FESC
Florida Energy Systems Consortium

University of South Florida

Energy Efficient Technologies and the Zero Energy Home Learning Center

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Description: The project is to create and evaluate an affordable residential scale Zero Energy building that will function as an exhibition of energy efficiency and Zero Energy Home [ZEH] technology on the University of South Florida campus. The project will feature the most cost-effective combination of renewable solar energy with high levels of building energy efficiency. The building will incorporate a carefully chosen package of the latest energy efficiency technologies and renewable energy systems to achieve the most successful and reliable results.
The building will utilize Photovoltaic solar electricity and solar domestic hot water heating systems using the grid as an energy storage system, producing more energy than needed during the day and relying on the grid at night. Plug-in hybrid automobile technology offers a promising means of providing distributed energy storage for such homes. Using a systems approach to couple zero energy home technology with PHEVs we will explore opportunities to develop marketable products that meet Florida's energy and environmental goals.

Budget: $344,600

Universities:
USF-School of architecture, College of Engineering, College of Mass Communications, School of Business
FSU-College of Engineering
UF- Department of Interior Design
UF-Rinker School of Building Construction
UCF-Florida Solar Energy Center

External Collaborators:
Palm Harbor Homes
Beck Construction
Hees and Associates Structural Engineers

Progress Summary

Design Development was completed in November of 2010. The 889 square foot Zero Energy House Learning Center is a flexible, modular, pre-fabricated, net zero energy prototype that can adapt easily to different site situations and client needs. The key factor shaping the design approach is Florida's mild climate and an indoor outdoor lifestyle. FLeX House combines the wisdom of vernacular Florida houses, ZEH research, with cutting edge technologies to make a holistic system engineering based, zero energy building package. The project will feature the most cost-effective combination of energy-.efficiency technologies and renewable energy systems. The ZEHLC will serve as a teaching and learning tool on campus while promoting the use of ZEH technologies throughout the southeastern US.

The prefabrication process maximizes efficiency and quality control and reduces waste when compared to the site built counterpart. Once fabricated, the main body of the house can be shipped to the site on a single truck minimizing transportation costs. The main body contains sliding modules that are deployed from the main body to complete setup at the site quickly with a minimum use of equipment and labor. The modular system is easily expandable and reconfigurable according to the wants and needs of the client and the site situation.

The plan is laid out on the east west axis to maximize shading and natural ventilation and minimize direct solar gain. Because of the hot climate, the living spaces focus on the cooler, north side of the site. The entire north wall, composed of sliding glass panels can be opened combining the interior living spaces, the exterior deck and the garden into one continuous indoor/outdoor space. The interior space can be left open with a continuous flow from the kitchen to the master suite/office area, or it can be partitioned to separate the living and bedroom areas for privacy and to create two separate thermal zones for energy conservation.

As a net zero energy house FLeX House utilizes Photovoltaic panels for site based, clean renewable energy generation. The grid tied 5 kW array will send electricity back to the municipal electric utility grid during peak hours of generation and FLeX House will take electricity from the grid in the evening or on cloudy days. Over the course of a year the net consumption from the grid will equal zero.
Flex House is equipped with low flow fixtures to conserve water. Rain water is diverted from the roof into a cistern where it is stored and used for irrigating the organic vegetable garden. To keep energy consumption to a minimum FLeX House includes high efficiency energy star rated appliances. To reduce the amount of energy required for lighting, FLeX House was designed to make the best use of natural day light for its interior spaces with large glazed areas on the north and south facades and light colored interior finishes that reflect the light and brighten the interior spaces.

The HVAC system consists of a heat pump and solar thermal panels that circulate refrigerant or heated water to two interior fan coils to cool or heat the house. The energy recovery ventilator [ERV], by precooling the outside supply air, allows the chilled water system to run more efficiently. The ERV combined with a liquid desiccant dehumidifying system allows the fan coil temperatures to exceed the dew point while still maintaining good indoor air quality.

Flex house is designed to meet Florida's demanding hurricane code. All exterior finish materials have been tested for impact in hurricane winds and have obtained the required Florida product approvals. The building skin is durable, galvanized corrugated metal and the wood lovers are made from cypress which has a natural resistance to rotting and intrusion from insects. In the off season the bedroom and entry modules can be slid back into the main body of the house and the entire exterior can be shuttered to protect the house from the weather and vandalism.

Construction Documents were completed in March and a contract between Beck Construction and USF was finalized. After delays in the contract process, construction began in mid-May, 2 months behind the original schedule. Construction continued through the summer and was completed in early September. The house was disassembled and shipped to Washington DC on September 12th. FLeX House was successfully reassembled in West Potomac Park in DC and was exhibited in the 2011 Solar Decathlon. Tens of thousands flocked to the popular house which was second in total attendance among the 19 houses on display. The house was disassembled and shipped back to Tampa where it is scheduled to arrive in the morning of 10/14. Once reassembled in its permanent location on campus the house will begin its life as the ZEHLC.

Funds leveraged/new partnerships created

New collaborations		
Florida Power and Light	Sponsor	\$10,000
TECO	Sponsor	\$10,000
OUC	Sponsor	\$10,000
Progress Energy	Sponsor	\$10,000
USF COE	Sponsor	\$20,000

UCF	Sponsor	$16,000
Wells Fargo	Sponsor	$15,000
CSI	Sponsor	$500
Solar World	Sponsor	Gift in Kind
Bosch	Sponsor	Gift in Kind
Sothern Cypress Manufacturers	Sponsor	Gift in Kind
Simpson Strongtie	Sponsor	Gift in Kind
Kohler	Sponsor	Gift in Kind
Dupont	Sponsor	Gift in Kind
Pella, CWS	Sponsor	Gift in Kind
Lithonia	Sponsor	Gift in Kind
Beck Construction	Industry Partner	

Proposals

Title	Agency	Reference Number	PI, Co-investigators and collaborators	Funding requested	Project time frame	Date submitted
2011 Solar Decathlon	DOE		Stanley Russell	$100,000	8/2010	12/2011
Technology Fee Grant	USF		Stanley Russell Mark Weston Yogi Goswami	$223,462	1 year	3/15/2011

Grants Awarded

Title	Agency	Reference Number	PI, Co-investigators and collaborators	Period of Performance	Funding awarded
2011 Solar Decathlon	DOE		Stanley Russell	16 months	$100,000

Before beginning design on the ZEH Learning Center we studied vernacular precedents and more recent building and research projects that have aimed at zero energy or near zero energy status. We looked at Vernacular Florida architecture as precedent for passive cooling, heating and daylighting. Building design in Florida changed considerably with advancements in mechanical systems in the mid- 20th century. Up until that time houses typically had wide overhangs to shade the walls and windows, wide covered porches for outdoor living and high ceilings with crawlspaces under the floor to induce natural ventilation. After air conditioning became popular houses were built to close out the heat with smaller windows, compartmentalized interiors, and low flat ceilings. Passive solar design was experimented with during the energy crisis of the 1970s and although it was mostly applied to cold climates, many of the lessons learned during that period are once again relevant in the current movement toward zero energy buildings.

Because the thermal comfort range of the average American has changed since the proliferation of air conditioning, it would be difficult for most to live in a passively cooled home especially in Southern Florida.

Regardless, the principles of vernacular buildings and passive solar design can complement advances in highly efficient mechanical systems to greatly reduce the energy consumption of buildings. There is also evidence that comfort levels can be gradually altered when standards are placed on heating and cooling levels in buildings. South Korea for example, has set a standard of not less than 26c [79f] in the summer for air conditioning and not more than 20c [68f] in the winter for heating in public buildings. In Japan, air conditioning in public buildings is mandated at not less than 28 [82f] degrees in the summer season.

Many of the examples of near zero and zero energy houses in Florida are projects implemented by The Florida Solar Energy Center® (FSEC), a research institute of the University of Central Florida. Since 1998 with funding from the department of energy's building America program FSEC has built and monitored several zero energy and near zero energy houses in the State of Florida. Data gathered from monitoring the performance of these houses is a valuable resource for ZEH research. The FSEC projects made it clear that combining energy efficiency in building design and appliances with PV and solar thermal systems for clean renewable energy generation can result in affordable zero energy houses.
The *Off Grid Zero Energy Building* [OGZEB] at Florida state university is an off grid zero energy test house which is just beginning to yield data. In addition to Photovoltaic panels, the OGZEB incorporates hydrogen fuel cells for storage and production of electric power. The *Florida House Learning Center* in Sarasota Florida, like the proposed ZEH Learning Center, was established to showcase sustainable building technologies to builders and the general public. The Florida House contains exhibits of various green building products and the building itself has explanatory text in various locations to describe the technologies at use. I traveled to Japan in June and met with engineers at two of Japan's largest housing manufacturers Misawa Homes and Sekisui Haimu. Misawa Homes produced its first Zero Energy House Model in 1998 and since then has sold thousands throughout Japan. Both companies take a systems approach to life cycle cost, energy use and CO_2 emissions with their highly efficient manufacturing processes. The experience in Japan made the advantages of factory built homes evident and led us to pursue a housing manufacturer as an industry partner.

In addition to documenting what has already been accomplished in the field of building energy efficiency we also feel that it is important to know about the emerging technologies that will transform Zero Energy Building design in the near future. Some of these are already beyond the testing stage and in commercial production but are expensive compared to more conventional alternatives. This is often a function of supply and demand and in many cases it can be assumed that an increased demand for these products will lead to lower prices. We think that raising public awareness to increase demand for quality products is one important function of the Zero Energy House Learning Center. Technologies like Aerogel insulation, vacuumed insulated glass, electro-chromic glass, building integrated photovoltaic materials and OLED lighting will revolutionize building design and construction when they reach an affordable level. Liquid desiccant cooling and dehumidification show promise for the next generation ZEH in the hot and humid southeast. Liquid Desiccant solar cooling systems developed as part of the Department of Energy's SBIR program convert hot water from solar thermal panels into cooling and dehumidification.

We are also interested in the interface between the ZEHLC and other related systems. The key to energy efficiency in the future will undoubtedly lie in smart grids that will regulate the flow of electricity to and from buildings according to peak and low demand periods. The plug-in hybrid electric vehicles, soon to be released by several auto makers, will be key elements in regulating this flow and storing energy for the grid and will be considered as an integral part of the ZEHLC design.

The Solar Decathlon is an event held every other year on the Mall in Washington DC to showcase the latest advances and emerging technologies for energy efficient buildings. 20 Teams are chosen from an international pool of applicants to design and build energy efficient buildings on the Mall. In answer to the RFP for the 2011 Solar Decathlon I assembled a team of experts from FSU, UF, UCF and USF in the fall of 2009 to make a proposal. Our proposal was deemed competitive in January 2010 and we were asked to submit a schematic design proposal by March of 2010. Based on the strength of our submission, Team Florida was chosen as one of 20 teams to compete in the 2011 Solar Decathlon. Participation in the 2011

Solar Decathlon expands the potential of the ZEHLC as a learning tool and facilitates additional funding and input from experts across the state.

Based on our research from the first year we began looking at architectural and engineering innovations that could improve on current ZEH technology and construction practices. The closed nature of recent Florida houses and early attempts at ZEH was identified as a problem that we wanted to address with the ZEHLC. We maintain that contemporary Florida houses can significantly reduce their annual energy consumption by incorporating the same passive solar strategies that were commonly used in Florida homes before the advent of air conditioning. A building envelope that is well sealed and insulated and can be opened during the cooler/dryer months of the year and closed when temperature and humidity levels are too high, can have a more open feeling and save energy at the same time. Furthermore, studies at FSEC have shown that the majority of heat gain comes through the roof of Florida homes and attic spaces reach extremely high temperatures in the range of 140^0. We considered the use of a shading device that would cover the entire roof and east and west walls of the house to significantly reduce or eliminate direct solar radiation coming in contact with the building envelope. A ventilated space between the shading device and the house would prevent the buildup of hot air that commonly occurs in the attic space of Florida houses. According to a life cycle assessment of energy use, we looked at a modular, factory built house to minimize construction waste and maximize efficiency in labor and energy use during the construction process. Innovative mechanical systems including a liquid desiccant system for controlling humidity levels and reducing latent heat load; a solar thermal system that takes advantage of a high thermal conversion of solar radiation and uses it for a variety of energy end uses and a heat pump tied to the solar thermal system to increase efficiency in both systems.

To test the effectiveness of different building envelope alternatives, we built 3- 8'x8'x8' structural insulated panel modules, each with a different envelope system. Module 1, the control case, had no additional treatment of the envelope. Module 2 had a 3/4" ventilated airspace on the exterior skin of the roof and walls. Module 3 had a shading device covering the roof and east and west walls.

Fig. 1: module construction

Fig. 2: module 2 complete

Fig. 3: testing module 3

The 3 modules were monitored under identical conditions simultaneously over an 8 hour period with a Campbell Scientific PS100 Data logger and 3 temperature and relative humidity sensors attached to determine the most efficient and economical configuration of the building envelope. The results confirmed that the module with the shading device had the lowest interior temperature at the end of the 10 hour period. The temperature difference within the modules continued to grow as the hours passed and the insolation continued to raise the temperature disproportionately in the unprotected module 1.

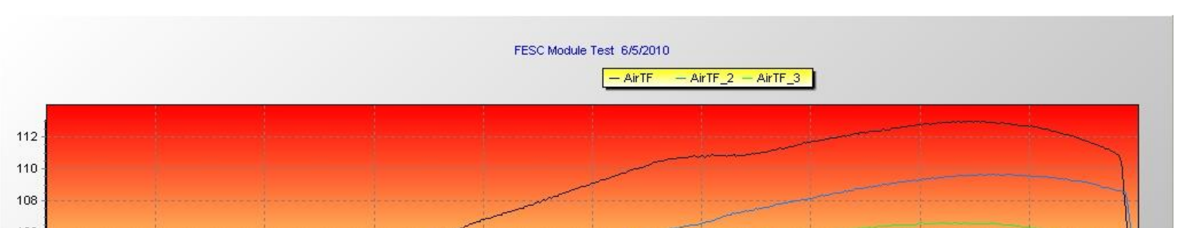

Fig.4: black line is module 1, blue line is module 2, green line is module 3

We applied our research from the first 11/2 years of the grant period to our schematic design concept. Based on our research we were convinced that contemporary houses can significantly reduce their annual energy consumption by incorporating passive solar strategies. We decided on a hybrid approach to the building envelope combining current thinking in ZEH technology with vernacular wisdom with an envelope that can be opened during the cooler/dryer months of the year and naturally ventilated and closed and mechanically cooled when the outdoor temperature and humidity levels are too high to achieve an acceptable comfort range by natural ventilation.

The entire north elevation is sliding glass panels that can be opened to the garden to allow natural ventilation and a sense of connection with the landscape promoting a healthy and energy efficient indoor/outdoor Florida lifestyle. On the south elevation all of the glass is shaded by louvers to eliminate insolation during most of the year. During winter when the sun is lowest in the sky there are typically several cold days when afternoon temperatures are low enough to require space heating. Louvers on the south side of the building will be adjustable so that the sun can be allowed to penetrate the space on cold days but can also shade the sun on warm winter afternoons.

A shading structure made of steel tubing and wood lovers will completely shade the roof and east and west walls of the house stopping the hot solar rays from radiating through the building envelope. An 18" space separating the shading device and the building will allow air to pass through freely and prevent the buildup of hot air between the two. The umbrella will also support the PV array and solar thermal panels making them easily accessible without disturbing the building envelope. The house is designed for pre fabrication to minimize construction waste and maximize efficiency in labor and energy use during the construction process. Since we plan to ship the house in one piece the exterior dimensions are limited by shipping restrictions. Portions of the building that go beyond the prescribed shipping width are designed to telescope out from the main building envelope making the house economical to ship and quickly deployable at the site. A 5 KW PV array will provide electric power to the house; a liquid desiccant system will control humidity levels and reduce latent heat load; a solar thermal system that takes advantage of Florida's high thermal conversion of solar radiation will be used for space heating, hot water and to regenerate the liquid desiccants. Hot and chilled water will be circulated around the house to fan coil units in 3 zones for localized control of temperatures and reduced temperature fluctuations when compared to forced air systems.

Design Development was completed in November of 2010 complete with a BIM model of the building a detailed half inch scale model and a digital animated walk thru. The scale models were exhibited at the International builder's show in Orlando in January 2011. A 70 page set of Construction Documents was completed in March of 2011 and a contract between Beck Construction and USF was finalized for the construction of FLeX House. After delays in the contract process, construction began in mid-May, 2 months behind the original schedule. Construction continued through the summer and was completed in early September. The house was disassembled and shipped to Washington DC where it was successfully reassembled in West Potomac Park and exhibited in the 2011 Solar Decathlon. Tens of thousands flocked to the popular house which was second in total attendance among the 19 houses on display. The Solar Decathlon gave students the opportunity to tour the other 18 houses and exchange ideas with their peers as well as explain their ideas to the thousands of visitors to the house. The 3 week event was an exceptionally intense and rich learning experience for the students involved. The house was disassembled and shipped back to Tampa where it is scheduled to arrive on the morning of 10/14. Once reassembled in its permanent location on campus the house will begin its life as the ZEHLC and become an exhibition of energy efficient technologies as well as a living laboratory for energy efficiency research.

ZEHLC research has been presented at the following conferences and meetings:
Russell S.R., *Reaching Zero Energy in Florida's Hot Humid Climate,* ARCC 2011 CONSIDERING RESEARCH: Reflecting upon current themes in Architectural Research, Detroit MI, spring 2011,
Russell S.R., Weston M., Goswami Y., Doll M. *Flex House*, ASME 2011 5th International Conference on Energy Sustainability & 9th Fuel Cell Science, Engineering and Technology Conference, Washington D.C. Summer 2011

Russell S.R. *Energy Efficiency and the Zero Energy Home Learning Center*, ACSA National Conference, RE.building, New Orleans Louisiana, Spring 2010
Russell S.R. *Evolution of the American Zero Energy House*, Eco-Architecture 2010, La Coruna Spain, Spring 2010
Russell S.R. *Evolution of the American Zero Energy House*, International Conference On Building Science And Engineering, Johor Bahru, Malaysia, December 2009
Eco House Symposium- Kanagawa University, Kanagawa Japan- summer 2011
AIA Florida Annual Conference- Naples Florida- summer 2011
ASME Tampa Bay Annual Meeting- FLeX House- summer 2011
AIA Tampa Bay Designer's Luncheon Lecture Series- fall 2010- 2011 Solar Decathlon - FLeX House
CSI Luncheon - FLeX House- spring 2011

ZEHLC research has been published in the following journals:
Russell S.R. *Hybrid ZEH for Florida's Hot Humid Climate,* The International Journal of Design & Nature and Ecodynamics, WIT Press.

The ZEHLC design model has been exhibited at the following venues:
Title- *U.S. Department of Energy Solar Decathlon 2011 Finalists: A Special Presentation,*
Venue- National Building Museum, Washington DC
Date- 5/ 1- 7/25, 2010
Title- *U.S. Department of Energy Solar Decathlon*
Venue- Orange County Convention Center
Date- 1/12-1/15, 2011
Title- *U.S. Department of Energy Solar Decathlon*
Venue- McCormick Place Chicago IL.
Date- 1/12-1/15, 2011
Title- *U.S. Department of Energy Solar Decathlon 2011 Finalists*
Venue- Portland Downtown Marriot Waterfront, Portland, Oregon
Date- 8/11-8/14, 2010
Title- *U.S. Department of Energy Solar Decathlon 2011 Finalists*
Venue- National Renewable Energy Laboratory Visitor Center
Date- April 2010

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Title- *Zero Energy House Learning Center*
Venue- ASCA National Conference Poster Session, Montreal, Canada
Date- 3/ 2011

We applied for and received a $100,000 from the DOE for the 2011 Solar Decathlon.

Our team raised $55,000 in cash donations and an additional $75,000 in gifts in kind.