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 Tampa campus. The Zero Energy Home Learning Center [ZEHLC] 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 as a means of providing distributed energy storage will also be tested. Using a systems approach to advance zero energy home technologies we will also explore opportunities to develop marketable products that meet Florida's energy and environmental goals

Budget: $344,600

Universities: USF, FSU, UF, UCF

External Collaborators: Palm Harbor Homes, Hees and Associates Structural Engineers, David Young Landscape Architect

Progress Summary

Research Objectives for Current Reporting Period: Our research objective for this reporting period was to develop the ZEHLC design with an interdisciplinary team.

Progress Made Toward Objectives During Reporting Period: With our interdisciplinary team including engineers from USF, FSU and the Florida Solar Energy Center, construction and interior design experts from UF, and industry partner Palm Harbor Homes we began the Design Development phase of the ZEHLC. Based on our belief that contemporary houses can significantly reduce their annual energy consumption by incorporating passive solar strategies, we developed a hybrid envelope that can be opened during the cooler/dryer months of the year and closed when temperature and humidity levels are too high to achieve an acceptable comfort range in the house. Informed by FSEC studies that have shown that the majority of heat gain comes through the roof of Florida homes, the ZEHLC employs a shading device that covers the entire roof and the east and west walls to reduce heat gain by eliminating direct solar radiation through the building envelope.

To test this theory we built 3- 8'x8' test modules from structural insulated panels [SIP] to monitor relative temperature fluctuations with different building envelope treatments. Module one was a control case with no additional treatment to the SIP envelope. Module two had plywood sheathing and a 3/4" ventilated airspace on the exterior skin of the roof and walls. Module three had a shading device covering the roof and east and west walls. The 3 modules were monitored simultaneously, under identical conditions, for an 8 hour period with a Campbell Scientific PS100 Data logger and 3 temperature and relative humidity sensors attached. The temperature difference within the modules continued to grow throughout the afternoon and the module with the shading device had the lowest interior temperature at the end of the 8 hour period and. The results supported our hypothesis that the shaded module would be the coolest and the module with the ventilated air space would also be cooler than the control case module with the bare SIP.

Based on the result of this experiment we decided to design the ZEHLC with a shading device that will cover the roof and east and west walls. The design includes a ventilated space between the shading device and the house to prevent the buildup of hot air that commonly occurs in the attic space of Florida houses. The house will be constructed in the factory of Palm Harbor Homes to minimize construction waste and maximize efficiency in labor and energy use during the construction process. A 4 KW PV array that will provide electric power to the house will be mounted to the shading device for easy access and maintenance; 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.

Since the ZEHLC was selected as one of 20 entries to the 2011 Solar Decathlon under the name "FlexHouse", we have been working closely with the other members of "Team Florida" to advance the design while meeting competition criteria. Team Florida is an interdisciplinary team of experts from USF, UF, FSU and UCF and the professional community. Competing in the 2011 Solar Decathlon will focus attention on the ZEHLC project and bring notoriety to USF and other Team Florida schools and their efforts to advance clean energy technologies in the state.

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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. We have established the following collaborations for the Solar Decathlon and ZEHLC projects:

Industry Partner- *Palm Harbor Homes* Plant City, Florida
USF School of Architecture and Community Design- Mark Weston- Faculty
USF College of Mass Communications- Rebecca Hagen- Instructor
USF College of Business- Sharon Hanna West-Faculty
FSU- Justin Kramer- OGZEB Project director
UF- Robert Rees- School of Building Construction- Faculty, Maruja Torres- Department of Interior Design- Faculty, Nam-Kyu Park- Department of Interior Design- Faculty
UCF/Florida Solar Energy Center- Stephanie Thomas Ries- Research Architect, David Click Photovoltaic researcher
Professionals- Hees and Associates Engineers, David Young landscape architect

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

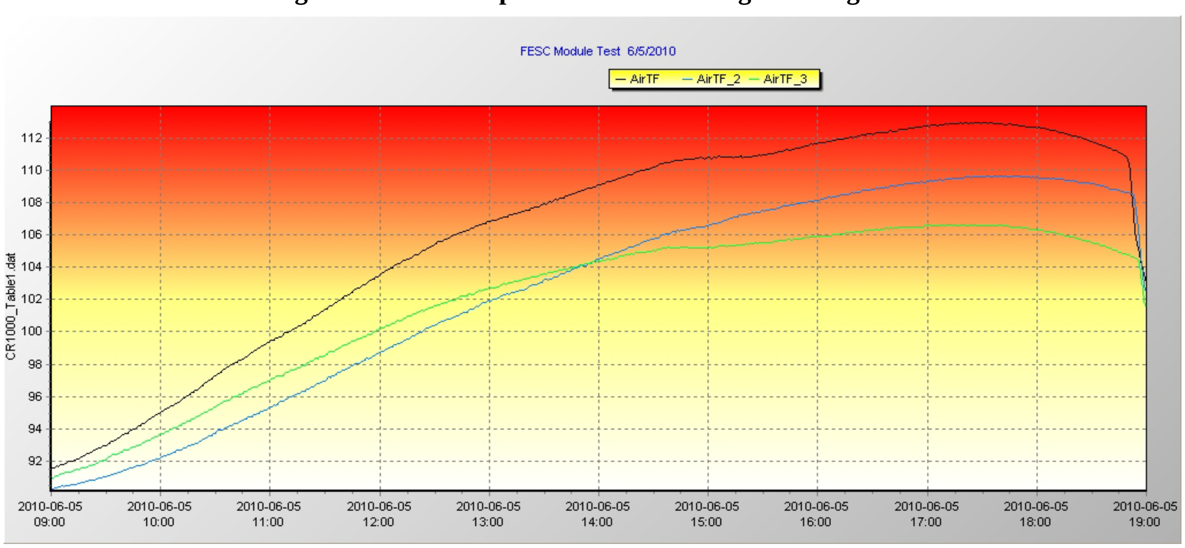

Fig.4 black line is module 1, blue line is module 2, green line is module 3

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.

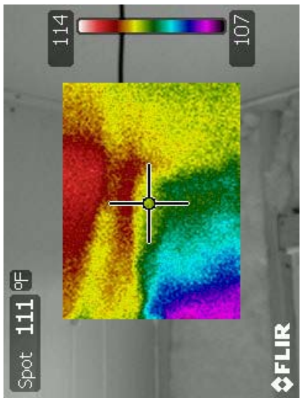

Fig. 5 Infrared photo in module 1

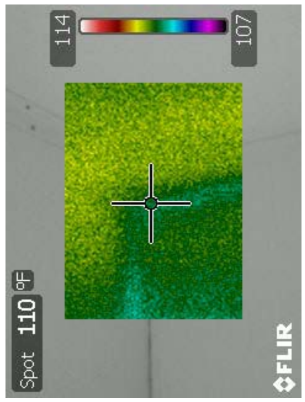

Fig 6 module 2

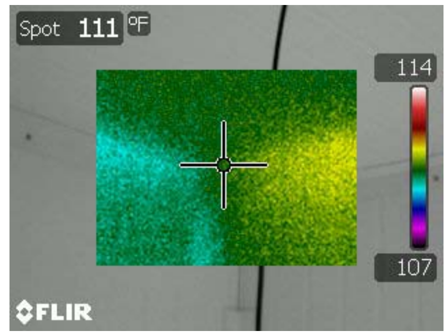

Fig 7 module 3

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.

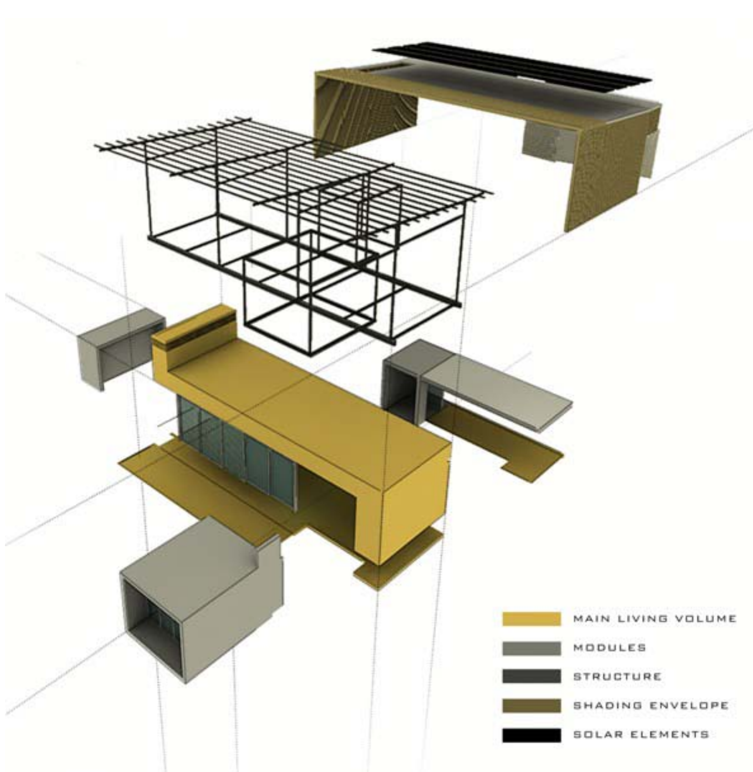

Fig 8. Exploded view of the ZEHLC system

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 insulation 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 Fig.8 exploded view of ZEHLC systemsbetween 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 will be constructed in the factory of Palm Harbor Homes 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 4 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. ZEHLC research has been presented at the following conferences:

- The International Conference on Building Science and Engineering, Johor Bahru Malaysia, December 2009
- Eco-Architecture Conference, La Coruna Spain, April 2010
- ACSA National Conference, New Orleans Louisiana, March 2010
- An abstract is currently under review for a poster session at the 2011 ACSA national conference. An abstract is under review for a paper presentation at the 2011 ARCC conference.
- A paper is currently under review for the International Journal of Design and Nature and Ecodynamics.

The ZEHLC design model has been exhibited at the following venues:

- NREL visitor Center exhibit April 2010
- *U.S. Department of Energy Solar Decathlon 2011 Finalists: A Special Presentation,* National Building Museum, Washington D.C., May 1, 2010 - July 25, 2010
- *U.S. Department of Energy Solar Decathlon 2011 Finalists*, American Institute of Building Design, Portland Downtown Marriot Waterfront, Portland, Oregon, August 11-14, 2010

We applied for and received a $100,000 from the DOE for the 2011 Solar Decathlon.
We have received $20,000 in support and expect much more from sponsors of Team Florida in the 2011 solar decathlon.

Fig. 9 South View of ZEHLC