various configurations to form larger communities. These investigations provided a launching point for intense and detailed studies and designs, looking at ways to incorporate the principles inherent to LEAFHouse into communities.

'LEAFHouse Larger', a phrase coined by the team, took earlier studies to a new level, trying to use the original LEAFHouse design and design principles to create higher density living which could be incorporated into existing urban environments. The goal was to achieve approximately thirty dwelling units per acre, which was deemed effective land planning. In addition, ways to mitigate impervious surface and parking, control water runoff, increase landscaping, and incorporate as many green technologies and strategies into the designs was strongly desired and encouraged. The open plan of the original design allowed for a lot of flexibility during this stage, and the early established guiding principles continued to help the team during this studio exercise.

Figure 64. Townhouse adaptation. [Adam MacDonald]

A successful adaptation of the original house design was found in its transformation into an urban townhouse. The townhouse design took the approach of a more rationalized, modular floor plan of LEAFHouse creating three-story row house/townhouse sited in downtown Baltimore. The first floor of the townhouse was a one bedroom apartment based on the enlarged LEAFHouse floor plan. To one side of the plan were stairs which led to the two-story townhouse apartment above. In the center of the plan was a large two-story atrium with a skylight.

Figure 65. LEAFHouse garden flats. [Florence Ho]

Another increase in LEAFHouse density was accomplished in a three to four story garden flat apartment complex which achieved 29 dwelling units per acre on the Inner Harbor in Baltimore. This design focused on an interior rainwater/grey water collection courtyard surround on two sides by 35 apartment units. In addition, the section of the design was stepped to utilize existing site topography. The southern apartment block was sited lower than the northern block, and the courtyard width was determined by sun angles in an effort to allow as much sun as possible to enter the courtyard and the north apartment units.

A third effective re-design using the guiding principles and the original LEAFHouse module was the urban villa. This design incorporates the original plan into a new zero-lot-line urban villa which can be scaled up based on the needs of the owner or the size of the family. This is done through the flexibility of added stories, as well as an added wing that can be incorporated into the house and which utilizes the original LEAFHouse module for its base plan. Unlike the previous two examples, this design is not quite as dense and urban. The main house block and the optional wings create a protected yet elegant inner courtyard for owner that allows for plenty of sunlight into all the rooms of the house. In addition, there is a lush front yard which helps mitigate street noise, yet still creates an inviting entrance.

Figure 66: LEAFHouse villa. [Liz Maeder]

Finally, an investigation was undertaken to try to rationalize the existing plan of LEAFHouse. Due to some of the constraints of the competition (height, solar envelope, and square footage), as well as lack of team experience in design and construction of buildings, the original plan for LEAFHouse was not one that worked well with traditional framing material's dimensions. As a result, a lot of waste was produced on site during the construction process as studs were cut eight inches shorter and plywood was sawn to be three foot wide instead of four, for example. In this exercise, termed *LEAFHouse Rationalized,* attempts were made to transform the original LEAFHouse plan into one that could be modularized and produced much more effectively, and efficiently than the original.

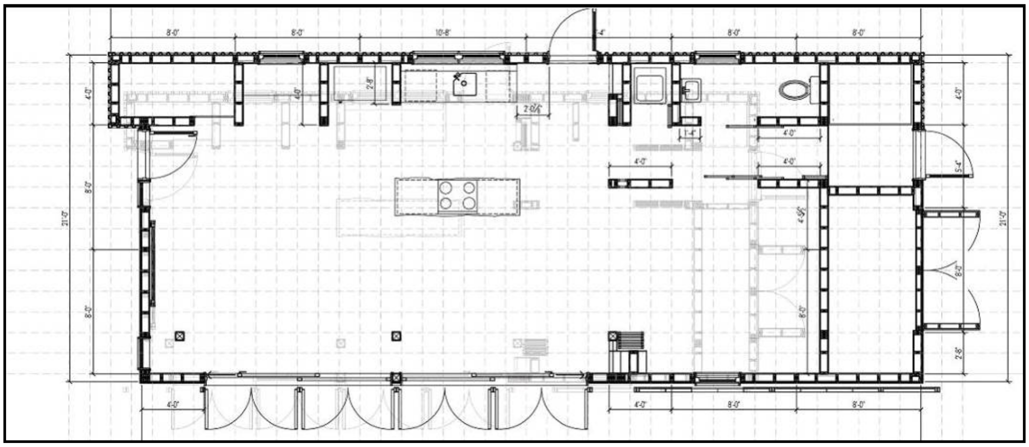


Figure 67. Existing LEAFHouse Plan overlaid with LEAFHouse Rationalized. [Morris]

The entire plan was first laid out on a sixteen inch interval for wall framing, and then a twenty-four inch grid was overlaid for roof framing. Every attempt was made to make these two grids meet the floor, wall, and roof, to maximize material usage and minimize material waste. With the grid now in place, a module was created, and it was this module that would become the basis for the extensions of the original plan into a 1200 square foot house (1 bedroom), a 1600 square foot house (2 bedroom), and a 2400 square foot house (3 bedroom). The team thought of these rationalized plans as something that could be ordered, efficiently manufactured, and sold to customers like a modern day Sears catalog home of the early 20th century.

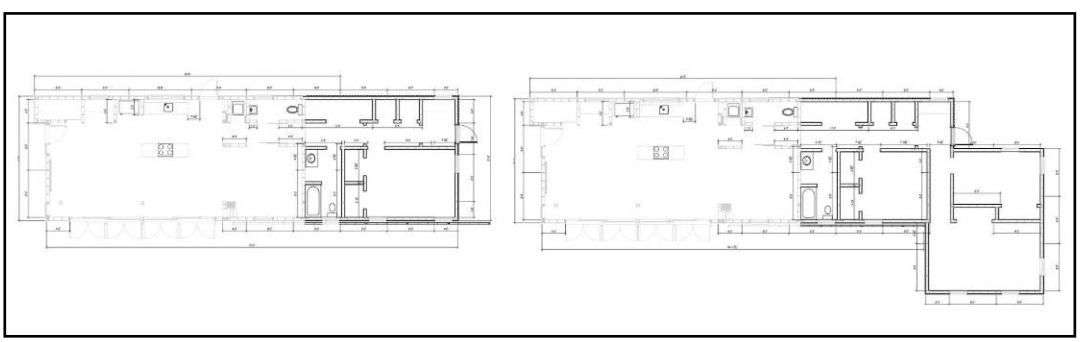


Figure 68. LEAFHouse rationalized with modular extensions. [Morris]

Construction

Construction Schedule

The construction schedule for LEAFHouse became a project in and of itself. Throughout the project, the schedule was constantly being adjusted to account for construction and material delays. Mentors were available to aid the team in making schedule adjustments, working with the team to make decisions based on the constraints of the schedule. The project pushed forward despite the constant schedule adjustments and seemingly constant setbacks.

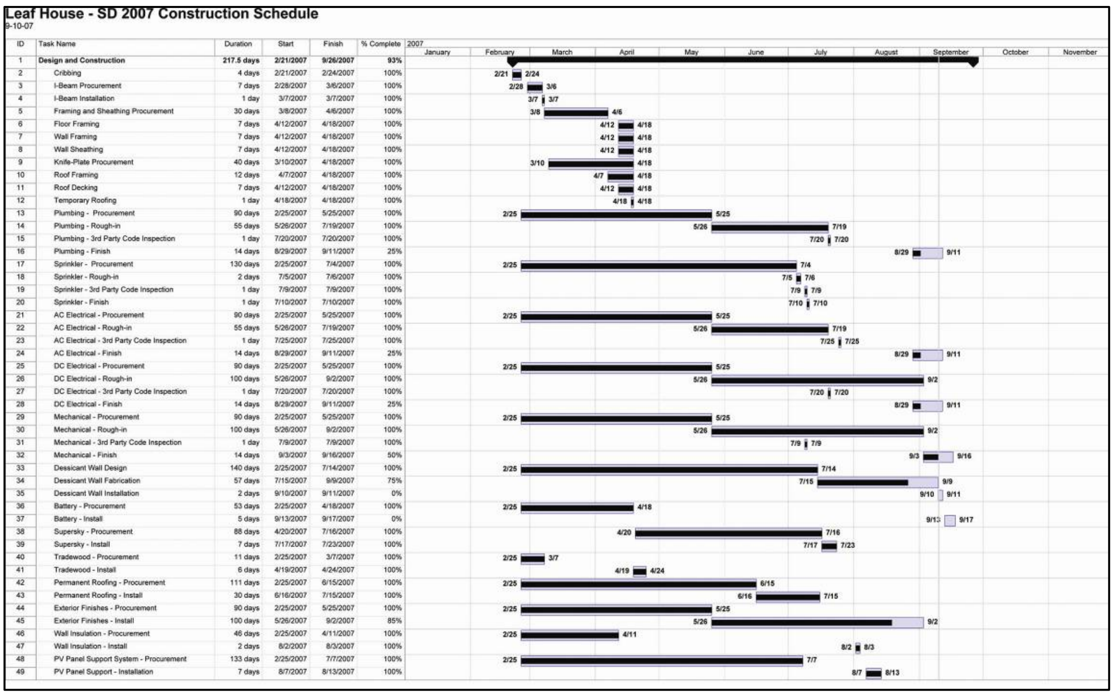


Figure 69. Final Construction Schedule [Dale Leidich]

The schedule was based on the amount of time that the team estimated that each task would take, from design hours and procurement, to the actual installation of the item. Each proceeding task relied on the one prior to it to be completed before it was activated in the schedule spreadsheet. Through this method, the team could keep a detailed account of everything that was going on in the project, and how long its subsequent items would be delayed if previous tasks were not completed on time. Constant team meetings were held in order to remain on schedule, keeping all team leaders aware of the state of construction on different aspects of the house. Once the house was enclosed, meetings were regularly held inside so that team members could see and understand how each task was related and would affect the next.

Figure 70. Weekly schedule meeting inside the house. [LEAFHouse Team]

As a result of these constant conversations, the team could easily see how any delay in the task they were working on was adversely affecting many more tasks to come. Scheduling of the project was often discouraging and difficult, as no student involved had much in-depth experience with such a monumental task. In the end, however, each student was able to gain a new appreciation for the scheduling of a project and how vital it is in moving a project along efficiently.

Construction Sequence

Foundation and Floor

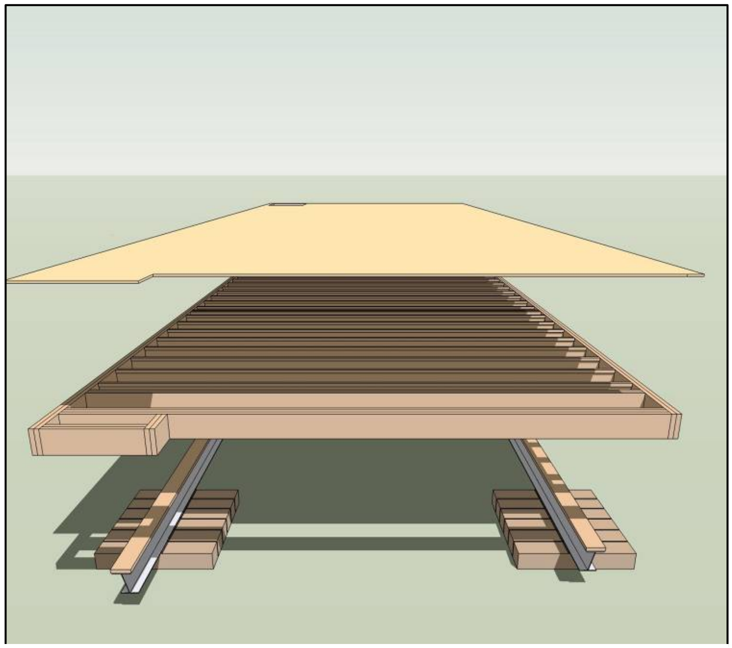


Figure 71. Foundation Sequence. [LEAFHouse Team]

In mid-February 2007, students arrived on site to begin construction by laying down the six gravel beds that were to support the cribbing for LEAFHouse. The pea gravel footings were first set on a layer of filter fabric which was surrounded by a wood frame to help contain the gravel on site. Each pad was then individually leveled. A week later, the 8”x8” poplar wood cribbing arrived from the sawmill and was laid into place on the gravel pads. Each “foundation”, which consisted of 10-14 pieces of interconnected cribbing, was designed to allow for specific load bearing capacities as regulated by the National Park Service and determined by our structural engineer. Since the gravel beds had already been leveled the week prior, setting the cribbing in place was straightforward and went quickly. Eventually, all the cribbing would also be tied down to prevent shifting of the foundation piers.

Two weeks later, during the first week of March 2007, the 2-40 foot W12 beams arrived on site. With the aid of a forklift, the team placed the two beams on top of the cribbing piles. The following weekend one of our structural mentors arrived on site with a transit level to aid the team in squaring and leveling the two beams. Over the course of a Saturday, the team shimmed the beams into place. The beam was then locked into place on the cribbing, and tied down to the site by an innumerable amount of 18 inch soil anchors and cable. A treated 2"x8" wood plate was then bolted to the steel beams through specified factory drilled holes, and the team was ready to begin framing for LEAFHouse.

Figure 72. Foundation Sequence. [LEAFHouse Team]

Walls

With the foundation and beams leveled and securely fastened in place, the LEAFHouse team set out to construct the exterior walls during the first week of April 2007. The team enlisted the help of subcontractors since there was not enough student labor and experience available to get the job done efficiently. However, it was stipulated that the framing process would be a teaching one, and thus any interested student could show up and help or learn. With the help and guidance of three more of our construction mentors, students erected the exterior shell of the building over the span of two days.

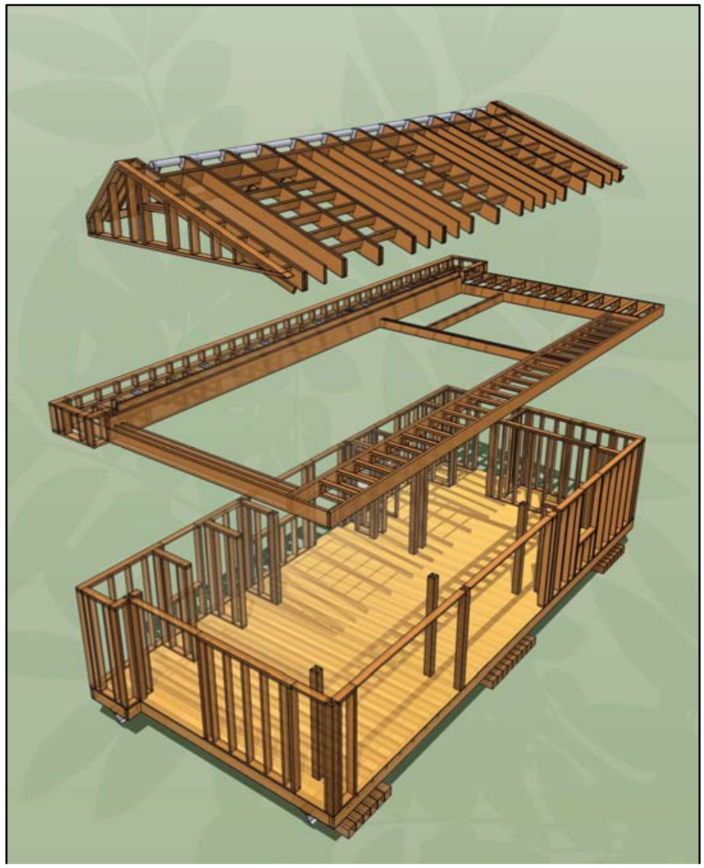


Figure 73. Wall Sequence. [LEAFHouse Team]

The exterior framing for LEAFHouse was somewhat conventional, utilizing 2"x6" studs (FSC certified) spaced 16" on center with ½" plywood sheathing on the exterior. This allowed for a rapid construction pace since it is a well established method. It also provided the needed flexibility in the placement of the systems later in the rough-in process. All of the walls were first built and squared on the deck (complete with plywood), and then lifted, leveled, and secured into place by the team. Once all the walls were up, additional leveling was done, and braces were added throughout the interior to keep the structure square until the roof framing and sheathing were constructed the following week. During the final stage of the wall construction process, the window openings were cut out, and the LVL structural rim was also added in preparation for the roof structure.

Figure 74. Wall Construction. [LEAFHouse Team]

Roof

In the second week of April 2007, the team set out to erect the roof of LEAFHouse, again with the aid of our three construction mentors. The roof had three components: the open steel ridge and skylight, the sloped roof for the photovoltaic array, and a series of flat roofs. The steel ridge was composed of a custom, team designed and specified, steel pipe with welded knife plates. This design allowed for the polycarbonate skylight.

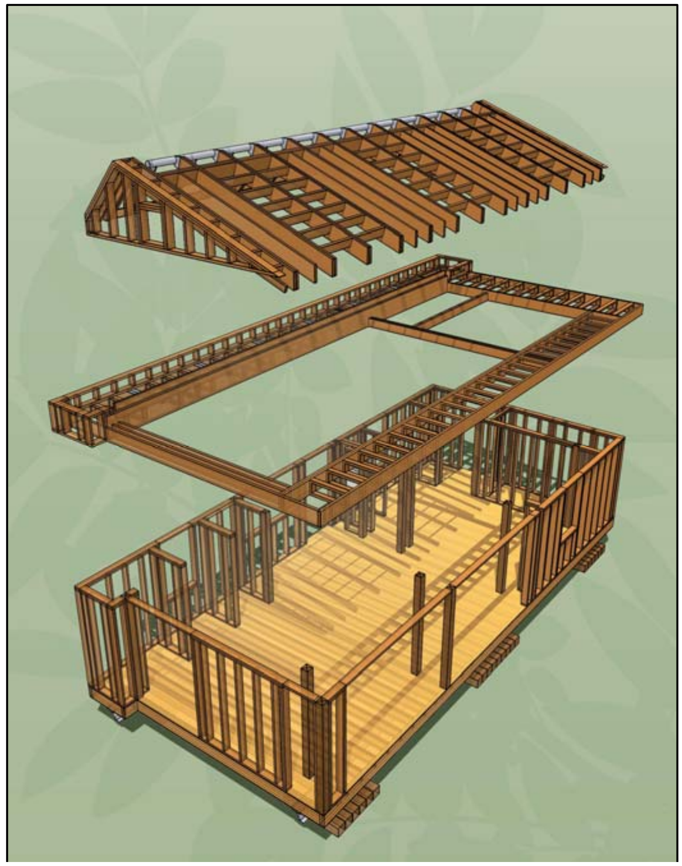


Figure 75. Roof Sequence. [LEAFHouse Team]

During the first day, the team set out to erect the flat roofs which surround the structure. The flat roof was constructed with 9-1/2" wood I-joists spaced 16" on center and covered with 5/8"plywood. The flat roof contained all of the electrical, mechanical, and plumbing systems for the house, and the wood I-joists allowed the team to easily drill through the web for these rough-ins. Originally open web trusses manufactured off site were specified, but due to the small span, the leftover I-joists on site were utilized. This portion of the roof was supported on one side by the exterior walls, and on the interior by paired 9-1/2" LVL beams supported by posts. These posts provided not only the support, but also allowed for the open plan of the house. During the next three days, the team erected staging to temporarily hold the steel knife-plate pipe in place. With the pipe in place, paired 2”x10” Douglas Fir rafters were bolted to the knife plates on the ridge. These rafters were eventually covered with 5/8” plywood and would become the supports for the photovoltaic array.

Figure 76. Roof Construction [LEAFHouse Team]

Doors and Windows

Following the completion of the rough framing for the walls and roof came the installation of the high performance, solid Douglas fir doors and windows. The doors and windows had arrived in April 2007 and had been waiting in storage due to construction delays. Prior to ordering the windows and doors, the team had worked with the manufacturer on the shop drawings and detailing. The windows and doors were custom designed and manufactured specific to the project.

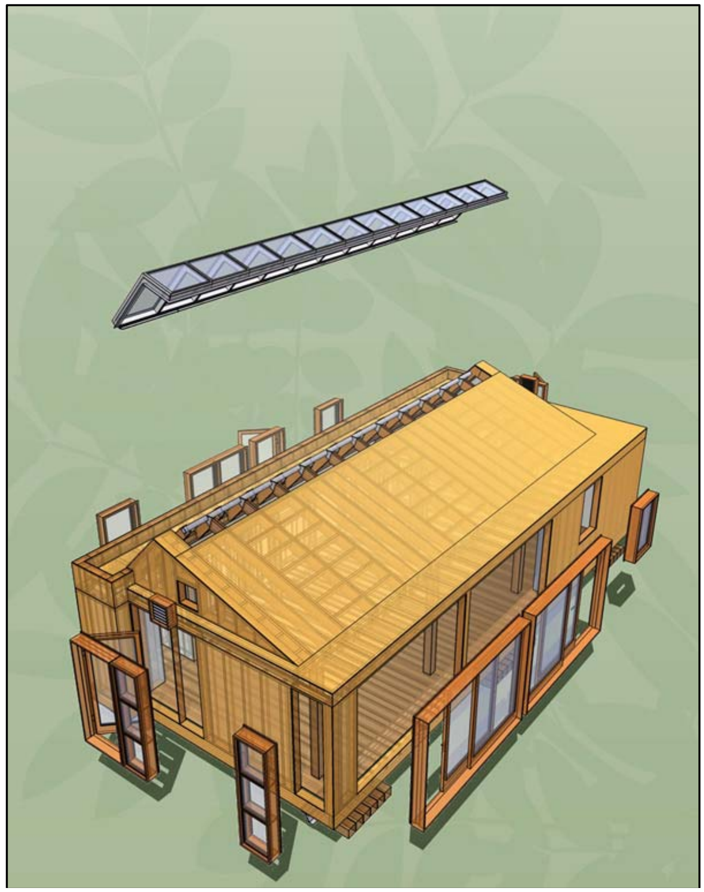


Figure 77. Door & Window Sequence. [LEAFHouse Team]

The first step in the installation process was to wrap all the openings in a rubber membrane to prevent water infiltration and rot around the opening. Metal nailing flanges were then attached to the heads and jambs in order to fasten the windows to the house. Once in the designated opening, the windows were centered and checked for square. They were then leveled vertically and horizontally, and shimmed as was deemed appropriate, with the final attachment occurring at the nailing flange. Additionally, the doors were set in caulk to seal at the sills. Months later, after countless delays, the polycarbonate skylight from SuperSky arrived and was installed over the span of a week. Team members installed the skylight with the aid of a mentor from the factory. They assembled the prefabricated, specially design pieces in place and then sealed the opening. With the skylight in place, the envelope was now sealed and the team could finally install the siding and begin systems rough-ins.

Figure 78. Door and Window Installation. [LEAFHouse Team]

Siding

In mid-June 2007, once the windows and doors were in place, it was time for the corrugated steel and FSC Eastern White Pine siding to be installed. Overall, the installation process took approximately two weeks, with the majority of the work occurring on weekends during that time. The team had obsessed for months over every detail of the siding, including trim profiles, directionality, and profile. The team detailed the siding and the way that it met other materials and parts of the house to reflect the overall ideas and goals of the team.

Figure 79. Siding Sequence. [LEAFHouse Team]

Prior to the siding installation, however, the entire house was first wrapped in HomeSlicker. This was a drainage matt product similar to the Tyvek product typically seen in residential construction locally. The difference comes in the profile of the HomeSlicker, which keeps the siding approximately ¼" off the drainage matt in order to allow for water drainage as well as air circulation. This product was most vital in order to ensure the longevity of the wood siding. After the HomeSlicker had been installed around the entire envelope, trim profiles for the corrugated metal siding were then installed around the windows and doors, as well as the drip edge at the bottom. The steel corrugated siding had arrived first and was therefore installed first. The wood siding arrived a couple weeks later, and had to be stained and sealed before installation. This was one of the most impressive tasks completed on the exterior, as all of this work was done solely through student labor. With the installation complete, the exterior was taking shape and the house construction was starting to come together.

Figure 80. Siding Installation. [LEAFHouse Team]

Finish Roof

Also occurring in mid-June 2007, concurrent with the siding installation, was the installation of the finish roof system, which consisted of rigid insulation topped off by a TPO membrane. As a result of specifying a commercial roofing system unfamiliar to the team, the team put this part of the project out to bid through the University system. However, after a couple weeks of waiting, no bids were returned and the team still did not have a roofer. After an additional strenuous and tumultuous month of searching, a professional roofing specialist was eventually found. He agreed to guide the team in the installation of the roof, with team members providing much of the labor under his watchful eye and constant supervision.

Figure 81. Finish Roof Sequence. [LEAFHouse Team]

The first step in the process was the installation of the rigid insulation, which served several purposes: adding R-value to the roof, providing taper on the flat roof for water drainage as well as adding an extra layer to raise the dew point and keep the roof sandwich dry. With the rigid insulation installed, a ¼” fiberglass board was then installed and screwed to the roof deck using fasteners and metal plates. With these two elements in place, the final TPO membrane was finally laid in place, glued and then finally sealed to the fiberglass board. Over the next three months, and over the course of countless weekend work sessions, the roof mentor continued to work with the team and the roof slowly came together. After the concealed gutter was built around the perimeter of the house, the roofing membrane was integrated into the gutter and the house was finally sealed and watertight.

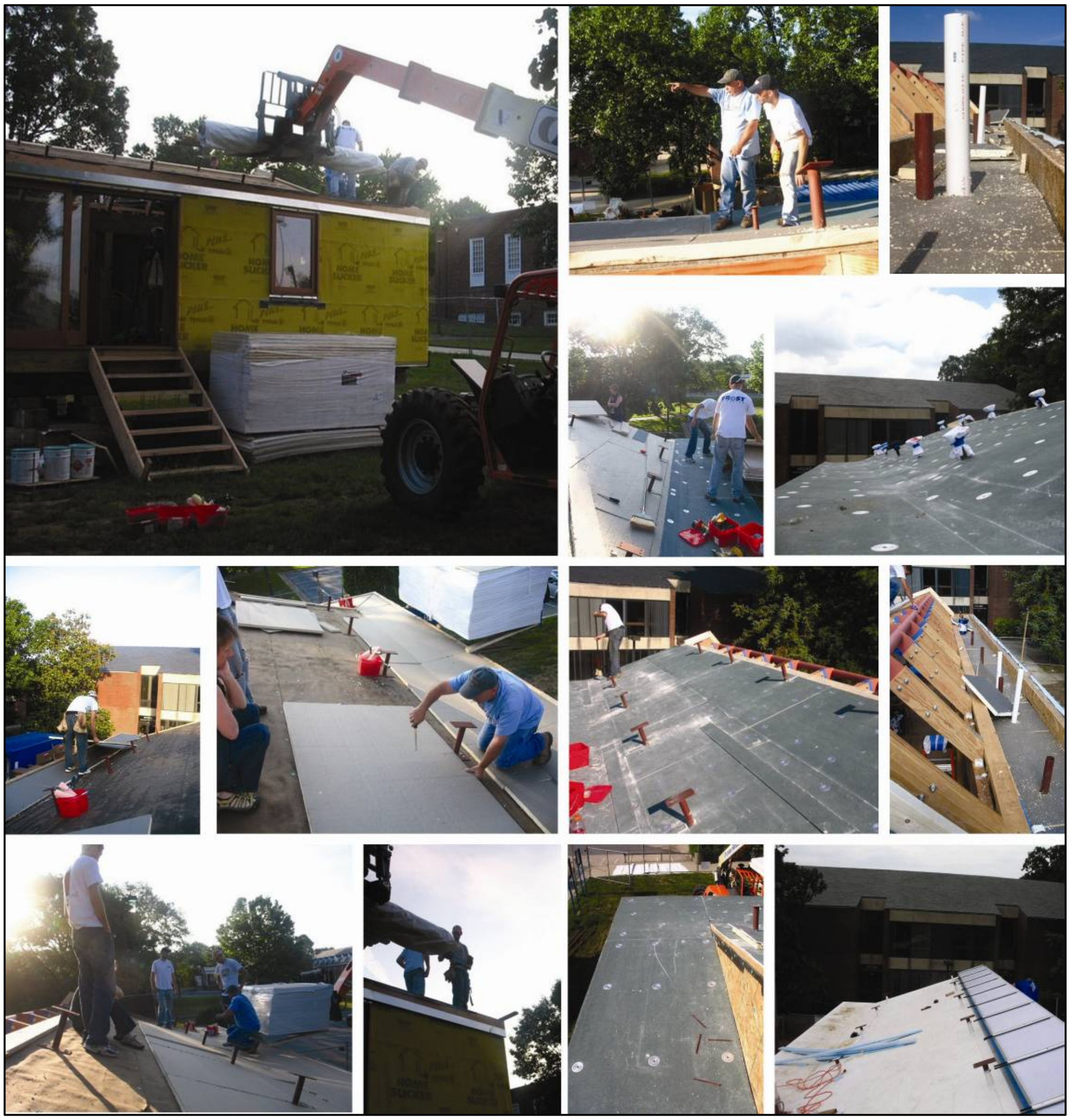


Figure 82. Finish Roof Installation. [LEAFHouse Team]

Rough-Ins

After much delay and anticipation, the rough-ins for LEAFHouse finally began in late -June/early-July 2007. The first trade to rough-in was the mechanical system. This was by far the easiest of the rough-ins, as the house only had one-30 foot duct run through the north bio-mechanical zone which would provide for ventilation. In addition, two vents were cut into the exterior siding in the east wall of the mechanical room for supply and return to the house's ERV system.

Figure 83. Rough-Ins Sequence. [LEAFHouse

With the flexible duct and register boots in place, the plumbing rough-in could commence following the conventional rough-in order of HVAC, plumbing, then electrical. This portion of the rough-in also included the installation of the radiant floor system. The team worked with the system manufacturer to create a radiant floor layout. Unlike traditional radiant systems, the panel used has 1-1/8" thick plywood panels covered in aluminum with pre-cut tube runs. The team used the Warmboard drawings to lay out the system. Installation began slowly, but as the team began to understand the system, the process sped up. Finally, the pex tubing runs were put in place in the channels and then run under the floor and into the manifold in the mechanical room. During this time, and with some aid from a professional plumber ,the plumbing fixtures, risers, vents, and waste drains were roughed-in, and the house was ready for its complex electrical components to be installed. With the constant supervision of our master electrician mentor, many hundreds of feet of wire, conduit, and data cable were pulled and boxes attached to the wall. Over the following month, rough-in work would continue at a hectic pace as runs and locations were finalized, trying to ready the house for our August 1st insulation installation appointment.

Figure 84. Rough-Ins. [LEAFHouse Team]

Insulation and Finishes

On August 1, 2007, the insulation installers arrived from Virginia and immediately began to prepare the house for the soy-based spray-foam insulation the team had chosen. This insulation is unique to the industry, as it uses water as the blowing agent for the insulation instead of the normal HCFC chemicals. This makes this insulation (BioBased 1701) much more environmentally friendly and thus appealing to the team.

Figure 85. Insulation & Finishes. [LEAFHouse Team]

One of the first tasks prior to blowing the insulation was to seal and caulk around all of the windows and the bases of the wall to reduce the air infiltration in those critical areas. Once that was complete, all openings were covered with plastic sheeting to keep the over-sprayed foam off the windows and doors. With the house now sealed and critical areas taped off, the installers took the next two days to blow 5” to 5-1/2” of insulation into all of our wall, roof, and floor cavities, giving the exterior envelope an R-value ranging from 27.5 to 30.25. The standard blowing process was lengthened to two days for this project because of the depth of insulation the team had chosen. In a normal application, insulation of this type is sprayed three to four inches thick. The depth the team had specified therefore had to be installed in two passes, with the second layer being blow once the first layer had dried substantially.

In early-August 2007, immediately following the completion of the insulation, interior finishes were installed. In one week, the drywall installers had hung, taped, and finished all of our interior drywall, and the walls and ceiling were now ready for a coat of paint. In addition, our wood floor installers came in and put down the wood floor in a day, with finishing coming much later in September. Our tile installers arrived and installed the recycled glass tile in the shower over the span of three days.

Figure 86. Insulation and Finishes Installation. [LEAFHouse Team]

Landscape and Decks

With the interior of the house almost complete, the team turned its attention once again to the exterior. Design and detailing of the deck and landscape elements had been progressing since February 2007, and the team had finally determined a solution to the function, aesthetic, and transportability aspects that were needed. The team investigated alternative framing materials, but in the end, pressure treated lumber was chosen.

Figure 87. Deck & Landscape. [LEAFHouse Team]

The landscaping elements and deck that surrounded the house were always an important aspect in the design in terms of creating a connection to nature. The decks and deck structure had to be designed so they could be easily disassembled and assembled many times for the competition. For this reason, the deck system was built very unconventionally using a panelized approach set on temporary concrete pier footings. Every attempt was made to design the deck so that each part could be managed by three to four team members during the assembly process. First, the 2”x10” deck beams were erected on their piers, leveled, and squared. Finally, the individual deck modules were constructed of 2”x6” pressure treated joists, with the final decking installed once all the panels were complete. The construction process continued during the months of August and September.

The second most visible landscape element to be installed was the green wall on the southeast of the house. The system the team chose was already a modular system, and thus it fit well into the design and transportability that was needed for these elements. The modules had been growing at a local nursery. In the first weeks of September 2007, the team brought them to the site to be installed on the paired 2"x4"s Doug Fir wood structure.

Figure 88. Landscape and Deck Installation. [LEAFHouse Team]

Solar Systems

During the final weeks of August 2007, and on into September, the team installed the solar systems for the house. The first step of the process was to erect the extruded aluminum grid on the sloped portion of the roof. The system was chosen because it provides the flexibility needed for the attachment of the various systems. This aluminum racking system was designed to be the support and attachment for the photovoltaic array, as well as the solar hot water tubes still to come. The team first planned out the installation on the ground, and then moved the installation to the roof piece by piece.

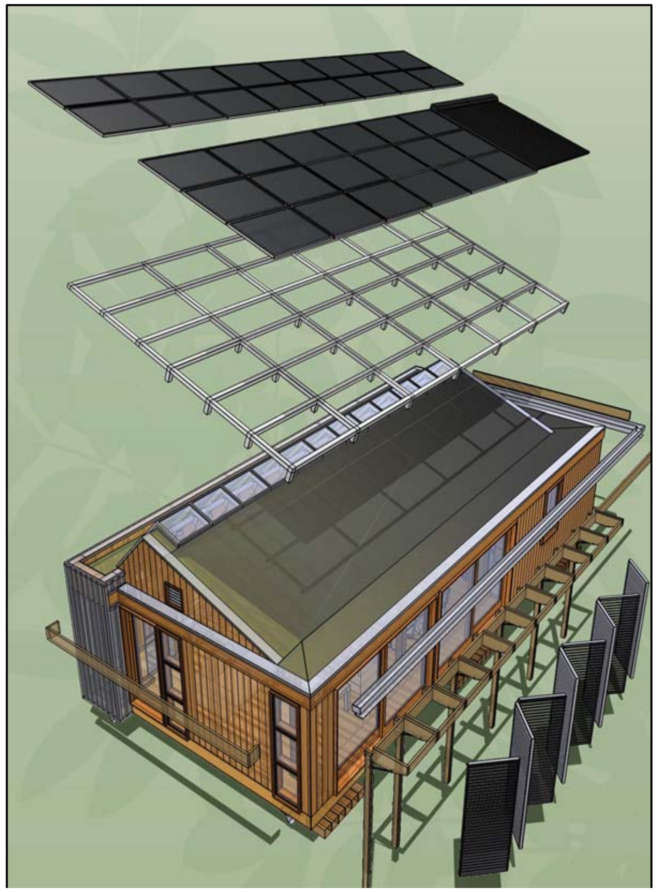


Figure 89. Solar Systems. [LEAFHouse Team]

With the grid in place, and despite brutally hot weather, the solar panels were quickly installed. A team of four students installed the solar panels on the roof, as well as the batteries that were under our north deck. Our master electrician was also constantly on site, tying together wires and batteries to get our electrical system up and running as quickly as possible so that we could begin to test and troubleshoot our equipment.

At the same time, a team of two mechanical engineering students were working hard to install and plumb our solar hot water system and all of its related components in the mechanical room. Work was now proceeding at break-neck pace in an effort to finish the house and various components before moving day in the first week of October 2007.

Figure 90. Solar System Installation. [LEAFHouse Team]

The Competition

Transportation

After completing construction on campus, the team then packed up the tools and readied the house for transportation to the National Mall, Washington, DC. The need for the house to be transported was constantly a part of the design process. Because of the close proximity to the National Mall, the team was afforded the opportunity to ship a very oversized load to the mall. The house was shipped intact as one piece with only the solar panels and associated racking system removed for transport. The exterior of the house was left exposed.

Figure 91. Preparing the House for the Move [Brittany Williams]

Expert House Movers were in charge of the move. They began preparing the house for the move early in the morning. The house was transported on the two steel beams that were included as part of the house construction for this reason. After raising the house on jacks, the movers backed the truck under the house and installed steel outriggers to carry the steel beams of the house. The house was then lowered onto the outriggers and began its move across campus.

Figure 92. The House Traveling Through Campus [Brittany Williams]

The house was taken through campus and then taken onto state roads at night. The house traveled at approximately 10-15 miles an hour and arrived safely on the mall around 1AM.

<u>Reassembly</u>

Before the start of the competition, the team had to reassemble the house and get it ready for public tours and the competition. A crew of approximately 20-30 students, faculty, mentors and friends of the team worked around the clock during the reassembly process.

Figure 93: Siting the House on the National Mall, Washington, DC.   [Amy Gardner]

First, the team had to site the house and set it on its cribbing foundation before any other work could begin. This took the entire effort of the team and the house movers.

After the completion of siting the house, the team was able to start work on various aspects of getting the house ready to open to the public. There were various groups of the team working to get the house completed and ready. Two of the first priorities during set up were completion of the deck and site items as well as the installation and re-hookup of the solar system including the assembly of the racking system and solar panels. This process moved fairly quickly and LEAFHouse was one of the first houses on the mall to be running off of solar power. After completion of these items, team members worked to complete and install the remaining casework, recharge the mechanical systems, complete landscaping, finish interior details, assembly house exterior house accessories and finish installing the smart house hardware and computer.

Figure 94. Reassembly of the PV Racking System [Brian Borak]

As these items were completed and the house was further completed, a series of inspections were required. They were carried out by representatives of the competition. These inspections were based on code compliances of our AC and DC electrical systems as well as compliance with building code and National Parks Service rules. In addition to code inspections the house was equipped with monitoring equipment to allow us to compete in the competition.

Figure 95. Installation of the Rainwater Filtration System [Brian Borak]

Competition Week

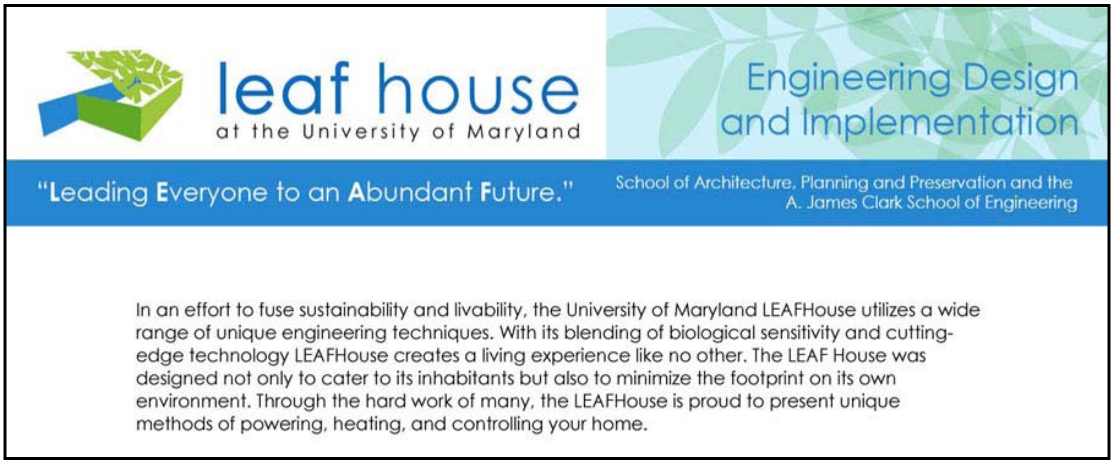
Introduction

During the competition week, the team had to complete contest activities including jury tours, driving the car, cooking a meal, and washing and drying clothes while also giving tours to the public and talking to the media.

The Contests

The competition spanned 7 days and included both subjective jury tours and objective tasks the team had to complete. The subjective contests involved giving a tour to judges and the results were announced each day. The subjective contests outcomes were tallied as they happened in real time. At the end of the week the overall winner was announced.

Figure 96. A Deliberating Jury - Kaye Evans-Lutterodt/Solar Decathlon [www.solardecathlon.org]


leaf house
at the University of Maryland
Engineering Design
and Implementation
"Leading Everyone to an Abundant Future."
School of Architecture, Planning and Preservation and the
A. James Clark School of Engineering

In an effort to fuse sustainability and livability, the University of Maryland LEAFHouse utilizes a wide range of unique engineering techniques. With its blending of biological sensitivity and cutting-edge technology LEAFHouse creates a living experience like no other. The LEAF House was designed not only to cater to its inhabitants but also to minimize the footprint on its own environment. Through the hard work of many, the LEAFHouse is proud to present unique methods of powering, heating, and controlling your home.

Figure 97: Excerpt from Engineering Design and Implementation Brief Contest Report [Team]

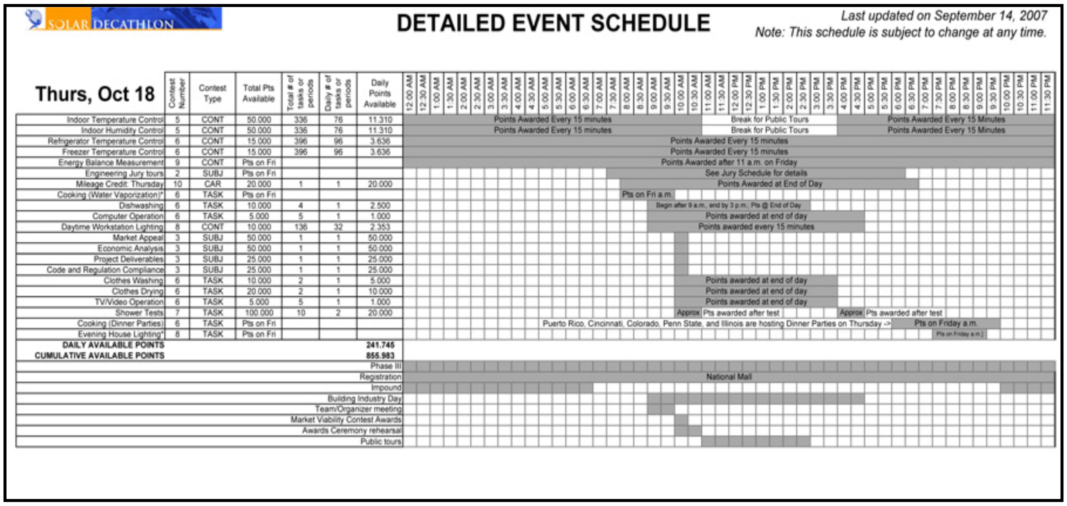
The jury tours were conducted over two days periods where the house was shut down and the team given the opportunity to allow the judges to tour the house. The tours lasted approximately 20 minutes. Prior to coming to the mall the team submitted Brief Contest Reports which were given to the judges before visiting each house. This allowed the judges to have a general understanding of the house and its overall idea and component and give the team an opportunity to be more detailed in the tour.

The jurors were instructed to look for specific things within each house. For example, the architecture jury is supposed to evaluate the houses based on the principles of firmness, commodity and delight.

Each of the five juries was comprised of successful individuals in their respective field. For example, Gregory Kiss, from Kiss Cathcart, a prominent architectural firm that focuses on the integration of solar technology and architecture, served on the Architecture Jury.

The LEAFHouse team paid the most attention to the jury tours portion of the competition. The team used the tour time to explain how the unique aspects of the house

as well as talk about the integration of the house systems and how the overachieving principles applied to all aspects of the house.



Thurs, Oct 18	Contest Number	Contest Type	Total Pts Available	Total # of tasks or periods	Daily # of tasks or periods	Daily Points Available
Indoor Temperature Control	5	CONT	50.000	336	76	11.310
Indoor Humidity Control	5	CONT	50.000	336	76	11.310
Refrigerator Temperature Control	6	CONT	15.000	396	96	3.636
Freezer Temperature Control	6	CONT	15.000	396	96	3.636
Energy Balance Measurement	9	CONT	Pts on Fri			
Engineering Jury tours	2	SUBJ	Pts on Fri			
Mileage Credit: Thursday	10	CAR	20.000	1	1	20.000
Cooking (Water Vaporization)*	6	TASK	Pts on Fri			
Dishwashing	6	TASK	10.000	4	1	2.500
Computer Operation	6	TASK	5.000	5	1	1.000
Daytime Workstation Lighting	8	CONT	10.000	136	32	2.353
Market Appeal	3	SUBJ	50.000	1	1	50.000
Economic Analysis	3	SUBJ	50.000	1	1	50.000
Project Deliverables	3	SUBJ	25.000	1	1	25.000
Code and Regulation Compliance	3	SUBJ	25.000	1	1	25.000
Clothes Washing	6	TASK	10.000	2	1	5.000
Clothes Drying	6	TASK	20.000	2	1	10.000
TV/Video Operation	6	TASK	5.000	5	1	1.000
Shower Tests	7	TASK	100.000	10	2	20.000
Cooking (Dinner Parties)	6	TASK	Pts on Fri			
Evening House Lighting*	8	TASK	Pts on Fri			
DAILY AVAILABLE POINTS						241.745
CUMULATIVE AVAILABLE POINTS						855.983
						Phase III
						Registration
						Impound
						Building Industry Day
						Team/Organizer meeting
						Market Viability Contest Awards
						Awards Ceremony rehearsal
						Public tours

Figure 98: Sample Event Calendar [www.solardecathlon.org]

Also during the competition week the team had to perform objective tasks each day and night. The tasks ranged from washing and drying towels to driving the electric powered GEM car to keeping a constant temperature and humidity level in the house. A team of students kept a constant strategy during the competition week. Despite the simple nature of the contests, the team faced challenges in the areas of washing and drying towels, boiling water and driving the car. In the face of adverse outcomes in some tasks and contests, the team still held first place during the competition for much of the week.

Ultimately, the German team from Darmstadt out played the LEAFHouse and in the end, the team placed 2nd over all while placing in the top two in 5 of the 10 contests. The competition concluded with a closing awards ceremony that took place on the last day of the competition. At this ceremony, the winners of the engineering contest were announced in addition to the overall winners of the competition. Santa Clara took third place, while the Maryland team placed second overall.

Team	Overall Points	Overall Standing
Darmstadt	1024.85	1
Maryland	999.807	2
Santa Clara	979.959	3
Penn State	975.432	4
Madrid	946.298	5
Georgia Tech	945.183	6
Colorado	943.369	7
Montreal	906.835	8
Illinois	886.956	9
Texas	877.503	10
Missouri-Rolla	869.179	11
NYIT	852.775	12
MIT	833.302	13
Carnegie Mellon	832.506	14
Cincinnati	830.865	15
Puerto Rico	819.502	16
Texas A&M	808.765	17
Kansas	807.049	18
Cornell	780.440	19
Lawrence Tech	691.350	20

Figure 99: Final Competition Standings [www.solardecathlon.org]

Maryland

Current Overall Points	999.807	Current Overall Standing	2

These are the final scores for the 2007 Solar Decathlon. The results were announced on Friday, Oct. 19, 2007, at 2 p.m.

Contest	Miles/Current Points	Current Standing
Architecture	189.50	2
Engineering	127.35	6
Market Viability	112.50	2
Communications	98.200	1
Comfort Zone	75.215	4
Appliances	56.626	17
Hot Water	92.900	8
Lighting	92.750	2
Energy Balance	100.00	1
Getting Around	/54.766	13

Figure 100: Maryland Final Competition Standings [www.solardecathlon.org]

The awards were presented by Samuel W. Bodman, the Secretary of Energy. When speaking about the Maryland team he said:

> "At the beginning of the week, people wondered if the Maryland team would have a home-field advantage because they are so close to Washington, D.C. As the week progressed, and Maryland won the Communications contest and was second in Architecture, Market Viability, and Lighting, it became clear that Maryland didn't need any advantage. The Communications Jury praised their excellent Web site and house tour. The Architecture Jury said the house definitely belonged in the top tier. The Lighting and Market Viability juries also had high praise. They were one of seven teams to score a perfect 100 points in the Energy Balance contest."

Figure 101: The Maryland Team Celebrates Their Second Place Finish [Al Santos]

Figure 102: The Team Gives Public Tours of LEAFHouse [Amy Gardner]

Carnegie Melon University

Much like adding a new "plug and play" device to a computer, the Carnegie Mellon home can be upgraded with smaller or larger rooms. All the rooms are arranged around the home's central core, which contains all the home's mechanical systems. Connections to mechanical supports are installed in the core and are easily accessible and adjustable.

"We want to encourage the housing industry to use our design system to create homes that families can design around their needs and change them as their needs change, like when they have a new baby or empty nest," said student Ben Saks.

The plug and play design works well with solar energy technologies, too. These include a day lighting design that reduces the need for electrical lighting; a 6.88-kW solar electric system on the roof; and a solar water heating system located above the bathroom.

Sustainable materials such as high-efficiency insulation and native white oak from Pennsylvania for the exterior were used as much as possible. To reinforce the sustainable living message, a "green-scape" composed of plants was added to provide insulation. It literally grows from the land, up the walls, and onto the roof, where the plants keep the home cool in summer.

A common space connects the Carnegie Mellon home with the home of the Decathlon team from Germany, softening the edges of the house and reinforcing the sense of community and neighborly interaction.

"This solar home is a fantastic educational tool for the public and the team," says student Rosemary Lapka. "I can't get the hands-on experience in the classroom I get working on this project. I work with real people, real time tables, and real budgets. It makes it very educational."

Carnegie Mellon worked with two other universities on this project. The Art Institute of Pittsburgh helped students design the furniture. The University of Pittsburgh helped with construction and will install the house permanently after the event in the Powder Mill Nature Reserve, an outdoor educational center affiliated with the Carnegie Museum of Natural History.

[http://www.solardecathlon.org/2007/team_carnegie.html]

Figure 103: Carnegie Melon University 2007 Solar Decathlon Entry [www/solardecathlon.org]

University of Cincinnati

The main living area of the University of Cincinnati Solar Decathlon home is a single airy space that has no walls to divide cooking, eating, and dining areas. Innovative walls, however, are key to the home's inventive design. The living space is particularly airy because the whole south-facing wall separating it from the home's courtyard is glass. That glass wall also lets in warming sunlight in the winter and provides great daylighting. The wall's specially produced triple-pane, low-e glass maintains excellent insulation, and louvered shades keep out unwanted summer solar heating.

Ingenuity is evident in the rest of the home's walls as well. All have clerestory windows at the top to complete the home's daylighting system. They are all also clad with a Formica rain screen separated by 3 in. (7.6 cm) from the main walls to reduce pressure on them—a novel use of a material normally found inside a home. "Novel, environmentally friendly, and efficient material use was a main goal," says architectural graduate student Christopher Davis.

The most distinctive feature of the Cincinnati Decathlon home, however, is a wall that stands separate from the house. A "fence" of 120 evacuated tube solar thermal collectors forms the outer wall of the courtyard. Hot water from these collectors is used and reused to heat and cool the house as well as to provide domestic hot water.

Hot water from the solar collector tubes flows into a "hot" storage tank, from which it goes to either the absorption chiller or a heat exchanger for the home's forced-air heating and cooling system, depending on the season. The "spent" hot water then flows to a "warm" storage tank to be put to work again. Both the domestic hot water system and a radiant floor heating system draw from this tank.

[http://www.solardecathlon.org/2007/team_cincinnati.html]

Figure 104: University of Cincinnati 2007 Solar Decathlon Entry [www.solardecathlon.org]

University of Colorado at Boulder

When you're the two-time champion at the Solar Decathlon, you have two ways to go: either try to perfect your previous entry to maximize your winning potential or take another approach altogether. Never ones to take the easy route, the team from the University of Colorado at Boulder is striking out in a new direction, with a focus on creating a marketable house.

"We're looking at it from a broader perspective," says Michael Brandemuehl, an associate professor in the Department of Civil, Environmental, and Architectural Engineering. "We're designing and building a full-size house to make our story more relevant to homeowners as well as the building industry."

Because the Colorado team considers the Solar Decathlon size guidelines too limiting, they've actually designed a much larger house, at 2,100 ft2 (196 m2). To make this work in the competition, the 700-ft2 (65-m2) central core of the house works as a home in its own right and will be built and brought to the competition in October. Decking around the house will demonstrate the outline of the full house.

"We have designed it as a full house, with just a piece that detaches," says Sara Hrynik, who recently graduated with a degree in environmental design. But for this team, the work is not complete when they return from the Solar Decathlon, because that's when they'll build the remaining 1,400 ft2 (131 m2) of the home, including three more bedrooms, two more baths, a breakfast nook, and additional living space.

On the plus side, though, that plan is also a major source of funding for the team. The enterprising Colorado students have already sold the final structure to the team's primary sponsor, Xcel Energy, which will use it as a permanent facility for research, education, and outreach to both the building industry and the public.

[http://www.solardecathlon.org/2007/team_colorado.html]

Figure 105: University of Colorado at Boulder 2007 Solar Decathlon Entry[www.solardecathlon.org]

Cornell University

How do you keep more than 100 students from architecture, engineering, and business disciplines focused on building a futuristic solar house? "Streamlined teams, flexibility, continuous meetings, and consensus building," says Andrew Chessen, who leads the business team.

Cornell's organizational strategy is reflected in the unique construction of a "Light Canopy," which is adapted to their solar house. The Light Canopy's streamlined framework of steel trusses serves as a support for PV, evacuated tubes for solar water heating, and a series of vegetated screens that provide shade in the summer. This framework allows homeowners a great deal of flexibility in how they integrate renewable energy systems because it can be set up independently of an existing structure. For example, they can add, remove, and rearrange components without having to modify the house. Raised flooring allows ductwork and wiring to be easily upgraded.

Cornell has a reputation for being particular—the team performed strongly in the 2005 Solar Decathlon and brought home second-place honors. "Cornell didn't need to build another house," says David Bosworth, who leads the architecture and construction team. "But we do need to raise public awareness and encourage residential solar energy." Honoring this commitment to educate their peers and the public, the team initiated educational activities in their community: introducing students in city schools to solar energy and energy efficiency; collaborating with Cornell's Ecology House on an Earth Day event; and setting up demonstrations at the local Farmers Market.

"This hands-on experience has shaped career directions of many of our students and changed the way they view the environment," says Faculty Advisor Matthew Ulinski. Bernardo Menezes, engineering team lead, agrees. "The independent nature of the team is what made this experience so valuable. The students decided the direction of the project and this gave us a sense of ownership." Controlling their destiny and their desire to raise public awareness on sustainable living is fundamental to the team's creativity.

[http://www.solardecathlon.org/2007/team_cornell.html]

Figure 106: Cornell University 2007 Solar Decathlon Entry [www.solardecathlon.org]

Georgia Institute of Technology

The Georgia Tech house is all about sunlight. These students are bringing on the sun... playing with light to see how it can transform and open up a living space. "We've placed a great emphasis on light and bringing light into the house in unique ways," says Jason Mabry, a recent architecture graduate and co-leader of the construction project. "Visitors will be able to see how the house works within itself. They'll see all the technologies we're putting into the house to make it more livable and efficient."

The approach is most obvious in the use of translucent walls, made of two sheets of polycarbonate that enclose an aerogel filler. Aerogel, sometimes referred to as "solid smoke," is the lightest solid known. The material is an excellent insulator and is translucent, allowing filtered light to enter the home. Even the building's roof transmits natural daylight. Made of translucent film, the lightweight roof comprises two layers—one of aerogel that insulates and another on top of that to shed water and drain the roof. Architecture student Alstan Jakubiec did the design drawings for the custom-built roof. "It's really exciting to have it on the house—this product is normally used for big installations like football stadiums," he says.

Joe Jamgochian, a recent Architecture graduate who co-leads the construction project with Mabry, relishes the opportunity to work in close collaboration with university professors, engineering students, and specialists in the construction industry. He is particularly proud of the team's work ethic. "There's been a real commitment by a core group of students and faculty to take individual responsibility for our project as a whole," he says. "They think of the potential issues ahead and address them."

Mabry echoes that notion. "You can sit in a design studio all day long, but the reward is to actually build it... to realize your design, build what you've drawn, and see what it's like in the real world."

[http://www.solardecathlon.org/2007/team_georgia.html]

Figure 107: Georgia Institute of Technology 2007 Solar Decathlon Entry [www.solardecathlon.org]

Technische Universitat Darmstadt

"Made in Germany" is a phrase that applies well to the Solar Decathlon entry from the Technische Universitat Darmstadt, because the team wants to present the German way of building, showcasing German technologies and materials in their solar house, including German oak.

The emphasis on "Made in Germany" products and technologies is apparent in the team's collaboration with German companies and manufacturers, such as Bosch, which provided three-month internships for two Darmstadt students. That arrangement provided a test bed for the students to study the performance of the systems that will provide hot water and climate control for the house.
"It was very interesting because we had all those experts right next to us, and when we had specific questions, we always got very good answers very quickly," says Toby Kern, an architecture student who was one of the interns.

After the Solar Decathlon, the house will return to Germany to be used as a solar power plant, as part of the university's project of a Solar Campus ("Solare Lichtwiese"), through which all buildings on campus will be equipped with building-integrated photovoltaics, feeding electricity into the German power grid.

Germany has a "solar feed-in tariff" that provides a guaranteed price for any solar power that is fed into the German power grid. Because the feed-in tariff is high enough to more than cover the cost of the installation over the long term, the university is selling shares to the public to finance these photovoltaic systems. This yields a return for the investors as the revenue from selling the power is split among them. The Solar Decathlon house will be the first piece in this ambitious project—continuing to showcase the potential of building-integrated solar power generation.

[http://www.solardecathlon.org/2007/team_darmstadt.html]

Figure 108: Technische Universitat Darmstadt 2007 Solar Decathlon Entry [www.solardecathlon.org]

Kansas State University/University of Kansas

"Go mobile"—one of five points in the Kansas team's mission statement—gives a good start at characterizing this home. Transporting their homes to Washington, D.C., is a major challenge for many of the teams, but the virtually fully assembled Kansas entry fits on one truck.

"It can be unloaded from the truck and set up in a matter of hours," says engineering student Brad Lutz. "On the way back from D.C., we will be stopping at major Kansas cities to display the home."

The home's extensive use of structural insulated panels makes it very "low labor." "We were able to build the home in just eight days," says architecture student Matt Teismann. The narrow shape is ideal for showing off its efficiency and renewable energy features. A facade of solar panels easily attached to standing-seam metal roofing covers most of the south wall, right at eye level and tilted at 64° to maximize winter sun. Three additional sets of panels on the roof are mounted on two-axis tracking systems to maximize energy capture.

Another point in the Kansas mission statement is to "redirect expectations," and the home challenges visitors to do just that. It demonstrates that you don't necessarily need heat or artificial lighting for common household tasks. The centrifugal clothes dryer uses a fraction of the energy of a conventional heated dryer. An induction cooktop heats only the cookware and the food inside it, never getting hot to the touch. A mix of daylighting and indirect fluorescent lights provide most of the light, with only a few LED can lights for task lighting. A key task for the home's sophisticated utility monitoring and control system is to know what systems to turn off first if the energy supply is tight. As a backup though, batteries hold three days worth of energy.

[http://www.solardecathlon.org/2007/team_kansas.html]

Figure 109: Kansas Solar Team 2007 Solar Decathlon Entry [www.solardecathlon.org]

Lawrence Technological University

For some teams coming to the Solar Decathlon for the first time, the challenges of designing a home, raising funds, procuring equipment, and actually building it and bringing it to the National Mall are enough to deal with. Not so for Michigan's Lawrence Technological University, which is aiming to achieve far more than the competition's requirements. "All of the design choices that we're making and all of the technical choices that we're making are really taking into consideration not only what's good for the competition, but what's good for the environment," says Christina Span, an architecture student.

That includes drawing on locally sourced, sustainable materials, such as decking material made of a composite of rice hulls and polymer. It also means packing the small house chock-full of technology. To achieve this mix required the close collaboration of engineering and architecture students, most of whom had never worked together before.
Lawrence Tech's cross-disciplinary team has generated four senior projects for undergraduates, as well as one graduate project. For the architecture students, nearly all are now considering graduate schools with design/build programs, because they realize the benefits of seeing a project through to its final construction.

"That's across the board, as far as the architecture students that have gotten involved," says Span. The project also has the strong backing of the school, and most important, the school's alumni. A special campaign sparked the interest of the school's alumni and yielded significant funding for the team. "We had one of the largest alumni-giving campaigns ever," says Assistant Professor Philip Plowright, who teaches in the College of Architecture and Design. "We've had people give to the university who have never given anything before, because they heard we were doing this."

[http://www.solardecathlon.org/2007/team_lawrence.html]

Figure 110: Lawrence Technological University 2007 Solar Decathlon Entry
[www.solardecathlon.org]

Universidad Politecnica de Madrid

The 26-member team from the Universidad Politécnica de Madrid is not the largest one competing in the Solar Decathlon, but it may be the most diverse. Most of its members are from Spain, but there are also graduate students from Brazil, Chile, Ecuador, Mexico, Peru, Puerto Rico, and Venezuela. "The points of view from so many countries brought out the best in everyone and inspired everyone to work harder," says Maria Perez, architecture student. "Our objectives are to demonstrate innovation in energy efficiency that is applicable to single- and multi-family homes, develop a prototype for commercial manufacturing, and advance the social conscience on sustainability and the environment," says Professor Sergio Vega.

To achieve these goals, they used light construction materials and manufactured-building techniques. The house incorporates water-saving technology and solid-state lighting. Electrochromic windows (which darken or lighten to either block or let in the sun's rays), a double envelope, and phase-change gels in the foundation help regulate the temperature. The home's south side can be opened directly to an ample outdoor deck that has seating and vegetation.

The team's social-awareness campaign included an exhibition of a prototype of their house at the SIMA 2007 Property Fair where they received about 4,000 visitors. At an official ceremony coinciding with the España Solar Exhibition, Spain's President, Jose Luis Rodriguez Zapatero, and two ministers were honored guests. Madrid's house is an ongoing project. After the Decathlon, the students will continue to refine the systems to improve the technologies further and aim for even greater efficiency. For the Solar Decathlon, the team feels confident that they have blended energy efficiency, functionality, and aesthetics in a way that will appeal to the average American consumer, which for them is a very important goal.

"We built on the lessons learned from the last Solar Decathlon and shifted the design concept from Mediterranean to one that will appeal to the average American," says Eva Gomez, interior design student.

[http://www.solardecathlon.org/2007/team_madrid.html]

Figure 111: Universidad Politecnica de Madrid 2007 Solar Decathlon Entry
[www.solardecathlon.org]

University of Missouri-Rolla

What happens when your university has entered three Solar Decathlons, producing three distinct solar houses? In the case of the University of Missouri-Rolla, an on-campus solar village happens, replete with student housing and unparalleled research facilities. "Our overriding goal every year has been to focus on the public and present solar energy in a way that appeals to them," says Jacob Colbert, one of the student team leaders. But the team also seeks to investigate something new each year and establish research opportunities for current and future students and faculty.

They share the view that architecture is important, but their goal as a team is to further solar and renewable energy. "To do that, we are seeking to optimize both energy efficiency and energy production to reach a balance," says Travis Brenneke, student and building project manager. "This is about showcasing not just what solar energy can do or a futuristic design, but striking a balance that will appeal to the masses and not go overboard in either direction." Automated systems have captured the attention of the 2007 Missouri-Rolla team. Integral to this is a home automation system with indoor and outdoor sensors that control air-conditioning, lighting, and windows.
The house takes advantage of natural light by incorporating many south-facing windows. A 12-ft (3.7-m) folding glass wall brightens the main living space. In the center of the glass is a door for egress—or the entire wall can be opened so the interior spaces join up with the deck.

The exterior is finished in Paperstone rain screen, which is UV resistant, easy to install, available in a multitude of colors, and 100% recyclable. Countertops are 50% recycled materials, and the floors are eucalyptus, which is harder and more resilient than bamboo flooring. A great source of pride for the Missouri-Rolla Decathletes is that everyone understands the entire project. "We've gotten everybody involved with design, fundraising, building... everything," says finance student Adam Smith. "This is a real-world experience that makes us more marketable when we graduate."

[http://www.solardecathlon.org/2007/team_rolla.html]

Figure 112: University of Missouri-Rolla 2007 Solar Decathlon Entry [www.solardecathlon.org]

Massachusetts Institute of Technology

Mens et manus — mind and hand. From adopting their historic university motto as a guiding philosophy to exercising the engineering institution's penchant for analysis, the MIT team incorporated their history, culture, and setting into their Decathlon house.

An MIT architecture class reviewed and analyzed all the 2002 and 2005 Solar Decathlon entries. Determining that the 2002 heat wave is more likely than the 2005 rainstorms, the team designed with the assumption of at least one sunny day for the week. In this spirit, the team sought to make minimization statements wherever possible—employing an efficient solar array, a small battery footprint, complete waste mitigation, and maximum use of passive solar design.

Although this is MIT's first Decathlon entry, it is by no means its first solar home. The team refers to the home as "Solar 7," because MIT has built six solar homes in the past, going back to the 1930s. Studying the history of these homes helped inspire the new home's primary technological feature, which is an innovative use of solar thermal systems. Passive solar thermal energy storage was a key feature in one of the historic homes. The new MIT Decathlon entry features a Trombe wall of translucent tiles that are used to passively convert sunlight into stored heat.

If you cannot make it to Washington, D.C., for the Solar Decathlon, you can still tour the MIT home on the virtual reality Web site secondlife.com. Another high-tech feature to help explain the home to visitors is a touchscreen computer coffee table that interfaces with software controls for the home's utility systems.

Graduate student Corey Fucetola speaks for himself and his teammates in summing up the Solar Decathlon experience. "It is a powerful opportunity to engineer, design, build, and finance the creation of an energy-efficient home," he says.

[http://www.solardecathlon.org/2007/team_mit.html]

Figure 113: Massachusetts Institute of Technology 2007 Solar Decathlon Entry
[www.solardecathlon.org]

Team Montreal

Team Montréal is starting a Polar revolution to make solar energy popular in cold northern climates. The biggest challenge for the students is convincing their northern audience that solar technology works well in very cold climates. "The most important thing for us was to focus on the building envelope," says Joanna Rosvalt, an architecture student from McGill University. "It had to be both functional and aesthetic."

The building envelope starts with a special structural steel frame that is easy to assemble and disassemble. The walls are "clipped" directly to the steel frame and are insulated with polyurethane made from soybeans and recycled plastic to trap heat inside the home. Windows are triple glazed, low e, and have automated shading to further trap heat. On the roof, 40 PV panels producing 8.2 kW will also be clipped to the structure, so they won't need any other roofing under the PV system, reducing the cost and use of unnecessary materials. Two solar thermal collectors heat enough water for the radiant floor and household use. The team tried to integrate as many locally made and raw materials into the house as possible to reduce the environmental impact caused by shipping. For example, most of the furniture in the house will be made of reused materials.

A unique feature of the home is the use of artificial intelligence for temperature control and energy use. The "house" will search the Web for the weather forecast to predict the amount of energy it will be able to produce in the days to come and how much it will need for its occupants. The system will recommend energy use choices to meet upcoming demands. The system controls heating, cooling, lighting, shading, and ventilation, all with one interface.
"I always dreamed of living in a smart home that could be autonomous and ecological," says École de Technologie Supérieure student Michael Chapman. "Isn't it amazing to be able to build one?"

[http://www.solardecathlon.org/2007/team_montreal.html]

Figure 114: Team Montreal 2007 Solar Decathlon Entry [www.solardecathlon.org]

New York Institute of Technology

Students from the New York Institute of Technology named their dwelling "Open House" for two reasons. First, they are targeting beachfront homeowners to show them how an open solar design can complement shoreline properties. Second, the term "open house" is an expression of the team's ideal home: a home with influence extending beyond its physical walls... a home that is one with its community and nature. Integration with nature and the community begins with the architecture: a unique southern wall opens completely to the beach, blending the line between sand and walls. A white ceiling helps to maximize natural light. A contained pond on the roof reflects light back into the open space.

On the roof, an evacuated-tube solar thermal system collects solar energy for water heating and space heating. A geothermal heat pump uses the roof pond (rather than the more typical underground installation, which can't be used on the National Mall) as a heat source to provide extra heating. A building-integrated 7.7-kW PV system doubles as the shading overhang for the south wall. Despite the home's advanced solar technology, the team was surprised at how tough it is to sell solar to the public. "We didn't realize how much more still needs to be done to have the public embrace solar," says student Daniel Rapka. "People don't realize a solar home operates like a normal home." Another layer of integration is the home automation system or "smart house" feature. This system allows people to get real-time data on energy use. The home automation system serves as an educational tool by giving the public a user-friendly way to view a home's energy use.

"The smart house feature ties into our open house idea where not only homeowners learn about the house, but homeowners could put their energy-use information up on a blog so the community could share in the information," says student Matt Mathosian. "People could log on to a Web site where they could comment about energy use."

[http://www.solardecathlon.org/2007/team_nyit.html]

Figure 115: New York Institute of Technology 2007 Solar Decathlon Entry
[www.solardecathlon.org]

Pennsylvania State University

When abundant opportunities and possibilities are on the horizon, people often get stuck deciding which ones to pursue. Not so for the Penn State Decathlon team. This high-energy group of students is taking them on one after another.

The Penn State students were inspired by the challenge of the Decathlon's Market Viability contest and decided to build two homes to test themselves and their market concept. The competition home is called MorningStar Pennsylvania. After the Decathlon, it will serve as a renewable energy research lab and educational residence on the Penn State campus. Its sister home, MorningStar Montana, will house visiting faculty at Chief Dull Knife College on the Northern Cheyenne Reservation. This affordable version of the MorningStar concept will help advance the use of solar energy in another climate and culture. "We see our Solar Decathlon home, and the one in Montana, as prototypes where people can learn," says member Sal Gimbert. The team used a hybrid construction process with a mix of prefab and site-built elements. The "Technical Core" of the house (kitchen, bath, mechanical components) is shipped to the home's location, and locally available "materials of opportunity" are used to complete the home.

An "Energy Dashboard" monitors and displays energy consumption and production to teach the inhabitants about how they are "spending" their energy. A curtain wall system with PV-powered LED lighting glows in different colors depending on weather forecasts. Pennsylvania bluestone and reclaimed slate shingles provide thermal mass. The students saw the talent and expertise available at Penn State as yet another opportunity. "From the beginning, we wanted to engage as many university programs as possible. So, we kept the design process open to a range of disciplines throughout the university. Close to 900 Penn State students have been involved in the Solar Decathlon," says member Andreas Phelps. "We want to be outstanding representatives for the Penn State community by using the Solar Decathlon as a catalyst to reach our long-term goals," says member Gretchen Miller. "There's no stopping us."

[http://www.solardecathlon.org/2007/team_penn.html]

Figure 116: Pennsylvania State University 2007 Solar Decathlon Entry

[www.solardecathlon.org]

Universidad de Puerto Rico

Biomimicry was the genesis for the Universidad de Puerto Rico's motto: Technology and Ecology: Partner for the Future. Biomimicry is the study of nature's best ideas, enabling astute observers to imitate design and process solutions provided by the natural world.

The team took its inspiration from a single cell. The simplest unit of a living organism, the cell produces energy, recycles waste, adapts to changing conditions, functions independently, and communicates with other cells. This is also an apt description of Puerto Rico's solar house.
Sustainability was fundamental to all design and building decisions. "Because we are transporting our house [to the National Mall] by sea and land," explains architecture student Fátima Olivieri, "the house was built using lightweight materials, and divided and shipped in two pieces. One half incorporates all the electrical equipment including PV modules and batteries, and the other half, the water components such as its solar thermal system."

Also contributing to the house's energy efficiency and sustainability are a unique louvered screen that provides shade when the windows are open; an insulated exterior reflective siding that softens and diffuses daylight entering the house; and recycled wood for flooring and walls.
Media attention helped the team reach its audience. The project was written up in two magazines and covered monthly by local TV news stations. According to Professor of Architecture, Jorge F. Ramirez, the project has not only raised the consciousness of the students and the community, but that of the university. "Sustainability is no longer an elective, but a required course in the School of Architecture." The team feels that their house demonstrates that energy efficiency and sustainability are practical options for comfortable, livable dwellings. "Using the cell as a model for our home put us in touch with the environment and ecosystems and has taught us how to lead cleaner, better lives," concludes Olivieri.

[http://www.solardecathlon.org/2007/team_puerto_rico.html]

Figure 117: Universidad de Puerto Rico 2007 Solar Decathlon Entry [www.solardecathlon.org]

Santa Clara University

Design with purpose. This succinct philosophy guided the Santa Clara University team in its quest to build a sustainable solar house that is functional, elegant, intelligent, and innovative. "Our house is dynamically smart. Its computers sense interior and exterior conditions and make automatic adjustments for thermal comfort and efficient energy usage," says Team Manager James Bickford.

It's not surprising that students from Silicon Valley would take this approach to operating their innovative house—starting with the electrochromic windows. With a flip of a switch, the glass darkens to block sunlight or lightens to let it in, depending on the temperature desired inside the house. Another innovation is a prototype solar thermal unit (with absorption chillers) for space and water heating as well as air-conditioning. The house was built to operate off the utility grid using the PV modules with backup batteries during the Solar Decathlon event. However, when it returns to campus, the house can easily be connected to the grid using an appropriate inverter, and its excess power sold to the utility provider.

To measure and certify the house's sustainability, the team uses a unique meter that quantifies the power used for heating and cooling and measures the amount of carbon emissions the house saves. In the future, this meter could be instrumental in the selling of carbon credits to carbon emitters, which could motivate people to save energy and accumulate carbon credits that can be turned into cash.

Purpose drives the Santa Clara students to innovate, and gratitude inspires them to share their knowledge with the community. "Our community has given us enormous support," says Communications Director Meghan Mooney. "We wanted to give back, so we organized a mini solar decathlon competition among three local high schools." The event resulted in greener schools and a heightened awareness of the environment and the importance of sustainability.

[http://www.solardecathlon.org/2007/team_santa_clara.html]

Figure 118: Santa Clara University 2007 Solar Decathlon Entry [www.solardecathlon.org]

Texas A&M University

Imagine instead of just moving furniture around when you wanted a change, being able to switch rooms around. The Texas A&M Decathlon team's vision is for a totally modular "plug-and-play" home. "You could swap the position of the kitchen and the bath without a problem, buy an extra kitchen on eBay, or sell off a couple of rooms after the kids move out," says recent architecture graduate Thomas Gerhardt.

The A&M "groHome" concept is based on interchangeable and interconnected "groWall" units, some of which will have all of a home's kitchen, bath, or entertainment utilities built into them. "All the electricity and plumbing is easy to get to, and the plug-and-play approach will give the homeowner great flexibility, but it made things challenging for us," says Environmental Design student Josh Canez.

Another distinctive feature of the Texas A&M home is that it is like an animal with two skeletons. An inner skeleton of steel columns and beams provides the basic structure to which a skin of groWall units and structural insulated panels attaches. Then an outer skeleton of cables set 2 ft (0.6 m) to 3 ft (0.9 m) apart from the walls provides support from which the home's PV panels (or other features such as flower trellises) are hung. Just as extra rooms can be easily added, so can extra PV panels to provide power for them. If a hurricane is forecast, the envelope of PV panels can be replaced with "armor."

Hot water for both space heating and domestic water comes from a set of vertical evacuated tube solar collectors on the north side of the house. Lighting features paper-thin, bendable CeeLite light-emitting capacitors (as opposed to diodes) that can be cut into any shape. The "healthy home" landscaping includes a reflecting pool—complete with fish—a wetland to treat the pool water, and even a "bat tower" to provide fertilizer and get rid of insects.

[http://www.solardecathlon.org/2007/team_texas-am.html]

Figure 119: Texas A&M University 2007 Solar Decathlon Entry [www.solardecathlon.org]

University of Texas at Austin

This house is about life and its boundless possibilities; it's also about a budding solar way of life. In fact, the name symbolizes a home that "blooms" like a rose under the sun.

"All the houses use solar. We wanted to take the technology out of the house and make people aware of their surroundings," says Russell Krepart, faculty advisor. The building's "skin" responds to the wind through shutters that allow for enormous flexibility in terms of light, heat, fresh air, and privacy. While solar collectors on the roof heat water for the home, the excess heat from the hot water system warms a hot tub outside. "The innovation is using a thing of joy like a hot tub as a technical amenity as well—it takes heat out of the system so you don't pay for heating the tub," says student Jack Wingerath.

A 7.6-kW PV system, together with a roof brim, invites people inside the home with its butterfly shape and proudly displays its technology. Interior materials are both sustainable and Texas-influenced to create an inviting interior. Although the home is high tech, the students used standard materials found in most home improvement stores. "We wanted to take the fear of using the technology out of the system and give people a starting point," says Krepart. "It's technical, but you can do creative things with it."

The struggle is to make the house livable and appeal to the general public and still be efficient, says Krepart. "People don't buy ugly things. The problem we're running into is that Europeans are more advanced as far as energy efficiency. We can get those things here, but we run into a problem with code compliance, etc. So what we've tried to do is be conscious design wise. If it's ugly, people aren't interested no matter how energy efficient."

[http://www.solardecathlon.org/2007/team_austin.html]

Figure 120: University of Texas at Austin 2007 Solar Decathlon Entry [www.solardecathlon.org]

University of Illinois at Urbana-Champaign

When the unpredictable Midwest climate interfered with building their house outdoors, the University of Illinois team simply built it in a warehouse. "We set up an assembly line, a rail system, to construct the home in three modules—we can roll modules out of the warehouse and onto the truck," says student Bob Kinsey. "We have demonstrated our ability to mass-produce these modules in a large-scale environment."

The concept of modular design is not something new, but people may think of it as low quality. "This is not true for us," says architecture student Nora Wang. "We designed the building to be flexible, comfortable, and livable. And you can customize the interior space, which helps engage the user's imagination." When it comes to making the house comfortable and easy to live in, the team has this covered, too. "This area may be the most innovative element for us," says student Ben Barnes. Cooling and heating is all radiant via ceiling panels—no forced air is used. The team's approach to lighting was also carefully conceived. Placement of windows and doors for daylighting was designed in parallel with the artificial lighting plan. They are using dimmable fluorescent lights and LED bulbs for task lighting. "The LED was invented by a graduate and current professor at the University of Illinois, so we take great pride in using this technology," says student Susan McKenna.

Every piece of furniture and cabinetry in the home is student-designed and customized with inhabitants' activities in mind. A local firm, which is headed by an Illinois alumnus, built the kitchen cabinets from 100% recycled particleboard. "Our industry contacts are excited to get their products out there. One of the greatest things is the way people have stepped up to the plate," says Wang. The team members feel certain that the modularity and flexibility of their design translates well to the consumer. "This is about the affordability of a solar home for everyone. It's the Volkswagen of homes," says Kinsey.

[http://www.solardecathlon.org/2007/team_illinois.html]

Figure 121: University of Illinois 2007 Solar Decathlon Entry [www.solardecathlon.org]

Public Tours

During much of the competition, the Solar Village was open to the public. The members of the public ranged from knowledgeable professionals to school groups to eager-to-learn adults. Approximately 200,000 people visited the houses and the public spent approximately 20 to 30 minutes visiting each house. During peak hours, the wait to get into some houses averaged around one hour.

The Maryland team wanted to give a concise and cohesive tour that allowed people of all learning levels to get the most of the tour. Thus, the team decided to have tour guides stationed throughout the house. Visitors to the house were encouraged to wander and browse as they pleased and the tour guides either volunteered information to curious members of the public or answered questions as needed.

To reinforce the team and allow some team members to focus solely on competition tasks, the team recruited and trained new team members to act as tour guides. These team members were trained before the start of the competition and learned information about the house through a series of talking points and from listening to other team members interact with the public.

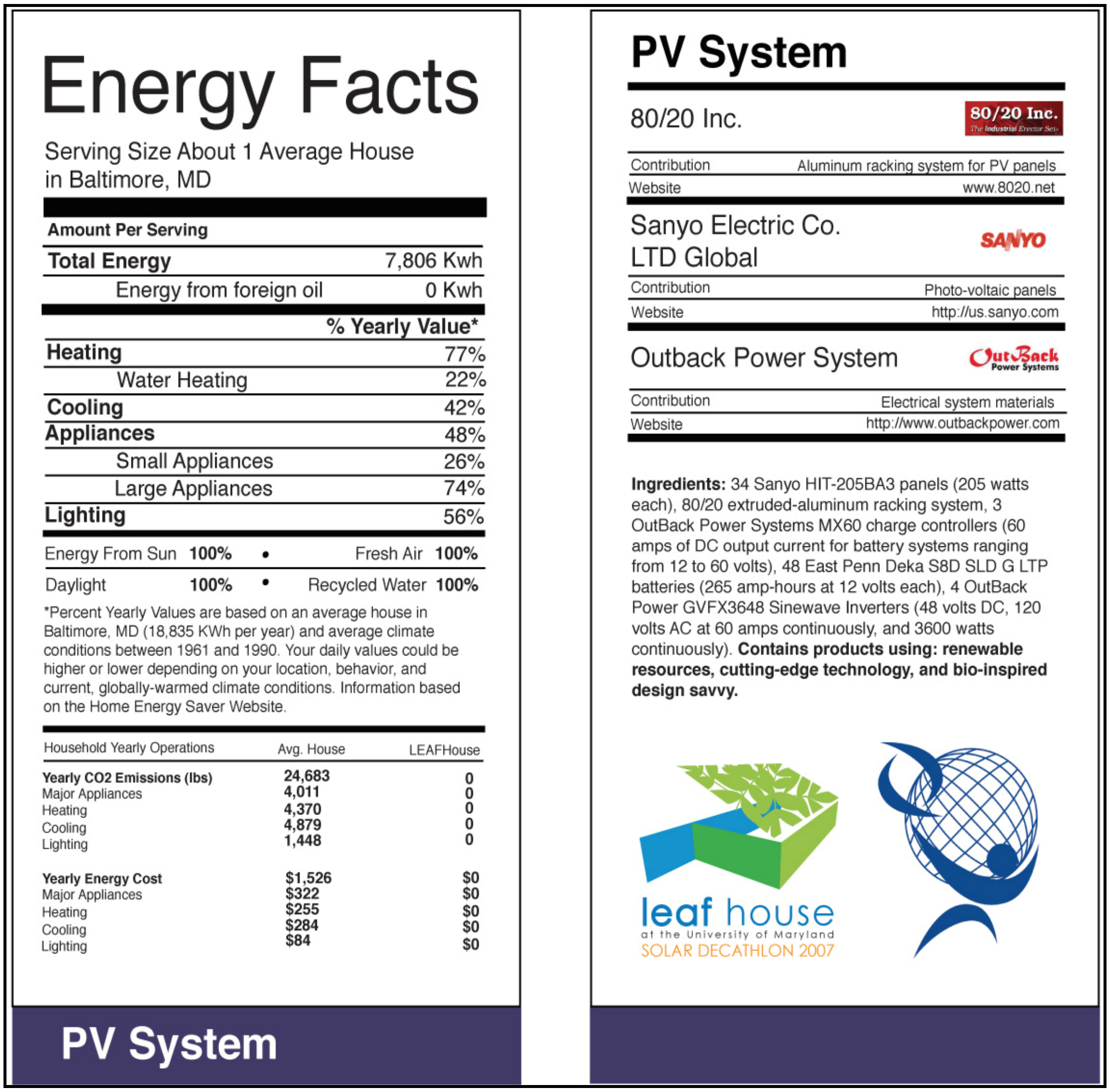


Figure 122: Example of Nutrition Label in the House [LEAFHouse Team]

In addition to the tour guides, LEAFHouse also utilized various print materials in the house tour to provide more information to guests. The team felt it was necessarily to provide information on all levels ranging from pictorial information about the building process to signs highlighting the house systems and materials to sponsor recognition to information about LEAFHouse at different scales. The media was integrated into the house as well as added to the architecture itself.

Figure 123: The Signage on the Mall [LEAFHouse Team]

The team used nutrition tags to provide more information about the house at a detailed level as well as recognize sponsors. These tags were placed around the house so that visitors could gain even more knowledge about specific portions or equipment in the house. They also provided energy facts comparing an average home in Baltimore to an energy efficient home.

LEAFHouse incorporated signage within the landscaping of the house to provide entertainment and information to those waiting in line for house tours and to entertain the public before and after public tours each day. There were a series of signs located at the front of the house that provided generalized information about the house, the team and the process as well as displayed a photo montage of the construction process.

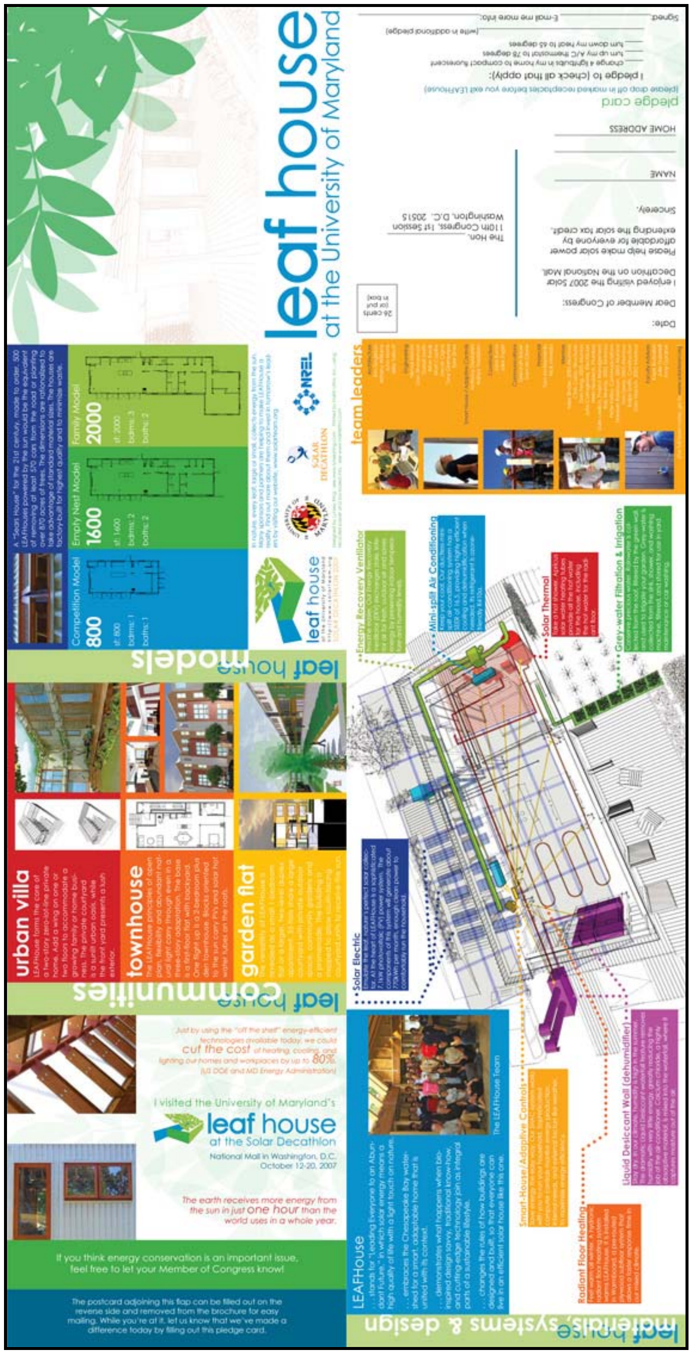


Figure 124: The Brochure Handed Out on the Mall [Lynsey Ring]

Another series of signs were located on the ramp and integrated into the site plan as well. These signs contained more detailed information and had information about the engineering systems and materials used in the house.

The team also handed out brochures to the public. The brochure was used to provide information about principles of the team, the house systems and the members team. It also told visitors about LEAFHouse at different scales and in different locations. In addition to information about the house and team, the brochure also encouraged visitors to write to their local government officials and take more energy efficient measures in their daily life.

In addition to print material and the tour itself, the team also offered a audio tour. The audio tour was a four minute tour describing the house and its systems that could be accessed over cell phone. This entertained guests waiting in line for a tour of the house and provided base information that tour guides could then elaborate.

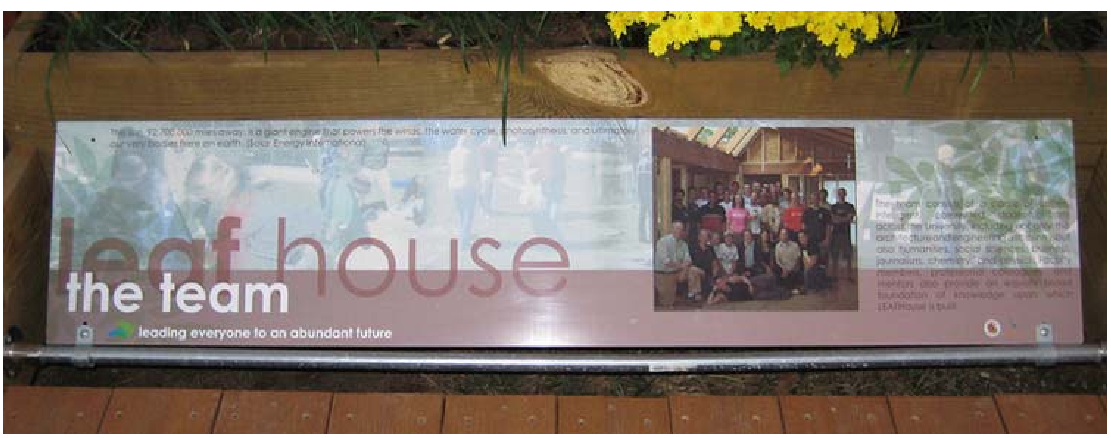


Figure 125: Example of Bench Signage on Front of House [LEAFHouse Team]

Media and Communications

In addition to the competition and giving public tours, the team was constantly interviewed by media. The team engaged in constant interviews for print media, online podcasts and blogs, local and network televisions and radio. Prior to the competition, the team had media training sessions to prepare them for the kinds of questions the media would be armed with.

The team was followed by Beyond Production, a film crew taping a special for the Discovery Channel, from the beginning of the summer through the competition. The one hour special focused on the University of Maryland team, the University of Colorado team and the Carnegie Melon University team and aired on the Discovery Channel's Planet Green network.

Figure 126: Film Crews at the Opening Ceremonies [Brittany Williams]

The team also gave tours and took advantage of media opportunities with government and university officials. University President Dr. C. D. Mote visited the house as well as U.S. Secretary of Energy Samuel W. Bodman and House Majority Leader and representative of Maryland's 5th congressional district Steny Hoyer.

Figure 127: Team Members give Steny Hoyer and Samuel Bodman a Tour [Aditya Gaddam]

Solar Decathlon 2007 Awards
2nd place overall
1st place in the Communications Contest
2nd place in the Architecture, Market Viability and Lighting Contests (1st place in the Lighting Subjective Contest)
One of seven teams to score a perfect score in the Energy Balance Contest

Solar Decathlon Other or Industry Awards:
Solar Decathlon's BP People's Choice Award
ASHRAE: Integration for Renewable for Sustainable Living
NAHB: First Place in the NAHB Marketing Curb Appeal Award

Other Awards:
10.20.07, award from the PV AIA annual awards program: Special Award for the "Advancement of the Art and Science of Architecture"

Figure 128: Awards Received

Post Construction/Post Competition

Figure 129: Proposed Site Location [LEAFHouse Team]

LEAFHouse was designed and built for use as a house; however its final location will be for a different more public use. After the competition, LEAFHouse returned to the University of Maryland campus and is intended to serve as the chapter house for the Potomac Valley Chapter of the American Institute of Architects and become the Potomac Valley Green Design Information Center. The house will be converted into an office while trying to preserve the integrity of the design and systems.

While LEAFHouse will be a working chapter house, it will also be open to the public for visits and tours. Members of the LEAFHouse team will also continue to work on the house and continue research and development on aspects of the house.

The Potomac Valley Architecture Foundation which will own the house holds the mission "to educate the general public about the importance of livable communities and sustainable architecture to improve the health, safety and welfare of the public," and "to educate architects, both professional and intern, about how to better deliver safe, sustainable and beautiful buildings and communities to the public” (Unsell).

Figure 130: Proposed Site Location [LEAFHouse Team]

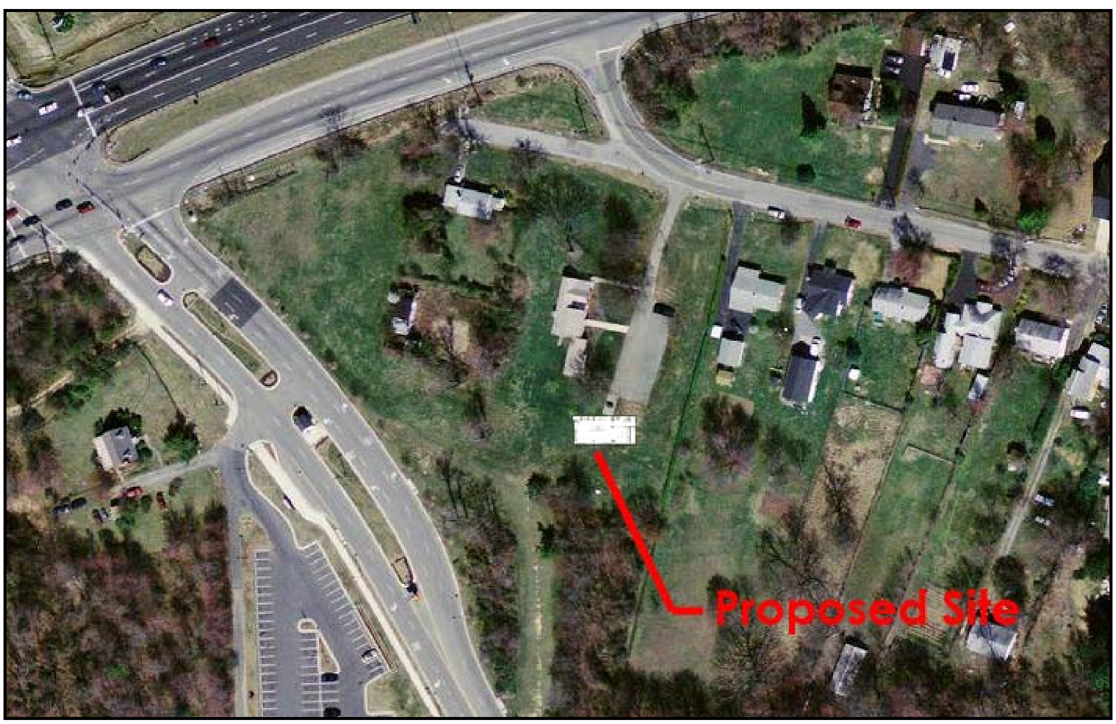


Figure 131: Proposed Site Location [LEAFHouse Team]

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