



FLORIDA SOLAR ENERGY CENTER®

Creating Energy Independence

Current Best Practices for High Performance, Deep Energy Retrofits in Florida Affordable Housing

FSEC-RR-444-13

September 2013

Version 2

Authors

**Janet McIlvaine
Karen Sutherland
David Beal**

Florida Solar Energy Center

1679 Clearlake Road
Cocoa, Florida 32922, USA
(321) 638-1000

www.floridaenergycenter.org



A Research Institute of the University of Central Florida

Disclaimer

The Florida Solar Energy Center/University of Central Florida nor any agency thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the Florida Solar Energy Center/University of Central Florida or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the Florida Solar Energy Center/University of Central Florida or any agency thereof.



Current Best Practices for High Performance, Deep Energy Retrofits in Florida Affordable Housing

Prepared by:

J. McIlvaine, K. Sutherland, and D. Beal

Florida Solar Energy Center

1679 Clearlake Rd

Cocoa, Florida, 32922

September 2013

[This page left blank]

Contents

- Definitions i**
- Acknowledgements..... ii**
- 1.0 Overview..... 1**
- 2.0 Critical Cautions 2**
- 3.0 Current Best Practice Recommendations 2**
 - 3.1 Heating, Ventilation, Cooling, and Air Conditioning (HVAC) Distribution Systems 2**
 - 3.1.1 Existing HVAC Equipment Not Being Replaced..... 2
 - 3.1.2 Full or Partial HVAC System Replacement 2
 - 3.1.3 All Homes Regardless of HVAC System Replacement 3
 - 3.2 Whole-House Airtightness 4**
 - 3.3 Roof Finish and Replacement..... 4**
 - 3.4 Attic Insulation 4**
 - 3.4.1 Vented Attics 4
 - 3.4.2 Attic Knee Walls..... 5
 - 3.4.3 Unvented Attics 5
 - 3.5 Windows 5**
 - 3.5.1 Window Replacement..... 5
 - 3.5.2 All Homes Regardless of Window Replacement..... 5
 - 3.6 Exterior Walls..... 5**
 - 3.7 Floors 6**
 - 3.8 Water Heating..... 6**
 - 3.8.1 Water Heater Replacement 6
 - 3.8.2 All Homes Regardless of Water Heater Replacement..... 6
 - 3.9 Appliances, Lighting, and Fans – All Homes..... 6**
 - 3.10 Site..... 6**
 - 3.11 Combustion Safety 7**
 - 3.11.1 Combustion Appliance Replacement..... 7
 - 3.11.2 All Homes With Combustion Appliances Regardless of Replacement..... 7
- 4.0 Certified Home Energy Rater Minimum Scope of Activity – All Homes 8**
 - 4.1 Duct Testing..... 8**
 - 4.2 Whole-House Testing..... 8**
- 5.0 Best Practices Review and FSEC Partnership: 10**
- Appendix - General Guidance on Passive, Run-time, Outside Air Ventilation System 11**
- Major Elements..... 11**

Intake Register	11
Duct (details may vary among air handler configurations)	12
Filtration.....	12
Outside Air Dampers and Controls.....	12
Example Outside Air Flow Rate Calculation:	13

Definitions

ACCA Manual D	Air Conditioning Contractors of America's procedure for determining room by room mechanical system duct size
ACCA Manual J	Air Conditioning Contractors of America's procedure for determining mechanical system size
ACH50	Air changes per hour measured at a test pressure of negative 50 pascals with respect to the outside, divided by the building volume
AHU	Air Handler Unit
ASHRAE	American Society of Heating, Refrigerating, and Air Conditioning Engineers
BPI	Building Performance Institute, Inc.
CFL	Compact fluorescent lamp (light bulb)
CO	Carbon monoxide
CFM	Cubic feet of air per minute
EF	Energy factor
FSEC	Florida Solar Energy Center
HERS	Home Energy Rating System
HVAC	Heating, ventilation, and air conditioning
ICAT	Recessed lighting units rated for insulation contact and airtightness
Knee Walls	Vertical attic surfaces. Shafts for skylights, for instance.
NFRC	National Fenestration Rating Council
Qn,out	Duct leakage measured at a test pressure of negative 25 pascals with respect to the outside, divided by the building's conditioned floor area
R-value	Value denoting thermal resistance
RESNET Grade I	Residential Energy Services Network's highest insulation installation standard (Nearly devoid of gaps; compression or incomplete fill < 30% of intended thickness to < 2% of area)
SEER	Seasonal energy efficiency ratio
SHGC	Solar heat gain coefficient
U-value	Value denoting thermal conductance

Acknowledgements

The research leading to the development of this guide was funded in part by the Florida Energy Systems Consortium (2009) and subsequently sponsored by DOE, Office of Energy Efficiency and Renewable Energy, Building America Program (www.buildingamerica.gov) under cooperative agreement number DE-FC26-06NT42767 (2010) and Subcontract No. KNDJ-0-40339-00 (2011-12).

The support and encouragement of past DOE program managers, George James, Terry Logee, Ed Pollock, and William Haslebacher, as well as current DOE program managers, Stacey Rothgeb, Ren Anderson, Eric Werling, Sam Rashkin, and David Lee, is gratefully acknowledged. This support does not constitute DOE endorsement of the views expressed in this paper. We thank Eric Martin, project director of BA-PIRC at FSEC, for his direction and support.

The best practices are a reflection of choices made by research partners. We are grateful for their participation in the study and allowing us access to their renovation projects. These include leadership and staff at the Sarasota Office of Housing and Community Development; the Florida House Foundation; Community Housing Trust of Sarasota County, Inc.; Newtown Community Redevelopment Corporation; Habitat for Humanity of Sarasota, Inc.; Goodwill Industries, Manasota; Brevard County Housing and Human Services Department; Volusia County Community Assistance; Florida H.E.R.O.; Alachua County Housing Programs; Orange County Housing & Community Development; City of Palm Bay; Habitat for Humanity, South Sarasota County, Inc.; and CalcsPlus.

We are especially grateful to the City of Ft. Myers and the City of Melbourne, whose early adoption of the best practices in this document led to technical improvements in comprehensiveness, flow, and utility.

We also express great appreciation to Danielle Daniel for excellent editorial assistance.

1.0 Overview

In the fall of 2009, researchers at the Florida Solar Energy Center (FSEC) began a field study with affordable housing entities that were conducting major renovation projects in unoccupied, foreclosed homes. The study was initially funded by the Florida Energy Systems Consortium, subsequently funded by the U.S. Department of Energy's Building America program (www.buildingamerica.gov), and conducted by researchers of the Building America Partnership for Improved Residential Construction led by FSEC.

The study was comprised of 70 homes. When partners were replacing components and equipment because they were worn out, researchers provided savings projections for higher-efficiency choices. Additionally savings were projected for improvements that were strictly for energy efficiency, such as adding ceiling insulation. Improvement was gauged using the Home Energy Rating System (HERS) Index and projected annual energy use. Average whole house improvement was 34% in HERS Index score and 25% in projected annual energy use savings.

The contents of this document are a refinement of the best practices presented in the original field study report ("Energy Retrofit Field Study and Best Practices"¹) and a direct excerpt from an follow-on implementation study (Applying Best Practices to Florida Local Government Retrofit Programs"²). Report and periodic updates based on user feedback will be posted on the BA-PIRC website publications page (<http://www.ba-pirc.org/pubs/index.htm>).

In the field study, project managers had the ultimate decision over what retrofit options to implement in each home. Researchers tracked the choices and culled the best practices from a sub-set of 46 homes that achieved a 30% improvement in efficiency. The homes with 30% improvement all included "deep" retrofit measures that involved major system and/or component replacements. They also included "shallow" retrofit measures that contribute to but have a smaller impact on overall savings.

The best practices summarized in this document are a mixture of assessment, design, specification, quality assurance, and verification measures. They represent *either* the most commonly adopted practice observed in this field work or, in some cases, the highest performance practice that did not involve additional cost. For example, although "medium" was the most commonly chosen exterior paint color, "white" is the highest performing color and herein the recommended practice. Additional building science measures from the *ENERGY STAR for Homes* program and Department of Energy's *Challenge Home* programs have been included in the best practices to address occupant health, safety, building durability, and comfort concerns.

The checklist is organized by building component or equipment type. Best practices applicable to "All Homes" are distinguished from those applicable only at the time of "Replacement". For example, ceiling insulation levels are applicable to all homes; however, some mechanical system efficiency practices are only applicable at the time of equipment replacement. Predictions show that it is cost-effective to choose higher-efficiency mechanical equipment at the time of replacement, but not to replace functioning equipment strictly for the efficiency gain. The projected annual energy use for practices recommended

¹ For further details see, "Energy Retrofit Field Study and Best Practices" (McIlvaine, Sutherland, Martin) <http://www.fsec.ucf.edu/en/publications/pdf/FSEC-RR-404-13.pdf>.

² Report currently in peer review as of September 2013. The final report will be available on the BA-PIRC website publications page www.bapirc.org/pubs.

for “All Homes” justifies the full expense of the measure (or has been included for occupant health, safety, building durability, and comfort). Those components or equipment recommended for “Replacements” justify only the *incremental* cost for higher-performance choices, not the total cost for replacing a functioning system with useful life.

As with all recommendations, common sense must prevail. The projected savings may not justify costs that exceed customary and reasonable bounds. For example, space constraints may increase labor and material costs. We highly recommend working with a home energy rater or other qualified consultant to evaluate the cost and benefit of specific measures in the context of a specific home or set of similar homes. However, in the absence of such individualized evaluation, these best practices may aid the decision-making process.

2.0 Critical Cautions

- For all homes with existing or planned atmospheric combustion furnaces or water heaters, refer to the Combustion Safety section (3.11) at the end of this checklist for cautions to be observed throughout the renovation process.**
- Do not implement measures that conflict with code or manufacturer instructions.
- Normal print indicates required measures for participation with the Building America Partnership for Improved Residential Construction (BA-PIRC), a U.S. Department of Energy Building team led by FSEC. Additional recommendations are in italics.
- Be advised that the required items affecting air, heat, or moisture flow should be implemented collectively to prevent safety, durability, and comfort issues.
- These recommendations are not a substitute for evaluation of individual homes. We highly recommend working with building science professionals with certifications in home energy rating and combustion safety (e.g. a certified HERS rater or a Building Performance Institute (BPI) certified professional.)

3.0 Current Best Practice Recommendations

3.1 Heating, Ventilation, Cooling, and Air Conditioning (HVAC) Distribution Systems

Caution: Reference the Combustion Safety section (3.11) if a gas furnace exists or is planned.

3.1.1 Existing HVAC Equipment Not Being Replaced

- Hire a heating, ventilation, and air conditioning (HVAC) contractor to evaluate, and service if needed, refrigerant charge, inside and outside coil condition, condensate drain lines, and gas furnace components including exhaust flues, combustion air supply, gas lines, and other major equipment components.
- Implement all items in “All Homes Regardless of System Replacement” below.

3.1.2 Full or Partial HVAC System Replacement

- Install, at minimum, an ENERGY STAR heat pump (seasonal energy efficiency ratio (SEER) 14.5 or greater). In south Florida, an ENERGY STAR air conditioner is acceptable.
- Equipment Sizing: Perform ACCA Manual J calculations (now required for replacements by the Florida Energy Code). Use projected home characteristics provided by house supervisor.

- Supply and Return Ducts: Seal accessible (30" clearance) ducts left in place with code-approved sealant (required at equipment change out by Florida Energy Code), including the return plenum air barrier (drywall, duct board, etc). Provide air barrier if not present.
- Air Handler (AHU) Closet at AHU Replacement: Modify AHU closets to create a dedicated, sealed return plenum with a correctly-sized wall or ceiling-mounted return air grille.
- Duct Replacement: Install new ducts with R-value ≥ 6 .
- Implement all items in "All Homes Regardless of System Replacement" below.
- AHU Location: When equipment and ducts are replaced, relocate AHU into conditioned space.*
- Perform ACCA Manual S equipment selection.*
- Perform ACCA Manual D duct sizing.*
- Produce a schematic duct design for field crew showing sizes for each component and conduct rough-in inspection to ensure installation meets design intent.*

3.1.3 All Homes Regardless of HVAC System Replacement

- Duct Sealing: Hire an HVAC contractor to seal all duct connections with UL181-rated materials, preferably fiberglass mesh embedded mastic, including joints and edges in supply and return runs, return plenum, and connections to AHU. Important note: Contractor will revisit site to conduct additional sealing for all duct systems (new and existing) that do not pass the post-renovation leakage test. Maximum acceptable test result is six cubic feet of air per minute (cfm) per 100 square feet of conditioned area at the test pressure of 25 pascals ($Q_{n,out} \leq 0.06$).
- Duct Airtightness Testing: Have a certified home energy rater conduct a duct airtightness test as outlined in the Duct Testing section (4.1).
- AHU Closet: Eliminate louvered doors that serve as returns. Eliminate metal AHU stands. Where the return plenum is formed by open framing and a plywood platform, install and seal an air barrier (drywall or duct board) to separate return from adjacent wall cavities. Provide partial door above return (or solid door on side wall) for AHU access. If necessary, extend platform to form door sill.
- Flex Ducts: Ensure flex duct insulation covers all collar and boot connections. Flex duct runs should not be kinked or have sharp bends, and they should have as little contact as possible with ceiling insulation. Strap flex ducts to trusses, 5' or less spacing, to achieve clearance over anticipated ceiling insulation. Ideally, locate ducts midway between roof deck and insulation.
- Outside Air Ventilation: Given pre-retrofit whole house airtightness test results with estimated natural infiltration ≤ 0.35 , seek technical support from home energy rater or other qualified consultant regarding possibility of mechanical ventilation system including need, space availability, and physical challenges. General guidance on a passive, run-time, outside air ventilation system is included in Appendix A.
- Filter: Do not obstruct under-AHU filter cavity, if present. Install MERV 6 filter.
- Ensure operational bathroom and kitchen exhaust fans ducted to outside. (Upon completion, ensure ceiling is insulated.)
- Vent clothes dryer to outside (not crawl spaces or attics).

- Bedroom Return Air: In homes with only one centrally-located return, hire an HVAC contractor to install passive return air pathways sized per guidelines in Florida Mechanical Code Section 601.4.*
- Install a bath fan timer.*

3.2 Whole-House Airtightness

- Ensure whole-house air leakage of 6 or less air changes per hour at the test pressure of 50 pascals ($ACH_{50} \leq 6.0$), similar to new construction in Florida.*
- Whole-House Airtightness Testing: Have a certified home energy rater conduct a whole-house tightness test as outlined in the Whole-House Testing section (4.2).*
- Seal with code-approved sealant the following common air infiltration points:*
 - *Windows*
 - *Doors – replace weather-stripping if missing or degraded*
 - *Lighting fixtures and ceiling fans (drywall gap behind cover/trim)*
 - *Kitchen exhaust fan chase (at ceiling)*
 - *Switches and outlets – if replacing covers, seal boxes to drywall*
 - *Plumbing penetrations through interior and exterior walls (e.g. under sinks)*
 - *Plumbing access panels – secure tightly and/or weather-strip*
 - *Attic hatch or stair – weather-strip*
 - *Interior AHU closet – seal all edges and seams of walls, ceiling, and ducts*
 - *Soffits over cabinets or housing lighting – add air barrier above*
 - *Holes in drywall*
 - *Frame floor penetrations for plumbing and electrical*

3.3 Roof Finish and Replacement

- If asphalt shingle, choose light or white-colored finish, Solar Reflectance ≥ 0.25 .*
- Ensure proper installation of roof flashing.*
- Install roof drip edge.*
- If replacing roof decking, install radiant-barrier roof decking. Reference roofing manufacturer specifications to assure no void in warranty.*

3.4 Attic Insulation

Caution: Complete mechanical, electrical, and plumbing rough-in prior to ceiling insulation.

3.4.1 Vented Attics

- Add insulation to achieve RESNET Grade I R-38 throughout.*
- Prior to adding ceiling insulation, box-in or eliminate all recessed lighting fixtures not rated air tight and approved for insulation contact (ICAT).*
- Strap flex duct above ceiling insulation. See description in section 3.1.3 above.*
- Insulate interior attic hatches and stairs with rigid foam or batt insulation to R-19 and weather-strip edge.*
- Where attics extend over porches, provide air barrier (house wrap, blue board, etc.) to prevent ceiling insulation spillage onto porch ceiling.*
- Where floor cavities abut attic space, provide air barrier to keep attic air out of floor cavity.*
- Install ventilation baffles at eaves.*

3.4.2 Attic Knee Walls

- Insulate knee walls to RESNET Grade I R-13 or greater. Ensure a durable installation that will hold insulation in contact with drywall.

3.4.3 Unvented Attics

- Consult an energy rater regarding existing or planned unvented attics. Careful detailing and quality control are required to prevent uncontrolled heat, air, and moisture flow.

3.5 Windows

3.5.1 Window Replacement

- Install, at minimum, ENERGY STAR-labeled windows (U-value ≤ 0.6 or lower and solar heat gain coefficient (SHGC) ≤ 0.27 or lower).
- Retain National Fenestration Rating Council (NFRC) label to provide project manager proof of window performance specification, including SHGC and U-value.
- Ensure proper window flashing installation.
- If installing house wrap, follow manufacturer instructions for cutting and wrapping at window openings.
- Check for and replace any rotted materials around window (e.g. studs, sheathing).
- Air seal between window frame and rough opening with a sealant designed for windows.

3.5.2 All Homes Regardless of Window Replacement

- Replace rotted materials around window (e.g. rough opening, sheathing).
- Replace missing head flashing at wood siding.
- Caulk edges of window frame/trim on both interior and exterior.*
- For existing clear windows not being replaced, apply window tint to achieve combined (glass + tint) SHGC ≤ 0.5 and preferably visible transmittance ≥ 0.5 . Note: Mock up tinting (e.g. tape in place) to assess aesthetics. For windows with active warranties, check with manufacturer before installing.*

3.6 Exterior Walls

- Eliminate vinyl wall paper.
- If painting, use light or white color.
- If replacing drywall in frame construction, install RESNET Grade I R-13 insulation
- If replacing drywall in block construction, install a continuous layer of rigid insulation followed by furring strips for drywall attachment.
- If replacing siding, check for and replace rotted materials, install and integrate continuous drainage plane with window and door flashing, and if concrete masonry unit, assure weep holes at bottom of siding.*

- If replacing drywall or siding, implement applicable criteria on the Thermal Enclosure System and Water Management System checklists of the Energy Star for New Homes version 3 Standard. http://www.energystar.gov/index.cfm?c=bldrs_lenders_raters.nh_v3_guidelines*

3.7 Floors

- If crawl space, repair or install 6 mil polyethylene ground cover, lapping joints 6", and continuing up stem wall and supports 2'. Add sump pump if potential for flooding.

3.8 Water Heating

Caution: Reference the Combustion Safety section (3.11) if a gas water heater exists or is planned.

3.8.1 Water Heater Replacement

- Discuss the following options and implications with home energy rater:*
 - *Solar: solar access, cost and maintenance implications of different systems, and local incentives.*
 - *Gas: direct-vent or tankless unit (energy factor (EF) ≥ 0.8 , may require exterior wall).*
 - *Electric: integrated heat pump water heater (COP ≥ 2.0 , space constraints) or standard tank-type unit, EF ≥ 0.92 .*

3.8.2 All Homes Regardless of Water Heater Replacement

- Insulate accessible hot water pipes.
- Wrap tank with R-5 blanket (for gas units, read instructions carefully).*

3.9 Appliances, Lighting, and Fans – All Homes

- Install ENERGY STAR-rated refrigerator upon replacement.
- Clean refrigerator coils, if not replacing.
- Install screw-in or pin-based compact fluorescent lamps (CFL).
- Install electronic ballast with T8 lamps upon replacement or repair in fluorescent tube fixtures.
- Eliminate all recessed fixtures not rated air tight and approved for insulation contact (often labeled "ICAT").
- Select ENERGY STAR-rated ceiling fans upon replacement.
- Install air barrier above soffit-mounted light fixtures to separate soffit from attic or floor cavity.*

3.10 Site

- Remove moisture loading at walls and foundation (e.g. irrigation system, roof runoff, soil contact).
- Add pool cover to all pools.
- Plant drought-tolerant shade trees near east and west-facing windows (Deciduous trees in North Florida).*

3.11 Combustion Safety

3.11.1 Combustion Appliance Replacement

No new atmospheric combustion furnaces or water heaters should be installed inside the conditioned space. Replacement gas furnaces should be high-efficiency, sealed combustion units. Replacement gas water heaters should be direct-vent (tank type or tankless). These options are not likely to be cost-effective; however, health and safety considerations are the first priority. Work with a home energy rater to conduct an evaluation of projected savings for these options. Consult the U.S. Department of Energy's Technology Fact Sheet "COMBUSTION EQUIPMENT SAFETY" for additional information on combustion safety³.

3.11.2 All Homes With Combustion Appliances Regardless of Replacement

Renovations can significantly alter combustion air-flow dynamics, potentially creating unsafe, life threatening situations that did not previously exist. Extreme caution is needed to ensure occupant and worker health and safety as well as building durability in any home with an atmospheric combustion furnace and/or water heater, even if it is not located inside the conditioned space. If combustion appliances exist and are being replaced with non-combustion appliances, disable appliances and remove from premises prior to retrofit, otherwise:

- Pre-retrofit: In addition to defining equipment specifications and installation details for combustion air supply and exhaust components, work with a BPI-certified home professional, or other qualified professionals such as a certified HERS rater with additional combustion safety training, to evaluate and devise a combustion safety plan to prevent accidentally back drafting exhaust fumes into the conditioned space before, during, and after renovation. Tests should be conducted to assess air pressure conditions in the combustion air zone where the furnace and/or water heater are located and air pressure differences between the combustion air zone and the occupied areas of the home. Conducting testing prior to renovation will help identify existing air flow and pressure dynamics.
- During retrofit: Disable combustion furnaces and water heaters unless a plan has been executed specifically to ensure combustion safety. Unpredictable activity during construction could inadvertently create dangerous conditions.
- Post-retrofit, prior to occupancy: Arrange for post-renovation testing to verify that no air pressure conditions have been created that jeopardize either combustion air supply or exhaust or that would result in combustion exhaust gases entering the conditioned space.
- Install carbon monoxide (CO) detectors and post an action plan near all combustion appliances and all bedrooms for occupants in the event of alarm.

³ http://apps1.eere.energy.gov/buildings/publications/pdfs/building_america/26464.pdf

4.0 Certified Home Energy Rater Minimum Scope of Activity – All Homes

Conduct all activity in accordance with RESNET standard, including taking all due combustion safety precautions prior to, during, and after testing.

4.1 Duct Testing

- Pre-retrofit (recommended only if AHU and duct system is not being replaced): Conduct standard RESNET duct airtightness assessment. If leakage to outside exceeds target of 6% ($Q_{n,out} \geq 0.06$), assess the following common leakage points, and where leakage exists, advise house supervisor of corrective action (→):*
 - *AHU closet → install drywall finish on all walls and ceiling, if not present. Seal all edges and seams.*
 - *Central ducted return → seal return grille connection to framing; return plenum (e.g. duct board) connection to framing and connection to AHU.*
 - *Open platform → seal all edges and seams.*
 - *Registers → if supply registers are being removed (e.g. for painting), seal between drywall and boot.*
 - *Joints → seal any loose connections, and ensure flex duct insulation fully covers collars.*
- Post-retrofit: Conduct/repeat duct testing to ensure target of 6% ($Q_{n,out} \geq 0.06$) is met. If not, assess leakage points and advise house supervisor of recommended action.*

4.2 Whole-House Testing

- Pre-retrofit: Conduct standard RESNET whole-house airtightness assessment. If test results exceed target of 6 or less air changes per hour at the test pressure of 50 pascals ($ACH_{50} \leq 6.0$), identify major leakage points (reference the Whole-House Airtightness section (3.2) for common leakage areas), and communicate prioritized list of sealing points to house supervisor.*
- Post-retrofit: Repeat whole-house testing to ensure target is met. If not, assess leakage points and advise house supervisor of recommended action.*

Table 1. Example Project Manager Verification Checklist for Heating, Cooling, and Air Distribution Systems

<p>PRE-RETROFIT:</p> <ul style="list-style-type: none"><input type="checkbox"/> Bid documents:<ul style="list-style-type: none">○ Include all applicable HVAC requirements from master specifications in the bid documents.○ Alert general and HVAC contractors to duct testing requirements.○ Provide list of common duct leakage points.○ Include “retest at contractor’s expense if target is not met” in scope of work.○ If passive outside air ventilation is being installed, provide general and HVAC contractors ‘General Guidance on Passive, Runtime, Outside Air Ventilation System’(see Appendix). <p>POST-RETROFIT:</p> <ul style="list-style-type: none"><input type="checkbox"/> Acquire documentation for Manual J calculation (required for permit at replacement in Florida). Verify system is within 125% of Manual J calculation. If not, request explanation and justification. Keep with house records, for reference, in the event of discomfort complaints.<input type="checkbox"/> Visually inspect the duct system and verify:<ul style="list-style-type: none">○ Duct R-value ≥ 6 for new ducts.○ Flex duct insulation fully covers collars and boot at connection insulated.○ Ductwork strapped to trusses above insulation.○ Recall contractor to attend to deficiencies.<input type="checkbox"/> Work with home energy rater to determine if duct airtightness targets have been met. Target test result is leakage to the outside ≤ 6 cfm per 100 square feet of conditioned space ($Q_{n,out} \leq 0.06$). If target is not met, visually inspect the following duct details, and recall contractor to attend to deficiencies (note: all sealants in air flow path must be code approved):<ul style="list-style-type: none">○ Dedicated, sealed path for return air through a return air grille. Louvered doors that serve as returns and metal AHU stands have been eliminated.○ Gap between return air grille and rough opening is sealed.○ Gap between AHU and platform is sealed.○ Gap between AHU platform and return plenum is sealed.○ Gap between drywall and supply boots (behind supply register).○ No visible holes or loose connections in duct system.<input type="checkbox"/> Retest to verify target is met.<input type="checkbox"/> If a mechanical ventilation system has been installed, inspect system to ensure proper installation of intake register, ducts, filters, and dampers. (See Appendix for guidance.)
--

Table 2. Example Project Manager Verification Checklist for Envelope Components, Post-Retrofit

- Visually inspect the building envelope and work with home energy rater to determine if whole-house airtightness targets have been met. Target test result is $ACH50 \leq 6.0$. If target is not met, work with rater to assess airtightness at the following common air infiltration points:
 - Windows – caulk edges of window/frame/trim on both interior and exterior
 - Doors – replace weather-stripping if missing or degraded
 - Lighting fixtures and ceiling fans (drywall gap behind cover/trim)
 - Kitchen exhaust fan chase (at ceiling)
 - Switches and outlets – if replacing covers, seal boxes to drywall
 - Plumbing penetrations through interior and exterior walls (e.g. under sinks)
 - Plumbing access panels – secure tightly and/or weather-strip
 - Attic hatch or stair – weather-strip
 - Interior AHU closet – seal all edges and seams of walls, ceiling, and ducts
 - Soffits over cabinets or housing lighting – add air barrier above rough framing, seal all edges and seams
 - Holes in drywall
 - Frame floor penetrations for plumbing and electrical
- Recall contractor to correct deficiencies.
- Retest to verify target is met.
- Visually inspect the attic to assess:
 - Even level and proper depth of new insulation, if installed.
 - Flex ducts are strapped above ceiling insulation.
 - Attic insulation does not obstruct ventilation at eaves (baffles are in place where possible).
- Acquire NFRC documentation for all newly-installed windows and glass doors to assure required performance specifications (SHGC and U-value) have been met.

5.0 Best Practices Review and FSEC Partnership:

All readers are encouraged to submit feedback and questions on the practicality and clarity of the best practices. Umbrella associations interested in adopting the Current Best Practices as required or recommended policy to member organizations are eligible for FSEC technical assistance. Please direct correspondence to:

Janet McIlvaine or Karen Sutherland
Florida Solar Energy Center
1679 Clearlake Road
Cocoa, FL 32922

Janet McIlvaine – 321-638-1434, janet@fsec.ucf.edu,
Karen Sutherland – 321-638-1474, ksutherland@fsec.ucf.edu

Please include the term “Building America” in your subject line.

Appendix - General Guidance on Passive, Run-time, Outside Air Ventilation System

Note: This system DOES NOT satisfy American Society of Heating, Refrigerating, and Air Conditioning Engineers (ASHRAE) Standard 62.2 requirements. This guidance is NOT intended to replace engineering calculations. Work with a licensed mechanical contractor to develop specific air flows, component sizing, and commissioning procedures.

This type of system provides outside air only during “run-time” of the heating and cooling system. In concept, an outside air duct is installed during the mechanical system rough-in. It runs from an outside air intake (mounted in a nearby soffit) through the attic to the top of the AHU closet. It makes one 90 degree turn and passes through a closely-cut hole in the ceiling of the AHU closet down to another closely-cut hole in the AHU support platform. Routing must respect code-required clearances. The outside air must pass through a filter before entering the AHU. This can be done at the outside air intake or at the AHU. Filter location will affect design due to differences in return plenum pressure drop. There must be a close-mesh insect screen permanently installed covering the outside air intake orifice (behind inlet register or behind filter if a filter-back grille is used). There must be an accessible manual damper with visible “closed” and “venting” marks to allow occupants to override the outside air ventilation system when conditions warrant, such as when there is a fire in the area.

Before design begins, meet with local code officials to determine acceptable clearances around all elements in the handler closet, materials for outside air duct, and sealants for penetrations at the AHU closet ceiling and return platform. Include the mechanical contractor in the design process. This type of system may be familiar to code officials and inspectors that have encountered it in multi-family ventilation systems.

Major Elements

Intake Register

- Outside air intake shall provide free flowing outside air (not attic air) to the outside air duct. The outside air duct should not terminate above the soffit. The intake register should be in the same plane as the soffit (Figure 1) or on an exterior wall with weather protection similar to a dryer exhaust duct. It should be within 25 feet of the AHU closet with tight-mesh insect screen mechanically-secured and sealed over the end of the outside air duct.
- At a minimum, the outside air duct shall terminate at a register sized to allow a free flow of outside air at a predetermined flow rate. Air shall not be drawn from the attic. It is preferable that the outside air duct terminates in a manufactured or field-fabricated boot mounted in the soffit framing with a mastic and fiberglass seal at the joint. Mechanically fasten boot to the duct and a standard size, filter-back register mounted in the soffit. *(If a filter-back grille is not installed, the outside air MUST be filtered at the AHU. See “Filtration” below.)*



Figure 1: At a minimum, outside air intake register mounted in vented vinyl soffit with outside air duct positioned in soffit above. Note that a filter-back return register is preferred whereas this is a fixed register.

Duct (details may vary among air handler configurations)

- Take truss location into consideration when planning duct layout. Fully inform the mechanical contractor of any other potential obstructions (supply plenums, furred-up chases, etc.) to the path of the outside air duct. The path length and layout can significantly affect flow.
- Code-approved duct sized to achieve the predetermined flow. Code-mandated clearances may apply.
- Minimize bends in the outside air duct to one 90 degree bend where it leaves the attic and enters the AHU closet. Make the bend at the intake with a manufactured or field-fabricated boot of adequate size to provide desired air flow.
- Limit duct length to 25’.
- Seal around duct penetration in the ceiling of AHU closet with code-approved sealant.
- Outside air duct should continue through the AHU support platform (seal penetration with code-approved sealant) into the return plenum.
- Terminate outside air duct as close to the AHU intake (at the machine where pressure is highest) as possible to improve flow.

Filtration

- Outside air must be filtered before it enters the AHU.
- If the main house return is through a filter-back grille, outdoor air filtration can be achieved by installing a second filter-back grille at the intake in the soffit. Contact the authors if you have difficulty finding a supplier. This may place a maintenance burden on the homeowner to change the filter outside.
- If a filter-back intake grille has not been used, the outside air **MUST** cross a filter at the entrance to the AHU to prevent deposit of materials on coils. In this case, an AHU with “under cabinet filter cavity” must be specified and installed. It is imperative that the HVAC installer avoids installing refrigerant or condensate lines in front of the filter access panel. Ensure adequate clearances for all components in advance.

Outside Air Dampers and Controls

- Install an inline, manual balancing damper with fittings accessible from the inside of the home.
- A gravity-fed, back-draft damper with override control may be substituted for the manual damper, provided that adjustments are possible for balance flow.
- A normally-closed, motorized damper may be installed in addition to the manual damper.
- Note that new electronic controls are entering the market that can tie motorized damper operation to other events such as exhaust fan operation.
- Conduct flow measurement (home energy rater or mechanical contractor) and adjust manual damper to setting for desired flow. Mark damper setting at control for “closed” and “ventilation” at a minimum.

Example Outside Air Flow Rate Calculation:

The ASHRAE Standard 62.2-2010 calculation formula for recommended flow⁴:

$$\text{Outside Air Flow Rate} = (7.5\text{cfm} * (\text{number of bedrooms} + 1)) + (0.01 * \text{conditioned area})$$

Applying the formula to different-sized homes with different numbers of bedrooms produces different recommended flow rates. For example:

2 Bedrooms with 1000 sq ft of conditioned space yields: $(7.5 * 3) + (0.01 * 1000) = 32$ cfm

3 Bedrooms with 1150 sq ft: $(7.5 * 4) + (0.01 * 1150) = 41.5$ cfm

4 Bedrooms with 1250 sq ft: $(7.5 * 5) + (0.01 * 1250) = 50$ cfm

In order to provide Standard 62.2 levels of ventilation, these flow rates would need to be delivered 24 hours a day. Higher flow rates for shorter periods that deliver the same total volume on an hourly basis are allowed.

In a small home, a small diameter PVC pipe (~3") or flex duct (~4") will typically accommodate the levels of flow shown in the examples. Sizing should be determined by a mechanical contractor. Remember that the duct layout, length, diameter; filter configuration; and return air plenum pressure conditions will affect actual flow. A balancing damper should be used to calibrate flow once the system is installed. Once all mechanical and electrical finish work is completed, the mechanical contractor or home energy rater can measure outside air flow under normal system operation and adjust the manual damper to achieve the desired outside air flow rate. Mark the position of the damper lever for "ventilation" as well as the position for "closed."

Provide homeowners and occupants with guidance on damper operation, preferably mounted near the damper.

⁴ ASHRAE Standard 62.2–2010, Ventilation and Acceptable Indoor Air Quality in Low-Rise Residential Buildings. American Society of Heating, Refrigeration, and Air Conditioning Engineers. Atlanta Georgia. Subject to revision. Check for more recent editions.

