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

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FSEC *A Research Institute of the University of Central Florida*

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

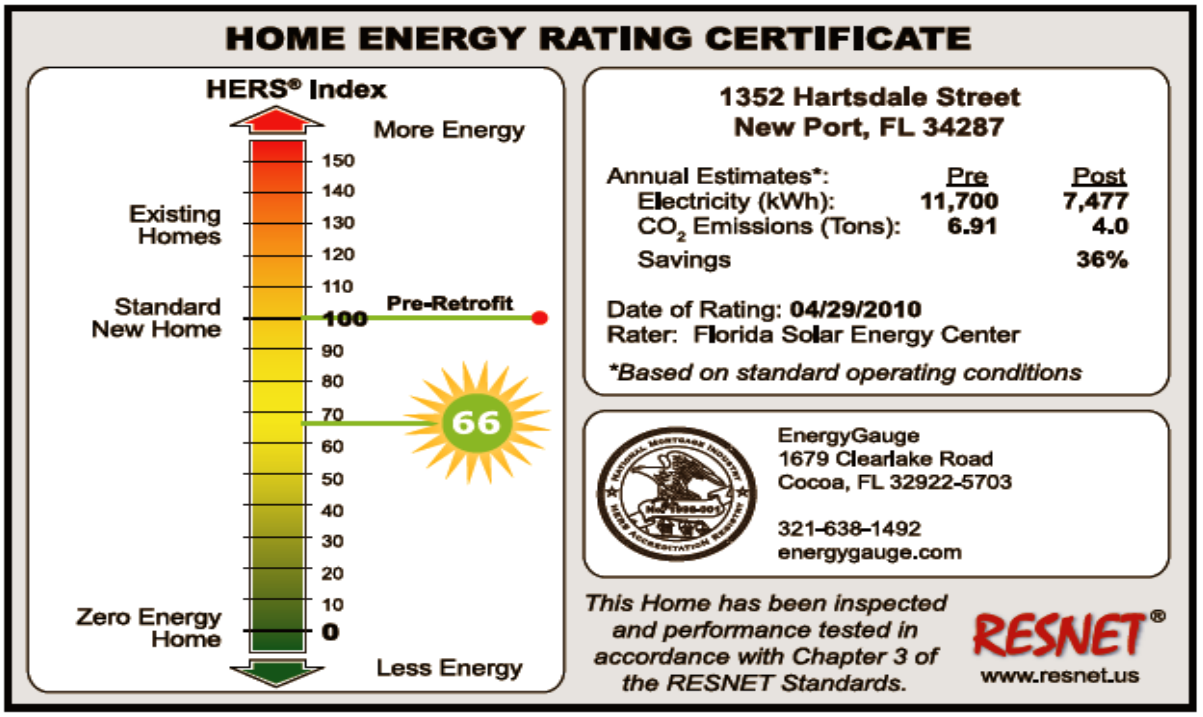
Retrofit Study Procedure

- 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 ft^2 Living Space
  - Range 792 ft^2 - 2408 ft^2
- Average Year Constructed: 1982
  - Range 1957 - 2006
- Typically Single Family, Ranch, Slab-on-Grade, Block Construction

Typical Existing Homes HERS Indicies



Retrofit Case Study: Sarasota Home

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- Concrete block, slab-on-grade
- Built in 1967, 1190 sf, 2 bedroom, 2 bath

Modeled Annual Energy Cost Profile

- EnergyGauge USA Simulation Results:

Annual Energy Use Profile by End Use				
End Use	Test-In	Test-Out	Savings ($)	Savings (%)
Cooling	$872			
Heating	$86			
Hot Water	$277			
Ceiling Fans	$71			
Lighting	$183			
Misc. Loads	$203			
Appliances	$293			
Total Annual Energy Cost	$1,985			
HERS Index	165			

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

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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

Plumbing access panel & miscellaneous drywall penetrations were repaired

Note: Example from alternate house

Infiltration Reduction

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

Pre-retrofit

Note angle of window in 'closed' position

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

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Post-retrofit

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

ENERGY STAR:
SHGC ≤ 0.27; U-value ≤ 0.60

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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

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White/Light Exterior

Pre-retrofit

Post-retrofit

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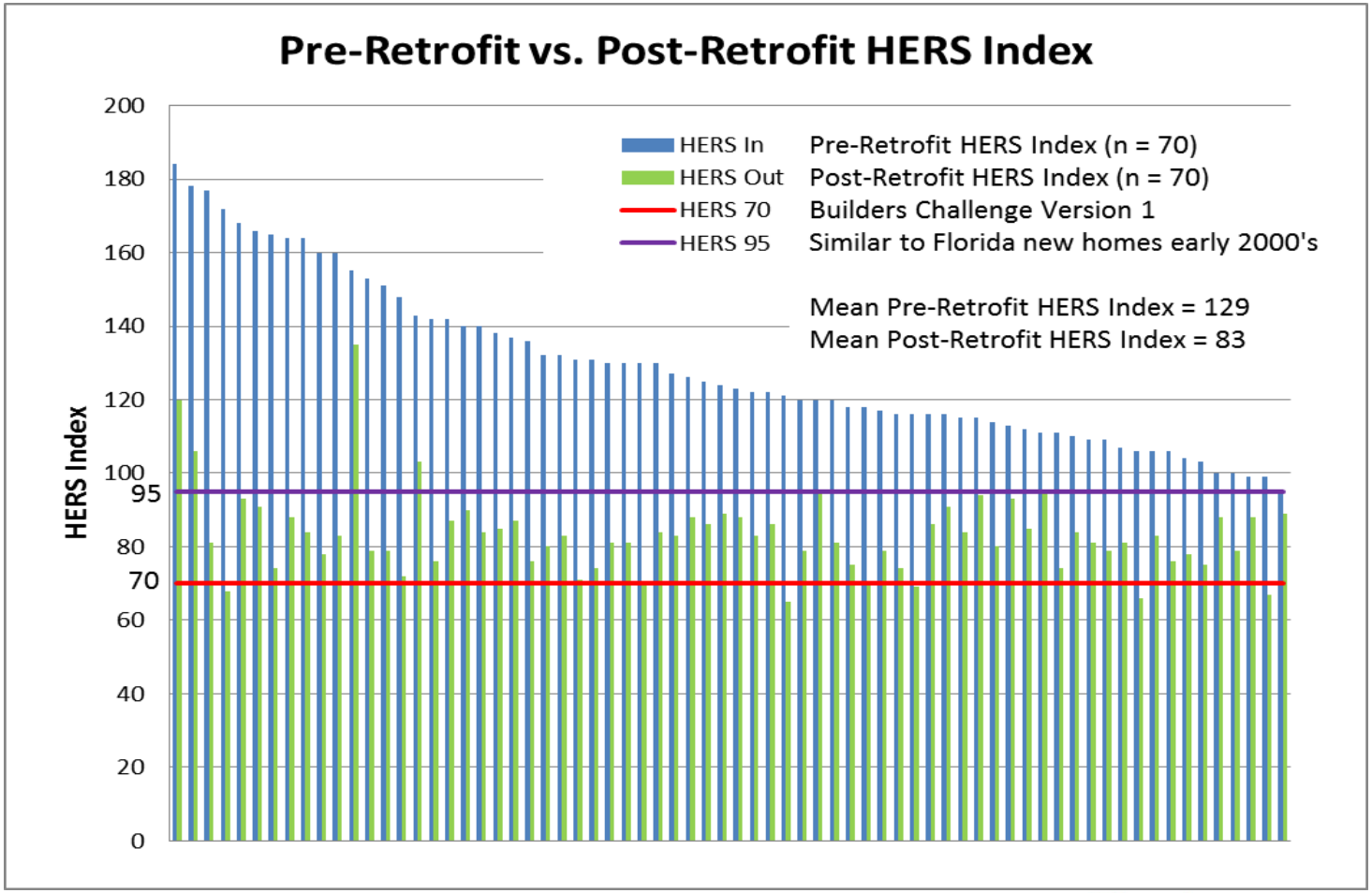
End Use Predicted Savings

Case Study - Sarasota, FL Simulated Annual Energy Use (Energy Gauge USA)				
End Use	**Test-In**	**Test-Out**	**Savings ($)**	**Savings (%)**
Cooling	$872	$228	$644	74%
Heating	$86	$34	$52	60%
Hot Water	$277	$256	$21	8%
Ceiling Fans	$71	$71	$0	0%
Lighting	$183	$76	$107	58%
Misc. Loads	$203	$203	$0	0%
Appliances	$293	$244	$49	17%
Total Annual Energy Cost	**$1,985**	**$1,112**	**$873**	**44%**
HERS Index	**165**	**73**	**92**	**56%**

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



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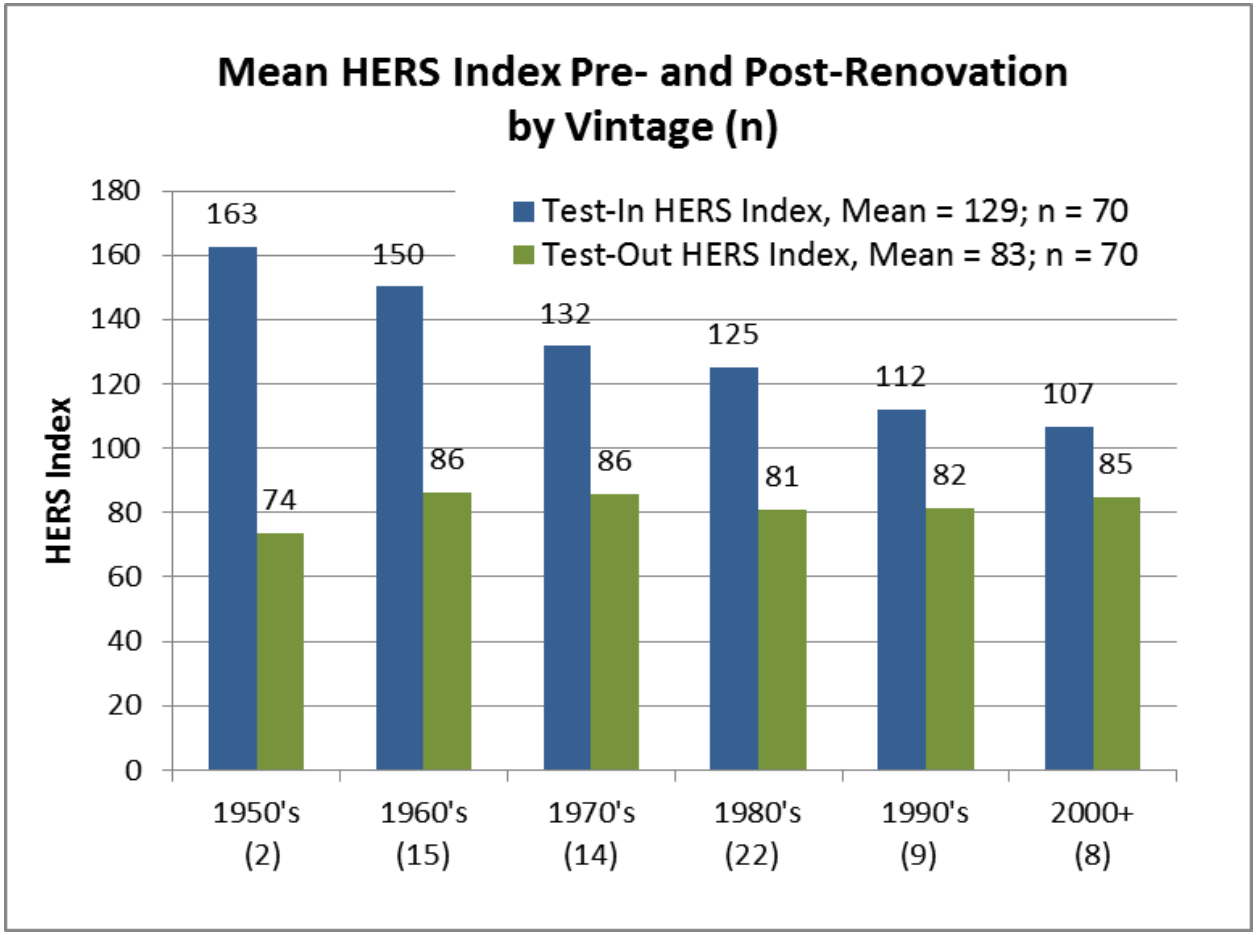

Deep Retrofit Savings Measures

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

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- 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)

Deep Retrofit Cost & Cash Flow

- 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 Minimum[1]	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

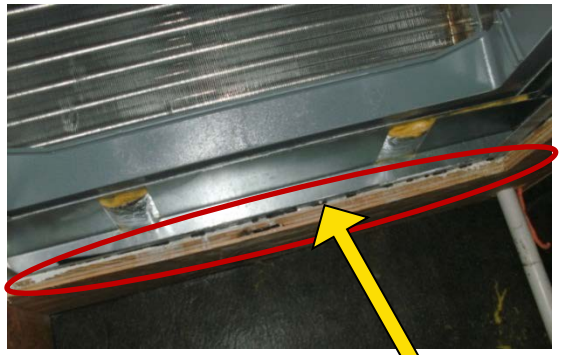
[1]The "Minimum" is a revision to the 'test-in' scenario to include: 1) the federal minimum efficiency standard for air conditioner replacement (SEER 13), if the system was replaced, and 2) test-out house envelope size alterations (with normalized test-in leakage results). Associated improvement costs 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

Hole from AHU closet to attic



Unsealed plenum areas

Ceiling insulation sucked through unsealed hole

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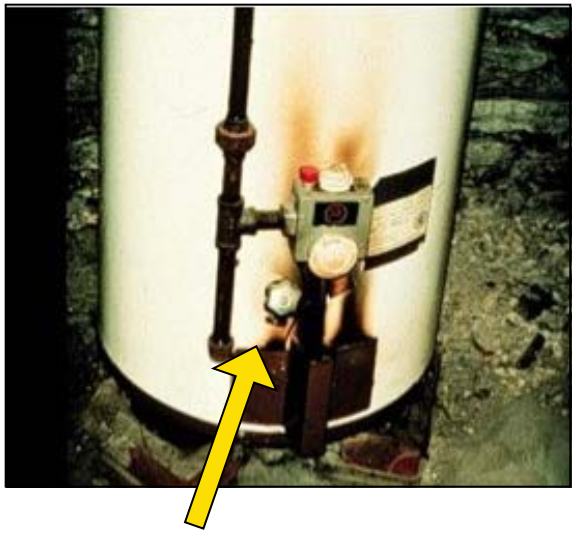
Retrofit Health, Durability, Comfort Issues: AC Installation

- 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

Ducts not strapped to trusses, buried in insulation

Insulation blown to bottom of trusses w/o baffels

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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

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  - 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

Unsealed wall cavity used as a supply duct

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

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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