Cost-Effective, Energy-Efficient Home Improvements for Florida Homes

August 8, 2012

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Florida Solar Energy Center
Research Sponsors

- U.S. Department of Energy, Building America Program (BA)
  - National Renewable Energy Lab (NREL)
  - Pacific Northwest National Lab (PNNL)
Buildings Research

• 30+ Years High Performance Residential Construction
• Building America Research Partners
  – Developers, Builders, Suppliers, Designers, State & National Laboratories, Municipalities, Utilities
• Flexible Residential Test Facility
  – Evaluate systems and house enclosure changes
Special Thanks To...

• Collaborators and Partners
  – Florida Local Government Housing Entities
    • Sarasota County and the City of Sarasota, Volusia County, Brevard County, City of Melbourne, City of Palm Bay, City of Lakeland, Orange County
  – Non-profit Housing providers
    • Florida: Sarasota Housing Trust, Newtown Housing Trust, and Habitat for Humanity Affiliates in Brevard, Lake Sumter, Leesburg, Palm Beach & Sarasota Counties
    • Alabama: Mobile & Birmingham
Research Objectives

• Identify Pathways for Achieving High Performance Renovations to Achieve 30%+ Energy Savings
  – Improve indoor air quality, durability, and comfort
  – Cost effectively
  – Off the shelf technology with existing labor pool

• Identify Gaps and Barriers to Broad Market Adoption
  – Availability of important materials, components & systems
  – Trade knowledge and skill sets
  – Code issues
Retrofit Study Procedure

- Primarily Unoccupied, Foreclosed Homes
- Test-In (Pre-Retrofit) Energy Audit
  - Measurements, observations, house & duct leakage tests
- Technical Assistance
  - Model home to project annual energy cost for various measures
- Test-Out (Post-Retrofit): Repeat Audit & Analysis
- Final Analysis with Cost Data
  - Energy costs savings vs. incremental costs
Study Home Description

• 100+ Homes Initially Analyzed
  – 70 Homes in characterized dataset
• Average Size: 1365 ft² Living Space
  – Range 792 ft² - 2408 ft²
• Average Year Constructed: 1982
  – Range 1957 - 2006
• Typically Single Family, Ranch, Slab-on-Grade, Block Construction
Typical Existing Homes HERS Indices

1960’s ~150
1970’s ~135
1980’s ~125
1990’s ~115
2000’s ~110

**HOME ENERGY RATING CERTIFICATE**

1352 Hartsdale Street
New Port, FL 34287

<table>
<thead>
<tr>
<th>HERS® Index</th>
<th>Pre-Retrofit</th>
</tr>
</thead>
<tbody>
<tr>
<td>More Energy</td>
<td>66</td>
</tr>
<tr>
<td>Less Energy</td>
<td>0</td>
</tr>
</tbody>
</table>

**1960’s HERS Index:** 150
**1970’s HERS Index:** 135
**1980’s HERS Index:** 125
**1990’s HERS Index:** 115
**2000’s HERS Index:** 110

**Annual Estimates:**
- **Electricity (kWh):** Pre - 11,700, Post - 7,477
- **CO₂ Emissions (Tons):** Pre - 6.91, Post - 4.0
- **Savings:** 36%

**Date of Rating:** 04/29/2010
**Rater:** Florida Solar Energy Center
*Based on standard operating conditions*

EnergyGauge
1679 Clearlake Road
Cocoa, FL 32922-5703
321-638-1492
energygauge.com

This Home has been inspected and performance tested in accordance with Chapter 3 of the RESNET Standards.

RESNET®
www.resnet.us
Retrofit Case Study: Sarasota Home
Retrofit Case Study: Sarasota Home

- Concrete block, slab-on-grade
- Built in 1967, 1190 sf, 2 bedroom, 2 bath
### Modeled Annual Energy Cost Profile

**EnergyGauge USA Simulation Results:**

<table>
<thead>
<tr>
<th>End Use</th>
<th>Test-In</th>
<th>Test-Out</th>
<th>Savings ($)</th>
<th>Savings (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cooling</td>
<td></td>
<td>$872</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Heating</td>
<td></td>
<td>$86</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hot Water</td>
<td></td>
<td>$277</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ceiling Fans</td>
<td></td>
<td>$71</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lighting</td>
<td></td>
<td>$183</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Misc. Loads</td>
<td></td>
<td>$203</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Appliances</td>
<td></td>
<td>$293</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Total Annual Energy Cost</strong></td>
<td></td>
<td><strong>$1,985</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>HERS Index</strong></td>
<td>165</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
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Annual Energy Cost from HERS Index Rating Guide
NEW Heating and AC System (HVAC)

- **Pre-retrofit**
  - SEER 8.7, HSPF 6.75 Heat Pump (Qn, out = 0.05 ~5% leakage to outside of home)

- **Post-retrofit**
  - SEER 15, HSPF 8.8 Heat Pump (Qn, out = 0.02 ~2% leakage to outside of home)
Infiltration Reduction

**AHU Closet Sealing**, Return Plenum Sealing, Drywall Repair, New Windows

**Pre-retrofit**
- Living room side of AHU closet
- Sparse ceiling in AHU closet, connected to attic & living room

**Post-retrofit**
- Closet gutted, drywalled; new return plenum & platform constructed
Infiltration Reduction

AHU Closet Sealing, Return Plenum Sealing, Drywall Repair, New Windows

Pre-retrofit

Living room side of AHU closet

Mysterious duct board in return plenum

Post-retrofit

Central return plenum constructed with duct board & sealed with mastic at edges, seams, & joints.
Infiltration Reduction

AHU Closet Sealing, Return Plenum Sealing, **Drywall Repair**, New Windows

Note: Example from alternate house

Plumbing access panel & miscellaneous drywall penetrations were repaired
Infiltration Reduction

AHU Closet Sealing, Return Plenum Sealing, Drywall Repair, **New Windows**

Pre-retrofit

Exceptionally leaky: ACH50 = 42 (Target is ACH50 = 6)

Note angle of window in ‘closed’ position

Post-retrofit

Major infiltration reduction: ACH50 = 8
Windows: SHGC = 0.37; U-Value = 0.47

**ENERGY STAR:**

SHGC ≤ 0.27; U-value ≤ 0.60
Ceiling Insulation

Insulated to R – 30 (R-38 preferred)

Pre-retrofit

Post-retrofit

Note: Image from alternate house
ENERGY STAR® Appliances & CFLs

Pre-retrofit

Post-retrofit
White/Light Exterior

Pre-retrofit

Post-retrofit
## End Use Predicted Savings

### Case Study - Sarasota, FL Simulated Annual Energy Use (Energy Gauge USA)

<table>
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<tr>
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<th>Test-Out</th>
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<th>Savings (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cooling</td>
<td>$872</td>
<td>$228</td>
<td>$644</td>
<td>74%</td>
</tr>
<tr>
<td>Heating</td>
<td>$86</td>
<td>$34</td>
<td>$52</td>
<td>60%</td>
</tr>
<tr>
<td>Hot Water</td>
<td>$277</td>
<td>$256</td>
<td>$21</td>
<td>8%</td>
</tr>
<tr>
<td>Ceiling Fans</td>
<td>$71</td>
<td>$71</td>
<td>$0</td>
<td>0%</td>
</tr>
<tr>
<td>Lighting</td>
<td>$183</td>
<td>$76</td>
<td>$107</td>
<td>58%</td>
</tr>
<tr>
<td>Misc. Loads</td>
<td>$203</td>
<td>$203</td>
<td>$0</td>
<td>0%</td>
</tr>
<tr>
<td>Appliances</td>
<td>$293</td>
<td>$244</td>
<td>$49</td>
<td>17%</td>
</tr>
<tr>
<td><strong>Total Annual Energy Cost</strong></td>
<td><strong>$1,985</strong></td>
<td><strong>$1,112</strong></td>
<td><strong>$873</strong></td>
<td><strong>44%</strong></td>
</tr>
<tr>
<td>HERS Index</td>
<td>165</td>
<td>73</td>
<td>92</td>
<td>56%</td>
</tr>
</tbody>
</table>

- **Total Incremental Cost**: $5,181
- **Monthly Cost (7%, 30 yr. mortgage)**: $35
- **Estimated Monthly Savings Over Minimum**: $60
- **Net Monthly Cash Flow**: $25
- **Net Annual Cash Flow**: $301
Pre- & Post-Retrofit HERS Indices

Pre-Retrofit vs. Post-Retrofit HERS Index

- **HERS In**: Pre-Retrofit HERS Index (n = 70)
- **HERS Out**: Post-Retrofit HERS Index (n = 70)
- **HERS 70**: Builders Challenge Version 1
- **HERS 95**: Similar to Florida new homes early 2000's

Mean Pre-Retrofit HERS Index = 129
Mean Post-Retrofit HERS Index = 83
Pre- & Post-Retrofit HERS Indices

Mean HERS Index Pre- and Post-Renovation by Vintage (n)

163 (2)
150 (15)
132 (14)
125 (22)
112 (9)
107 (8)

Test-In HERS Index, Mean = 129; n = 70
Test-Out HERS Index, Mean = 83; n = 70
Deep Retrofit Savings Measures

- Average Predicted Savings for 70 Homes = 25%
- 30%+ HERS Index Reduction in 46 (66%) Homes (Deep Retrofits)
- Deep Retrofits Accomplished Through 13 Measures
Deep Retrofit Savings Measures

• Average Predicted Savings for 70 Homes = 25%
• 30%+ HERS Index Reduction in 46 (66%) Homes (Deep Retrofits)
• Deep Retrofits Accomplished Through 13 Measures
  – Low full cost
  – Moderate full cost
  – No/Low incremental cost
  – Moderate/High incremental cost

Higher efficiency choices at change-out
Deep Retrofit Savings Measures

• Low *full* cost, low hanging fruit (% of study homes):
  1. House sealing* (92%)
  2. Duct sealing* (86%)
  3. CFLs (52% increased CFL count by 30%+)
  4. Programmable thermostat (48%)

• Moderate *full* cost measures
  5. Insulate ceiling to R-38 (93% insulated to R-30+)

*Heed combustion safety risks
Deep Retrofit Savings Measures

- No/low *incremental* cost:
  
  (Higher efficiency choices at change-out)

  6. ENERGY STAR® appliances (76%)

  7. Higher efficiency water heater (EF ≥ 0.92) (70%)
     – Consider much bigger savings with heat pump water heater

  8. Choose higher insulated (R-6) duct work (39%)

  9. Choose lighter exterior colors when time to reroof (30%)

  10. ...or paint exterior (30%)

  11. ENERGY STAR® fans (15%)
Deep Retrofit Savings Measures

• Moderate to high *incremental* cost measures:
  (Higher efficiency choices at change-out)

  12. ≥15 SEER AC; Heat pump in Central FL (96% replaced ACs, 95% of those SEER ≥ 15)
  13. ENERGY STAR® windows or apply low SHGC film (80%) (SHGC ≤ 0.27; U-value ≤ 0.60)
86% of Deep Retrofits had Positive Cash Flow
- 5 of the 6 only marginally negative (-$7 to -$26/year)
- 1 (-$79/year) expensive electric tankless water heater

| 30% HERS Reduction or more (n = 42): Energy Costs, Savings, Improvement Costs, & Incremental Cash Flow |
|---|---|---|---|---|
| Projected Annual Energy Cost Savings | Projected Annual Energy Cost Savings Over Minimum¹ | Total Improvement Costs | Incremental Improvement Costs | Incremental Annual Cash Flow |
| Min: $277 | $177 | $4,536 | $780 | -$79 |
| Max: $1,338 | $1,021 | $45,326 | $8,382 | $626 |
| Average: $598 | $479 | $16,424 | $3,854 | $169 |

¹ The "Minimum" is a revision to the 'test-in' scenario to include: 1) the federal minimum efficiency standard for air conditioner replacement (SEER 13), if the system was replaced, and 2) test-out house envelope size alterations (with normalized test-in leakage results). Associated improvement costs and energy cost savings for both have been removed from the cash flow calculation.
Retrofit Health, Durability, Comfort Issues: AC Installation

• Small, Poorly Sealed Air Handler Closets & Leaky Air Handlers
  – Pressure issues
  – Dirt build-up
  – Longer operation times

Confined space: Little access for sealing measures

Unsealed plenum areas

Hole from AHU closet to attic

Ceiling insulation sucked through unsealed hole
Retrofit Health, Durability, Comfort Issues: AC Installation

- Over Sized Equipment
  - Shorter operation times
    - Humidity & moisture issues
- 19% of Ducts Leakier Post-Retrofit
- High Pressures Differences Between Rooms
  - Combustion safety issues
  - Moisture issues (Mold)
  - Durability issues

Negative pressure caused flame roll-out
Retrofit Health, Durability, Comfort Issues: Ceiling Insulation

- Partially or Fully Buried Ducts
  - Possible moisture condensation on outer surface
- Ceiling Insulation Restricting Attic Air Flow, Potential:
  - Temperature issues
  - Moisture issues

- Insulation blown to bottom of trusses w/o baffles
- Ducts not strapped to trusses, buried in insulation
Retrofit Health, Durability, Comfort Issues: Air Infiltration

• Missed House Sealing Measures:
  – Behind newly installed cabinetry
  – Surrounding can light fixtures
  – Kitchen exhaust fan chase
  – Plumbing penetrations
  – Attic hatches
  – Switches and outlets

➢ Impacts house temperature and humidity
➢ Increases demand on heating and AC
Identified Gaps and Barriers

• Inconsistent Code Perspectives
  – Partners specify “All HVAC work shall be done in compliance with prevailing codes.”
  – Limited applicable code for HVAC for existing homes (Florida Residential Energy Code, March 2012):
    • Proper equipment sizing (Manual J)
    • Seal accessible ducts
Identified Gaps and Barriers

• Inconsistent Code Perspectives
  – Partners specify “All HVAC work shall be done in compliance with prevailing codes.”
  – Limited applicable code for HVAC for existing homes (Florida Residential Energy Code, March 2012):
    • Proper equipment sizing (Manual J)
    • Seal accessible ducts
  – Code does not address... for existing homes:
    • Unsealed air handler closet
    • Disconnected ducts
    • Building cavities as ducts
    • Ducts unstrapped to trusses
    • House pressure imbalances
Identified Gaps and Barriers

• Physical Limitations of Mechanical Closets
• Gap in contracting paradigm
  – Lack of responsibility for whole house performance
    • Who ensures all house sealing measures are addressed?
    • Who ensures proper attic ventilation?
  – Various trades overlapping influences on whole house performance (staging concerns):
    • HVAC contractor leaves AHU closet gap. Drywall contractor?
    • Electrical and plumbing contractors access ceiling and wall assemblies, duct work vulnerable to damage
    • Finish carpenter covers drywall gaps hiding gaps from drywall contractor
Identified Gaps and Barriers

• Identification of critical QA tasks
  – Spell out specifications for HVAC installation (not relying on “prevailing code” – not applicable)
  – Mechanical contractors to identify and seal all joints and seams to reduce duct leakage
  – Test to ensure leakage levels below threshold
  – Test to ensure pressure differences below threshold
  – Identify responsibility for:
    • Ensuring house sealing, attic ventilation, overlapping influence on home performance among trades
Partner’s Responses

• Partner Developed Energy Conservation Standards
  – Provides minimums for existing conditions (maintenance) and replacements
  – Incorporates 3rd Party role in ensuring quality
    • Duct testing to assure leakage below set threshold
  – Achieves a bulk of the 30%+ reduction
What’s Next?

• Community Scale “Best Practices” Retrofit Study
  – Applying Lessons Learned from 100+ houses
  – Standard set of specifications for replacement and maintenance
  – Apply across a whole community
  – Document problematic aspects of specifications
  – Develop and test solutions
Contact & Resources

Karen Sutherland
321-638-1474  ksutherland@fsec.ucf.edu

Janet McIlvaine
321-638-1434  janet@fsec.ucf.edu

Building America Partnership for Improved Residential Construction (BA-PIRC): http://www.ba-pirc.org/

Florida Solar Energy Center: http://www.fsec.ucf.edu/

USDOE Building America: www.buildingamerica.gov

Certified Building Energy Rater Search: https://securedb.fsec.ucf.edu/engauge/engauge_search_rater