Reaching Zero Energy in Florida's Hot Humid Climate

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ABSTRACT:

Once considered economically impractical and technology unfeasible, the zero energy home [ZEH] is now a reality, zero energy communities are on the rise and the world is poised to enter a new clean renewable energy era. In the State of Florida the hot humid climate presents certain challenges to energy efficiency, comfort and the development of ZEH. Vernacular and modern buildings built before the influx of air conditioning hold valuable lessons about designing in harmony with the climate. Research on ZEH in Florida has resulted in a wealth of useful information but many problems still remain. Most ZEH have been built with conventional site built methods and have reduced cooling loads with well-sealed, highly insulated envelopes. As a result, the homes are often closed off to the exterior and few innovations in cooling technology have been introduced.

This paper describes the research and design of a ZEH prototype for a hot humid climate, funded by a Florida Energy Systems Consortium grant. Taking vernacular architecture, modern architecture and recent ZEH research as points of departure the author describes the design and construction strategy for a ZEH prototype for a hot humid climate that will attempt to improve on current ZEH examples. The author argues that a Florida ZEH should have the potential to open up and take advantage of natural ventilation during the cool mild season and close during the hot humid season for mechanical cooling. A ZEH designed in this way would be more connected with the environment and the cooling load would be reduced with the use of natural ventilation also reducing the need for expensive PV panels and making the house more affordable. Prefabrication of ZEH can reduce waste associated with site building while shortening the construction period and reducing the overall cost of the house.

CONFERENCE THEME: Measurement
KEYWORDS: zero energy, sustainability, energy efficient, hot humid climate, renewable energy

INTRODUCTION

In recent years the dream of building houses that produce as much or more energy than they use has become a reality. Prefabricated home makers in Japan have offered net zero energy homes commercially since the late 1990's and entire communities of ZEH are being built around the world. In the state of Florida the hot humid climate presents special challenges for energy efficiency in buildings but the state enjoys one of the country's highest rates of incoming solar radiation making it a natural location for photovoltaic electrical generation. In fact Florida Power and Light [FPL] recently opened the DeSoto Next Generation Solar Energy Center the largest solar photovoltaic facility in the country. Early settlers had to live in Florida's sometimes severe climate without the luxury of mechanical air conditioning and the adaptations that their buildings made to the Florida climate are instructive when considering a new, energy efficient building paradigm for the state. As recent as the 1950's the so called Sarasota School architects were skillfully designing contemporary houses in tune with the Florida climate and lifestyle. Once air conditioning became the norm for creating comfortable interior environments, the common sense design features of vernacular Florida architecture and the Sarasota school were all but forgotten and houses were designed to optimize air conditioning systems rather than responding proactively to the climate. The once popular indoor outdoor Florida lifestyle was replaced by an indoor lifestyle that was quite separate from what happened outdoors. By the late 1990s an environmental crisis, high energy prices and the falling cost of PV technology all conspired to stimulate interest in sustainability and energy efficiency and research began on ZEH designed specifically for Florida. Research done since that time has generated many strategies for dealing with Florida's climate in energy efficient ways but little has been done to integrate these strategies with Florida's climate or the Florida lifestyle. Flex house is a ZEH prototype designed by Team Florida[1] to revive the dream of the indoor/outdoor Florida lifestyle while responding to assets and demerits of the Florida climate. Flex house takes lessons from vernacular architecture, Sarasota School architecture and recent research on ZEH for a new kind of ZEH uniquely designed for Florida.

1. FLORIDA BUILDING PRECEDENTS

1.1. PASSIVE STRATEGIES IN VERNACULAR ARCHITECTURE

From the early 1800s white settlers began to trickle down from the northern states and establish homesteads in the Florida wilderness. Their houses became known as cracker houses. Like most homesteaders at the time, the Crackers built walls by stacking pine logs on top of each other with notched ends that interlock with adjoining walls at the corners. Although the same type of dwelling was built across the country, the Cracker house had features that were unique adaptations to the hot, humid Florida climate. While in cold climates it was often much easier to place the logs directly on the ground or on a layer of foundation stones, the cracker house logs were raised on piers to protect the wood from rotting on Florida's moist, warm ground. In cold climates the floor was often made of earth but in Florida, where air movement is essential to thermal comfort and the longevity of building materials, the floor was framed in wood and raised off of the ground so that air could circulate under the building. Whereas the northern settler's dwellings had little or no roof overhang, the cracker house typically had a wide covered porch on one, two or three sides that shaded the building from the hot sun and provided a covered, exterior space for work or leisure. (Hasse 1992)

Cracker houses were built of wood and metal, materials with low thermal mass that are well suited to the Florida climate. Given that the Crackers were adapted to Florida's climate and their thermal comfort zone must have been several degrees higher than ours is today, one can imagine that the Cracker house with its wide shady porches provided them with a reasonably comfortable living environment. Meanwhile, the architectural style of choice of the high society people vacationing in Florida in the late 1800's was not the humble wooden cracker house but the masonry and stucco style of the exotic Spanish Mediterranean. With masonry walls and heavy tile roofs that absorb heat, small windows that inhibit ventilation and minimal roof overhangs that allow the sun to bake the masonry walls, these houses were the antithesis of effective passive solar design in a hot, humid climate. But despite its lack of affinity for the Florida climate, the Mediterranean Revival style [Med-Rev] is

Figure 1: Typical Florida Cracker House
Source: (Forest Capital State Museum 2010)

favored by many, to this day, for its image of substance and wealth. One important exception to the Med-Rev trend began in the early 1940's when a small handful of Ivy league trained architects brought their brand of modern, regional, functionalism to Florida to redefine Florida vernacular in a way that celebrated the region's environmental assets while responding to its climatic challenges.

1.2. PASSIVE STRATEGIES IN MODERN ARCHITECTURE

Columbia University educated Ralph Twitchell, a designer and builder, opened his office in Sarasota, Florida in 1936 after spending the early part of his career in New York and France. Twitchell saw Florida as a paradise and sought to design buildings that worked with and accentuated Florida's natural beauty. In the early 1940s Paul Rudolph graduated from Alabama Polytechnic Institute [API] and went to work for Twitchell. While in Alabama, Rudolph had studied the climatic responses of local vernacular architecture and those ideas were fresh in his mind when he arrived in Florida to begin working with Twitchell (Domin 2002). The combination of environmental awareness, construction experience, and design savvy of the Twitchell /Rudolph team led quickly to works that brought national attention to Sarasota and the uniquely Florida houses that the team designed. The houses were built in a distinctly modern vocabulary that was also distinctly regional. The deep overhanging eaves, absent in the Med-Rev architecture of the day, were used to shade the building and to make shaded outdoor spaces recalling the cracker house design. Many houses included outdoor rooms enclosed with screens. Large sliding glass panels or louvered windows allowed entire walls to be opened for ventilation and to expand the interior space into the landscape. A variety of shading devices including louvers and screens helped protect the windows and walls from the hot Florida sun. In many cases the louvers were adjustable to respond to various sun angles or weather conditions such as vertical storm shutters that pivoted up to become horizontal sun shading devices. The plans were often elongated on the east west axis to allow cross ventilation in rooms and maximum shading for walls. The relevance of the Twitchell/Rudolf houses today lies in their skillfully conceived passive responses to the hot humid climate and their open planning and clean modern aesthetics that continue to suit contemporary tastes and lifestyles (Howey 1995). As air conditioning became more prevalent in the 1950's however, the necessity for climatically responsive architecture in Florida diminished. With the exception of a brief period of revived interest in the Cracker house, little serious consideration was given to passive solar design and energy efficiency again in Florida until the late 1990s, when the Florida Solar Energy Center [FSEC] began its research on ZEH.

Figure 2: Indoor/outdoor space by Rudolph
Source: (Stanley Russell 2008)

1.3. ZERO ENERGY HOUSE RESEARCH IN FLORIDA.

In the state of Florida in the 1990s the increasing affordability of PV technology began to open the door to site based electrical generation which, along with solar thermal technology, takes advantage of the state's wealth of insolation. In 1998 the Florida Solar Energy Center [FSEC] began its ZEH research program in collaboration with the City of Lakeland municipal utility. The team constructed a 2400 sq. ft. energy-efficient photovoltaic residence [PVRES] and a standard model [the Control] with the same footprint and tested them both for more than a year. In one year, the PVRES home used 6960 kWh of electricity and had a PV system production of 5180 kWh. For the same year, the control used 22,600 kWh without any PV production. The yearly energy savings due to differences in energy efficiency of the two homes was 70% for the PVRES house. Deducting the PV system's production, the PVRES house's net energy use for the entire year was only 1780 kWh a 92% utility energy savings compared to the standard house. Perhaps even more important than annual energy use is the fact that during periods of peak electric demand, the PVRES house, due to the PV system, placed nearly zero net demand on the utility system. Both test homes have R-30 fiberglass insulation blown in the attic, but there are major differences in the building envelope and mechanical systems of the two buildings. The building envelope of the PVRES house features a 77% reflective white concrete tile roof. The control home's roof is made of conventional, 7% reflective gray asphalt shingles. When the outside summer air temperatures were at their peak the coincident peak attic air temperature was 91.4oF in the PVRES compared to 131.50 in the house with gray asphalt shingles. For solar control on walls and windows, the PVRES home has a 3 foot wide overhang around the entire perimeter of the building while the standard home has a one and a half foot roof overhang. The overhang of the PVRES home shades most of the wall and at least 75% of the south and east window area. In conventional residential construction in Florida, walls are insulated on the interior of the masonry walls exposing the exterior to the hot sun and ambient air temperature and allowing the masonry to store excess heat and pass it slowly to the interior spaces. Conversely, the concrete block walls of the PVRES home were covered with R-10 insulation on the exterior to keep the masonry from absorbing excess heat from the outside. The mechanical systems of the two buildings also had marked differences. In conventional Florida house construction the ducts and often the air-handler are located in an uninsulated attic space. In Florida, the attic sometimes reaches 130o F and studies show that heat transfer to the duct system can reduce the cooling capacity of the air conditioner by 30%. In the PVRES house the air handler and ductwork are placed within the conditioned space of the building. The PVRES home uses a solar water heating system with propane back up. The system consists of a forty square foot solar collector mounted on the south side of the home's roof. The control home contains a standard electric resistance 52 gallon storage tank in the garage rated to use

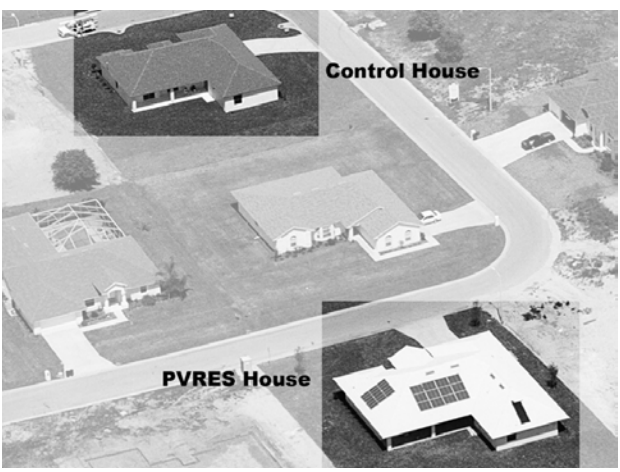

Figure 3: PVRES house
Source: (Florida Solar Energy Center 1998)

4,828kWh/year. The PV generation system for the PVRES was sized to provide power that would offset most of the daytime household electrical loads. Based on the predicted loads for a peak day, it was determined that a 4kW solar array should be installed (Parker 2008). The Lakeland project and several other research projects in the past 12 years have shown that a well-designed building envelope, energy efficient mechanical systems and appliances and a solar array for electric generation and hot water production, can be combined to produce affordable houses that achieve near net zero or net zero energy consumption in Florida. Team Florida took the lessons derived from research and vernacular and modern precedents as a starting point for the design of Flex House.

2. FLEX HOUSE DESIGN APPROACH

2.1. CONCEPT

FLeX House is designed in a holistic way as a sustainable, flexible, modular, pre-fabricated, net zero energy house [ZEH] prototype that can adapt easily to differ¬ent site situations and plan configurations. The house can be shipped on one truck and quickly deployed at the building site. The Flex house base module is designed for a young couple or a couple with a small child living in central Florida on a moderate income. As a family grows modules can be added to the base expanding living space as necessary.[2] While the emphasis in energy efficient houses in Florida in recent years has been to reduce heat gain with well-sealed and insulated building envelopes the result has often been an interior living space that is conditioned year round with little connection to the exterior climate or the surrounding site. Flex house is designed to open up to take advantage of passive cooling in Florida's mild weather months and close down to utilize highly efficient mechanical systems during the months of temperature extremes when passive strategies are not effective. This hybrid open and closed building type is conducive to a healthy indoor/outdoor Florida lifestyle and is reinforced by the design of the landscape, floor plan, building section, building envelope, and the choice of building materials and me¬chanical systems. The size of American houses has steadily grown since the 1970's. U.S census data shows that in 1973 the average house size was 1660 s.f. and by 2009 that size had increased to 2438 s.f. Larger houses mean that more resources are necessary for construction and operation [US Census]. A variety of space conserving design strategies give residents of Flex house an affordable, functional and comfortable living environment in an unconventionally small footprint.

2.2. PREFABRICATION

To be a viable housing alternative and to make a significant impact on our country's energy consumption, ZEH must be affordable for people earn-ing a moderate income. Although individual materials and technologies affect the cost of home construction the building process itself is a more significant factor. Site built construction is inefficient in the use of time and materials and makes quality control difficult. Building homes in a controlled factory environment facilitates quality control and the efficient use of time and materials leading to the potential for a higher quality product at a lower cost with less waste going to landfills. Flex house is designed for prefabrication with dimensions that allow it to be shipped to the site in single truck increments corresponding to the size of the house. Sliding modules that fit inside of the main unit are deployed on site to allow a maximum square footage to be shipped on one truck. The single unit home concept emphasizes the viability of relo¬cation, expandability, flexibility and recyclability to keep pace with the evolving American housing market and the demand for more sustainable building practices. The modular system allows expansion to accommodate a growing family or a new owner with different needs.

2.3. PLANNING

Abundant glazing and an uncluttered, open floor plan give the interior spaces a sense of light¬ness and openness with a visual and physical connection to the garden and surrounding environment. The kitchen, living, bedroom and bath areas can all flow together into one continuous space or they can be partitioned for privacy and thermal zoning. The entire north wall of the living/Kitchen area

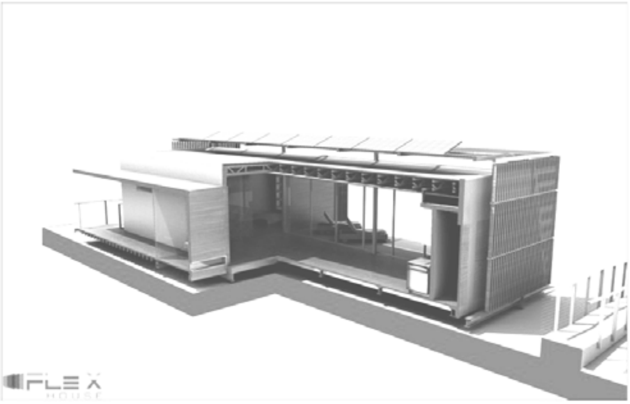

Figure 4: Section through FLeX House
Source:(Miguel Sanchez 2010)

is composed of sliding glass doors that can be opened to join the interior space, with the exterior deck and garden allowing for the hybrid open/closed building type. The plan includes many space saving features that create comfort within a smaller more economical envelope. A rolling kitchen island doubles as a dining table. A Murphy bed that folds up into the wall gives flexibility to the bedroom area which can also be used as a study or exercise area. A loft above the built in desk area can accommodate guests or children. A compact washer/dryer unit fits into a closet next to the bathroom. The bathroom can be partitioned into 3 separate zones for the shower, the lavatory and the toilet so that 3 people can use the same space at once and still have privacy. Me¬chanical equipment is located in a mechanical module and is easily accessible from the exterior of the house to give residents privacy and to prevent the interruption of daily activities when equipment needs to be changed or serviced.

2.4. SITE PLAN /LANDSCAPE

The FLeX House is elongated on its east west axis to facilitate shading of the building envelope. Because cooling is desirable during most of the year the house sits on the sun baked southern half of the site to free up space for a shaded courtyard on the house's cooler north side. A pedestrian spine along the west edge of the site connects the house's main entry to a street on the north or south side lending flexibility to the siting of the building. The building height and setbacks are designed to minimize shading of adjacent properties to ensure solar access to neighbours. The landscape design integrates landscape and architecture in a way that is utilitarian and aesthetic while also being environmentally responsible. The landscape provides food, shelter, wildlife habitat, microclimate modification, cleaner air and water, solar heat gain reduction and storm water runoff reduction. The plant palette consists largely of native species found within the region which are drought tolerant and insect resistant and require little water, maintenance and care. Various species of palm trees provide shade while allowing wind penetration of the site, ornamental clumping grass species and canopy trees placed within vegetated swales reduce storm water runoff and allow water uptake while providing food and substrate for other plants. Citrus trees, Muscadine and Scuppernong vines provide privacy, shade, and edible fruit. Saw palmetto provides privacy, shade, and fragrant flowers. Rainwater is collected from the roof and piped to a below ground cistern for use in irrigation of the landscape and for flushing toilets, reducing the demand on the municipal water system. To ease the impact of perennial water shortages in central Florida rainwater from the roof is collected in an onsite water feature and in an underground cistern where it is combined with Grey water from the kitchen and bathroom and used for irrigation of the landscape.

2.5. BUILDING ENVELOPE

Flex house is designed to function equally well throughout the year, combin¬ing optimum insulation for temperature differentials, resistance to air infiltration, daylight, and flexibility. SIP and stick built configurations were analyzed to find the best balance of efficiency, sus¬tainability and economics. Both systems offer advantages over the other but in the case of the Flex house design, stick built construction was chosen for its strength, economy and sustainable aspects. Because of the low temperature differentials between indoor and outdoor air in Florida, insulation values in walls and floors can be relatively low. The roof is subject to very intense sun and heat build-up so the highest insulation value would typically be used there. Exterior finish Materials were evaluated and selected based on durability, energy efficiency, recyclability, maintainability, origin and economy. In Florida's high heat and small diurnal temperature range, materials with high thermal mass store heat and put extra load on AC systems. Light materials with low thermal mass and high reflectivity are preferable. Because of its low thermal mass, reflectivity, durability and economy, corrugated metal siding was chosen for the exterior walls of Flex house. Cypress is a locally grown wood that has a natural resistance to weathering and also possesses the other desired characteristics so it was chosen as a second exterior finish material. Traditionally, insulated glass has not been used in Florida because of the initial cost vs. payback comparison in the mild climate. For economy, Flex house has low-e, single pane glass throughout but more research is necessary to determine the efficacy of using insulating glass.

2.6. NATURAL VENTILATION

Flex house is designed to take advantage of Florida's mild seasons with passive cooling through natural ventilation instead of relying on energy consuming mechanical systems. Passive cooling begins with the site plan and vegetation which creates shade and cools the air before entering the house. FLeX House makes a strong connection between indoors and the landscape with carefully placed fenestration and sliding glass panels that allow the house to open out inviting air movement from across the site and through the house. Ceiling fans throughout the interior help to create air movement on days when there is no breeze. Raising the building off of the ground and ventilating the crawlspace helps to mitigate the negative effects of ground moisture, insect intrusion, and radon gas.

2.7. SHADING

Throughout the year the majority of heat gain in central Florida happens through the roof where attic spaces can reach temperatures exceeding 1400. The Florida Cracker house, homes designed by the Sarasota School, and FSEC research all demonstrate that shading is a criti¬cal strategy for reducing heat gain in Florida houses. To test the effect of building envelope composition on heat gain we constructed 3- 8'x8'x8' test modules each having a different skin configuration.[3] The test revealed that complete shading of the roof and walls resulted in the greatest reduction in heat gain. Flex House incorporates an umbrella like outer structure composed of cypress wood louvers and photovoltaic panels that shade the roof and walls minimizing heat gain through the building envelope. The open space between the umbrella and the building envelope ventilates freely and prevents the build-up of hot air typically found in attic spaces. Movable shading devices give the umbrella the flexibility to allow sun in for passive heating on cold winter days.

2.8. MECHANICAL SYSTEMS

The Flex House engineering approach combines conservation measures with cutting edge technologies in a system uniquely suited to the central Florida climate. Flex house uses a combined system of photovoltaic panels and solar thermal con¬centrating panels to optimize the energy conversion system. The exterior walls and roof have a relatively high reflectivity to serve as a radiation barrier. Louvers in the umbrella structure allow indirect light to penetrate for day lighting but prevent direct solar radiation from reaching the walls. The HVAC system consists of a small air-cooled chiller

Figure 5: Indoor/Outdoor connection
Source: (Jean-Frederic Monod 2010)

and solar thermal panels serving two interior fan coil units that circulate air via ducts to the living spaces. Movable interior partitions between the sleeping/office area and the living area allow the wall to be opened or closed creating two distinct thermal zones. The HVAC system conserves energy by responding to the seasonal temperature and relative humidity fluctuations of the individual zones and the residents are able to regulate the temperature in each zone according to their needs. Flex house employs a solar thermal system to generate hot water for use in the house and for space heating. The water based HVAC system allows simple integration of hot water from the solar thermal panels into the space heating system. Hot water end uses like showers, sinks, dishwasher and washing machine are also supplied by the solar thermal system. The system is composed of two 4'x8' solar hot water collectors mounted on the umbrella connected to an insulated water tank. When there is sufficient heat to be drawn from the collectors, the controller automatically activates a pump which pulls cooler water from the storage tank through the collectors to be heated. Once heated, the water is pumped back down into the storage tank for consumption. This process continues as long as there is heat to be drawn from the collectors. When there is little or no sun, a backup heating element self-activates to provide ample hot water for the house. In this system a thermostatic mixing valve is used to ensure the proper supply temperature to the end uses regardless of the tank temperature, allowing the tank temperature to stay around 160 F0. In order to provide water to the fan coils at the desired temperature, a thermostatic mixing valve blends water from a warm tank and a cold tank. The cold tank is maintained at 55°F by the chiller. Waste heat from the chiller is used to heat the warm tank with additional heat provided from the solar thermal storage tank. A valve and control system determines whether to circulate chilled or hot water to the fan coil units. Chilled water is sent to the storage tank in the early morning when the chiller can run more efficiently due to the lower outdoor temperatures. The water is allowed to rise to a certain temperature according to the season and then cooled back down reducing cycling and allowing the chiller to remain off as long as possible during periods of peak electrical demand and higher ambient temperatures.

In Florida, where average relative humidity hovers around 75% during most of the year, dehumidification is crucial to creating a sense of thermal comfort. Flex house employs an innovative, liquid desiccant duct system connected to an *energy recovery ventilator* [ERV] to dehumidify incoming air and reduce the cooling load on the chiller and fan coil units [Oberg, Goswami, 1992]. The ERV exchanges exhaust air from the inside of the house with external supply air allowing fresh air to enter the house in a controlled manner. This is im¬portant for maintaining indoor air quality. The air leaving the house passes heat to and from the incoming air, reducing the heating and cooling loads allowing the chilled/hot water system to run more efficiently. The liquid desiccant system improves efficiency of the HVAC system by removing moisture from the supply air allowing the fan coil temperatures to exceed the dew point while still maintaining good indoor air quality. The Flex house HVAC system is designed to maintain a time-averaged interior dry-bulb temperature between 71.0°F (21.7°C) and 76.0°F (24.4°C) and a time-averaged interior relative humidity below 60.0% in all thermal zones. To keep energy consumption at a minimum, efficient appliances are essential. Flex house is equipped with energy star rated, smart grid appli¬ances that communicate with each other to prevent multiple high draw appliances from turning on at the same time, reducing spikes in electrical demand. Low flow fixtures are used in the kitchen and bathroom to reduce water consumption and also reduce the energy required to heat water.

2.9. ELECTRICAL

Flex house utilizes both, a grid connected Photovoltaic array and a standard grid connection to provide all of its electric power. The grid connected system eliminates the need for expensive batteries used in standalone PV systems and allows for a give and take from the power utilities that results in a net zero electrical demand from the utility when averaged over the course of a year. Flex house draws electricity from the utility at night or on cloudy days when the PV array is not generating enough electricity to power the house and sends electricity back to the utility company when the PV array is producing more than the house needs. To facilitate periodic maintenance of PV equipment in a way that minimizes disturbance to the occupants and the building, the solar panels are mounted on the umbrella structure separate from the building envelope. Until recently PV systems used a single *central inverter* to convert DC power from the PV array into AC power that can be used in common household appliances or sent back to the utility company. Recent developments in *micro inverters* allow power from each PV panel or pairs of panels to be converted to AC directly, eliminating potentially hazardous high voltage DC lines from the system. Inverters operate with mean power point tracking [MPPT] that identifies the best combination of voltage and amperage for the panels to run at peak power. With a central inverter, the MPPT is applied to the array's performance as a whole so some of the panels are forced to perform below their capacity, resulting in wasted energy. Micro inverters optimize performance for each panel so that all panels perform at maximum output improving the overall efficiency of the array. In the micro inverter system, if one panel is covered with leaves, gets dusty, or is shaded it will not affect the output of the other panels. Flex house utilizes one micro inverter for every pair of panels in a 20 panel array that is rated at 4.4 kW DC.

Energy efficiency is the key to keeping the photovoltaic array as small as possible thus making the house more affordable. Flex house includes the most energy efficient appliances available along with compact fluorescent, LED, and day lighting to minimize electricity demand. Solar thermal panels for heating water and space heating further reduce the need for electric or other power sources. Because energy efficiency is also related to the operation and monitoring of building systems, Flex house will incorporate whole building systems control and diagnostic software that monitors more than 35 channels of data (i.e. temperature, humidity, power, occupancy schedules, window operation incidences, etc.) Most systems will be operable by cell phone or other portable electronic device. Accessible wire chases will allow data cables to be upgraded as necessary.

CONCLUSION

Many breakthroughs have been made recently in ZEH and clean renewable energy technologies that will inevitably lead the way to widespread implementation of zero energy houses and zero energy buildings in the near future. In Florida where the insolation rate is one of the highest in the country ZEH powered by PV systems that will also charge electric vehicles are undoubtedly coming in the near future. To build the most efficient, economical and comfortable houses that promote a healthy lifestyle a holistic design approach is necessary. Unlike ZEH or near ZEH that have been built up to this time in Florida, FLeX House is designed with a comprehensive view of the environment, climate, lifestyle, economics, construction processes, and technology and will serve as an example of how ZEH can be designed and built in the future. FLeX House is scheduled to begin construction in the spring of 2011 and will be finished by early summer. It will be prefabricated as a single unit and shipped to Washington D.C. for the 2011 Solar Decathlon before returning to the University of South Florida's Tampa campus where it will become a zero energy house learning center for the entire Tampa Bay area. In addition to a learning center, FLeX House will also be a living laboratory to test emerging ZEH technologies and sustainable building materials and systems for use in the Florida ZEH of the future.

ACKNOWLEDGEMENT

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ENDNOTES

1 Team Florida is made up of faculty and students from the University of South Florida, University of Florida, University of Central Florida and Florida State University and professional consultants.

2 The basic unit with two slide-out modules is 950 ft^2. Two of the units can be joined to make a 1900 ft^2 house or smaller modules can be added to increase size in 100 ft^2 increments.

3. Three modules were built for testing. The first had no skin treatment. The second had a ventilated skin made by furring out plywood with ¾" furring strips, and the third had a louver structure covering the top and sides. The three modules were equipped with heat sensors and set in the sun for one day. At the time of peek temperature the house