University of Central Florida

Energy Efficient Building Technologies and Zero Energy Homes

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Description: The project consists of two elements: 1) the construction of two flexible research homes at FSEC to conduct research on advanced building energy efficiency technologies under controlled conditions; and 2) a staged, field retrofit study in a small number of unoccupied homes to measure and document the effectiveness of a series of retrofit measures that can be deployed using current technology. The project will also conduct an annual meeting where other FESC participants, other university members and utility, industry, the U.S. Department of Energy, and other stake holders will be briefed on plans and progress. Inputs from meeting participants will be sought.

Budget: $1,224,000
Universities: UCF/FSEC

Executive Summary

This report summarizes work conducted at the Florida Solar Energy Center (FSEC) with funding support from the Florida Energy Systems Consortia (FESC) to improve the energy efficiency of Florida residences. Thanks to FESC funding, the state of Florida is competitively obtaining federal research dollars through enhancing research capabilities, improving facilities, and conducting initial work that was leveraged into larger studies. The FESC funding along with the federal funding has allowed for quantifying projected energy savings from a variety of retrofit strategies for existing homes, a market sector with substantial growth during the current down turn in new construction. Furthermore, the FESC funding will continue to deliver results through facility and equipment upgrades. Specifically this report presents summaries of four different types of work:

1. Whole house field studies in which contractors, local government agencies, non-profits and others were assisted in delivering improvements to existing homes and creating high performance new homes, data was gathered on issues, costs, and in one study code compliance. Some studies included monitoring of temperature and energy use.

2. Whole house laboratory studies where, under controlled conditions, the efficiency of one component is measured.

3. Facility and capability expansion to facilitate research and be used to attract federal and private funding.

4. Outreach to Floridians via meetings and publications.

Whole House Field Studies

Researchers assisted government and non-profit housing entities with incorporating energy efficiency, indoor air quality, durability, and comfort measures into existing homes prior to resale as part of comprehensive renovations needed to bring homes up to market standards. The target efficiency improvement was a 30% reduction in Home Energy Rating System (HERS) Index in each house. On the HERS Index, lower scores are better. The HERS index was used as occupancy was not the same before and after the retrofits thus there was no historic utility data to rely on.

Critical start-up funds from FESC enabled FSEC to begin work on this area of rising interest prior to availability of funding from the U.S. Department of Energy which later awarded continuation funding through FSEC's Building America Partnership for Improved Residential Construction (BA-PIRC). Most of the retrofits were conducted under HUD's Neighborhood Stabilization Program.

Typically, the study homes were single-story, single family detached, concrete block structures built between 1957 and 2006. The conditioned area ranged from 792 to 2408 ft^2 with split-system forced air heating and cooling systems.
One hundred homes were initially analyzed prior to retrofit for efficiency improvement opportunities. Of those, 70 renovations were completed with 66 in central Florida and 4 in north Florida. Pre-retrofit HERS Index ranged from 95 to 185. Forty-six of the renovations achieved the "deep" retrofit goal of a HERS Index reduction of at least 30%.

While average pre-retrofit HERS Index was higher for older vintage homes, average post-retrofit HERS Index was similar across the decades (Figure A).

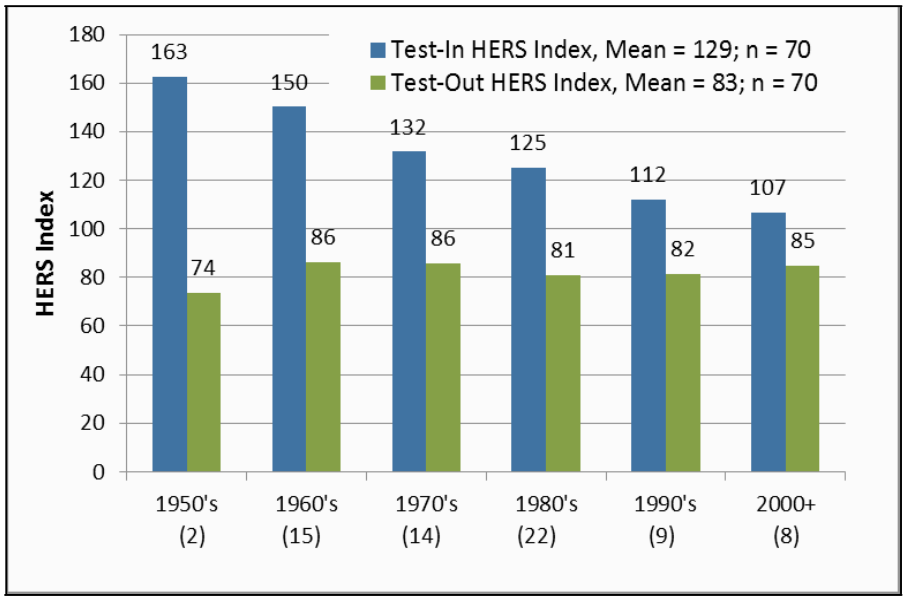

Figure A. Pre- and post-retrofit HERS Index trends by decade.

Among the 42 deep retrofits for which we have cost information, projected incremental annual cash flow ranged from -$79 to $626, and averaged $169 (Figure B). Thirty-six homes had neutral or positive cash flow. Five of the six negative cash flow retrofits were marginal, -$7 to -$26, which might have gone the other way under less conservative financing terms and/or local utility rates. In fact, all of the retrofits would have a higher projected cash flow under the current, lower financing terms available in the market than the previous Building America standard of a 7%, 30 year mortgage.

In another retrofit field study, 24 candidate homes received a pre-retrofit energy audit, parametric analysis of potential improvements, recommendations for reaching a 30% target of energy reduction, and follow up during renovation. Ten renovations were completed and had post-retrofit audit and analysis conducted by the end of the project. Nine of those homes achieved the 30% or greater savings in the predicted annual energy cost. The last home achieved a 26% savings even though the mechanical system was not replaced, indicating strong potential for savings from combined envelope, appliance, and lighting retrofits.

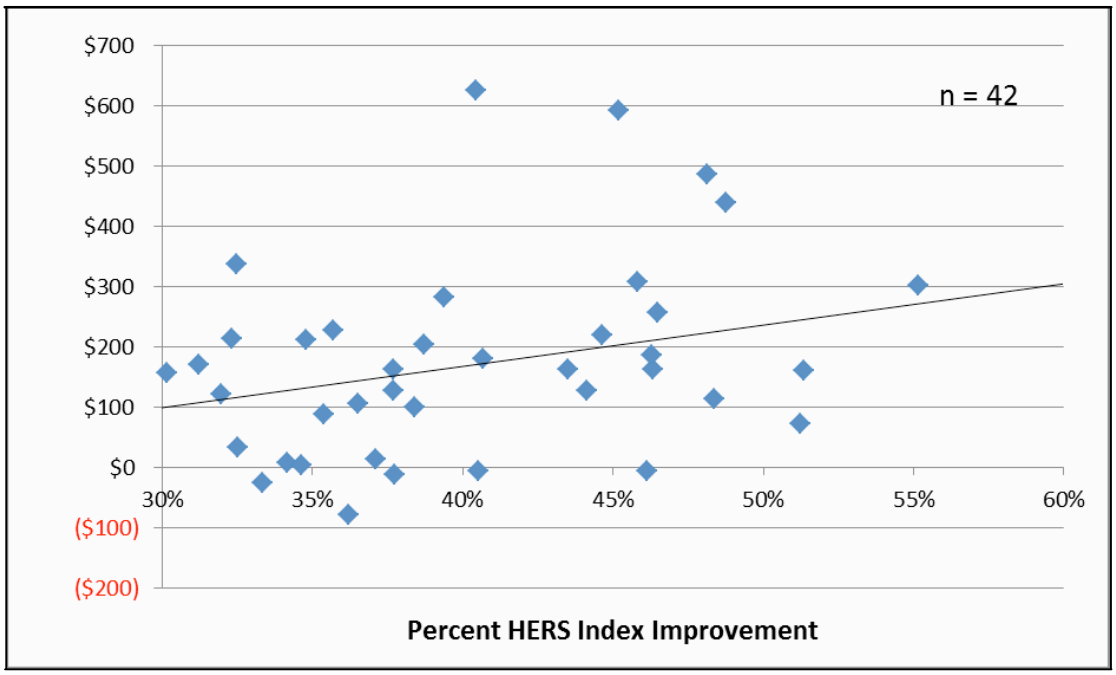

Figure B. Incremental cost as a function of achieved improvement in HERS Index

Retrofit cost data were available for five of the ten study homes. Projected annual incremental cash flow is positive for all of these homes, ranging from $250 to $572. Each house had projected cash flow comparable to the highest homes in the larger BA-PIRC study, indicating great potential for replication of a standardized retrofit approach in the broader Florida existing housing stock.

FESC supplemented funding from the U.S. Department of Energy's Pacific Northwest National Laboratory for this study as well as one on new home solutions in hot-humid climates.

The energy efficiency measures employed in eleven high performance affordable new homes provided a projected annual cash flow to Habitat for Humanity homeowners (20 year mortgage at 0% interest) ranging from $95 to $359. Given the same efficiency measures financed under a typical conventional mortgage (30 years at 7% interest), annual cash flow ranged between $45 and $313. HERS indexes ranged from 57 to 71.

In another field study, FESC funding helped acquire data loggers that were used to instrument homes of two vintages to compare energy used for heating, cooling and water heating. The project compared homes built to the 1984 Florida Energy Code to those built to the 2009 Florida Energy Code and was primarily funded by the US Department of Energy through the Florida Energy Office and the Department of Business and Professional Regulation. The newer code homes used 7 to 13% less energy for the combination of heating, cooling and hot water than the older code homes in their current state (most had improved equipment).

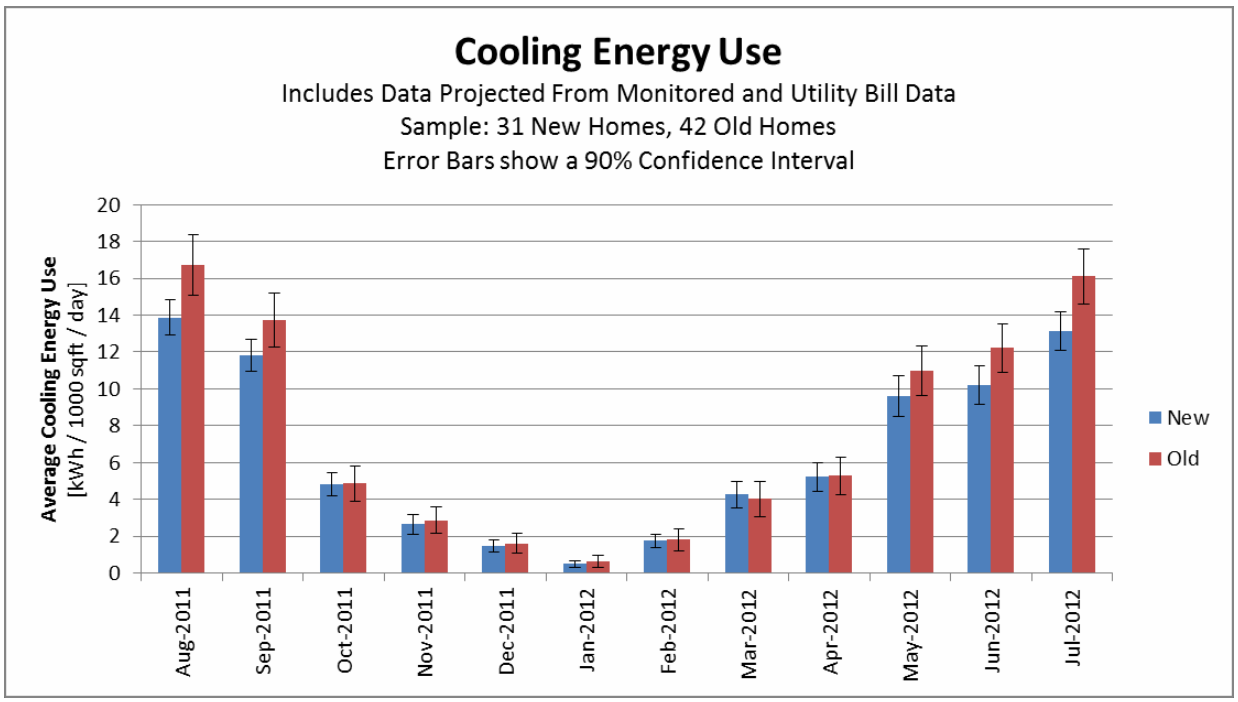

Figure C. A monthly comparison of projected energy used for cooling energy use based on monitored and utility bill data for homes built to two different code periods.

The newer code homes had tighter envelopes, tighter ductwork and better return air pathways when interior doors were closed than the older code homes. The average house tightness of old code homes was 9.07 ACH50 (n=47) compared to 5.66 ACH50 (n=31) for the new code group, indicating the 2009 homes are 37.6% tighter than the older 1985 era homes.

Under normal mechanical system operation, the newer homes performed better than the older ones. Using a simple pressure method of testing ductwork, sixteen (34.0%) old code homes had return duct pressure measurements exceeding 3.0 pascals. Only one new code home (3.2%) exceeded 3.0 pascals on the return side. In the old code group, 85% of homes had at least one room that exceeded the pressure limit for bedroom with closed doors compared to only 63% in the new code group.

Newer code homes were also inspected for compliance and enforcement. Energy code forms were collected and energy audit data was used to create EnergyGauge USA building files to calculate the audited building e-ratio. All of the homes in this sample had been permitted using the performance methodology even though a prescriptive alternative was available to builders. The performance method requires the permitted home to be built to an e-ratio of 0.85 or less compared to the reference home which has set efficiency levels. Twenty-eight of the 31 audited e-ratios were still at 0.85 or less, indicating a 90% e-ratio compliance rate.

Whole House Laboratory Studies

The FESC provided funding for the design and construction of two highly-reconfigurable, geometrically-identical, side-by-side residential buildings to serve as full-scale energy research facilities at FSEC (Figure D). The U.S. Department of Energy's Building America Partnership for Improved Residential Construction (BA-PIRC) has instrumented these flexible research homes, and will monitor them to conduct research on advanced building energy-efficiency technologies under controlled conditions.

The Flexible Residential Test Facility (FRTF) will provide a controlled research environment for research and evaluation of advanced energy-efficiency technologies and operational strategies as well as a venue to improve simulation programs and algorithms. A detailed experiment plan proposes retrofits to one home performed in a sequential, phased manner while the second home remains constant as a control home. An automated system controls heat and moisture sources in the home to simulate a standard occupancy pattern in both homes.

Figure D. Flexible Residential Test Facility Comprised of two reconfigurable, identical side-by-side homes

Development of this facility under FESC funding made it possible to attract funding from the U.S. Department of Energy to conduct the first experiment, an investigation of winter infiltration effects. After ensuring the labs were operating in unison, air sealing was conducted in both homes to achieve very tight construction (2.0 ACH50). Then, one was made leakier (8.0 ACH50) with 70% of the leakage paths through the attic and 30% through windows. The tighter home (2.0 ACH50) exhibited 15% to 16.5% lower energy use relative to the leaky (8 ACH50) home as well as co-effects related to moisture that could negatively impact indoor air quality, durability and comfort. This continuing experiment will cover summer season effects and the impact of outside air ventilation in the coming months.

Facility and Capability Expansion

FESC support in this area provided for a new data acquisition system for FSEC's onsite environmental test facility and a major field study of Florida energy code effectiveness (described above) as well as diagnostic equipment for field investigations.

FSEC's environmental test facility for residential mechanical systems has served researchers needs for 25 years, providing valuable insight into equipment performance and opportunities for efficiency gains. FESC support upgraded the data acquisition system to enable more thorough investigation. Current testing in this facility includes investigating improved condenser fan design which shows approximately a 3% improvement in system energy efficiency ratio (EER). Additional testing to determine improvements due to an evaporative-cooled condenser is underway and shows an additional savings of 28%. Overall improvement for the high-efficiency 21 SEER system exceeds 30%. A prototype unit is being fabricated for additional field tests over the coming year.

Outreach

In 2010 and 2011 Rob Vieira led stakeholders interested in discussion and idea generation at the annual FESC meeting. These sessions ranged from 10 to 20 people and represented students, faculty, utility representatives and others.

In addition to the seven FSEC authored publications referenced in the document, the PI and other FSEC staff members reviewed, submitted content and edited four public documents written by FESC and available on the FESC Website covering insulation, programmable thermostats, tankless water heaters, and blower door testing.

With FESC support, the state of Florida is competitively obtaining federal research dollars by enhancing capabilities, improving facilities, and conducting initial work that can be leveraged into larger studies. The FESC funding along with the federal funding has allowed for quantifying energy savings from a variety of retrofit strategies a market sector with substantial growth during the current down turn in new construction. Help was provided to local housing authorities so they are now more aware of efficiency programs to implement. Furthermore, the FESC funding will continue to deliver results through facility and equipment upgrades.

This Project is completed. Final Report here.