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IN DEPTH

Historic Pittsburgh Building Transforms into Passive House Retrofit (Part 2)

Taking an affordable housing facility, located within an historic Pittsburgh YMCA®, and successfully transitioning the building to meet Passive House criteria is an impressive feat. In Part 1 of this article ACTION-Housing Inc. (*http://www.actionhousing.org/*) and Thoughtful Balance, Inc. (*http://www.thoughtful-balance.com/*) detailed the McKeesport YMCA's initial conditions and diagnostics, and described how challenges presented by factors like the original brick facing were overcome. For Part 2, ***Energy Design Update*** speaks with Linda Metropulos, Director of Housing and Neighborhood Development at ACTION, and Laura Nettleton and Michael Whartnaby of Thoughtful Balance, to delve deeper into windows, mechanicals, and lessons from the project.

When it came to selecting windows for the project, how did you balance the historical aspect of the building with the performance criteria from PHIUS?

MW: The windows we used were from Zola (*http://www.zolawindows.com/*), meet European Passivhaus standards, and feature triple glazing. We went with European windows because the coatings used on the glass in Europe actually allow for solar heat gain. Domestic windows in the US, because of poor envelopes and air conditioning, tend to exclude solar heat gain and use coatings with low solar heat gain coefficients (SHGC) to block heat. But if you have a super insulated package, then you're not worried about overheating the building in the summer, and you want to capture heat passively in the winter. We still have a high insulation value from our windows' films and triple glazing, but the coating also allows for a high SHGC, to capture free heat as much as possible. The Zola glass-only specifications are SHGC of 0.5 and U-value of 0.09, which corresponds

Figure 1. Exterior of the McKeesport YMCA, located outside of Pittsburgh, Pennsylvania, prior to new window installation. High performance windows from Zola were built to maintain the integrity of the building's historic place in the community. Photo courtesy Michael Whartnaby of Thoughtful Balance, Inc.

IN THIS ISSUE

Wolters Kluwer Law & Business

Figure 2. High performance windows prior to installation. The team had to calculate minimum projection of drip edges and overcome rowlock brick sill details to make sure window installation would be durable. The team ran metal flashing beyond its normal point on the upper face to better protect the sill brick by going past the top surface of rowlock. Photo courtesy Michael Whartnaby of Thoughtful Balance, Inc.

to an R-11.5. The average overall window and components system, depending on size, earned between a 0.17 to 0.19 U-value. All windows at the YMCA were better than R-5 in performance.

The existing windows in the building were double-hung (see Figure 1). Double-hung windows are not good performers for air-tightness. Zola knew we wanted to maintain the historical elements of the structure. Zola took the jamb profile and was able to marry it to the right performance characteristics by creating a fixed over operable unit (refer to Figure 2). Each window has an upper fixed pane and lower tilt-turn operational pane with gaskets for superior sealing. The beauty of maintaining the jamb was to move the upper pane out closer to the exterior, so that the shadow line mimicked the original double-hung.

What decisions did you make with regard to mechanicals?

LN: The inescapable factor of almost all projects is cost. It really depends on solutions to meet that standard.

The new building would feature single room occupancy (SRO) units, each approximately 80 to 100 square feet (see Figure 3). Because of the small size, we weren't able to offer occupants individual thermostats. However, that also meant we were able to reduce the number of heat pumps you would typically have in a multifamily housing situation. In a standard building of 1 bedroom apartments, each unit would have its own heat pump. For the YMCA retrofit, we only needed 17 heat pumps. From a square footage standpoint, our initial estimate was 42 heat pumps, so 17 is a significant reduction in both cost and energy use.

MW: Adhering to Passive House criteria enabled us to cut demand, and therefore required equipment, way down. On average, 10 units run off of a single heat pump, which brings fresh and conditioned air to all 10 units in a row, and maintains the units at the same comfortable temperature.

LN: Not only do we have smaller, localized systems, our geothermal well field and piping back to systems were also significantly reduced. The larger building reduction in mechanical equipment and costs offset the costs of the envelope to be cost neutral – all that energy efficiency came at no additional cost.

Specific to Passive House criteria, we used 3 energy recovery ventilators (ERVs) from UltimateAir®. When

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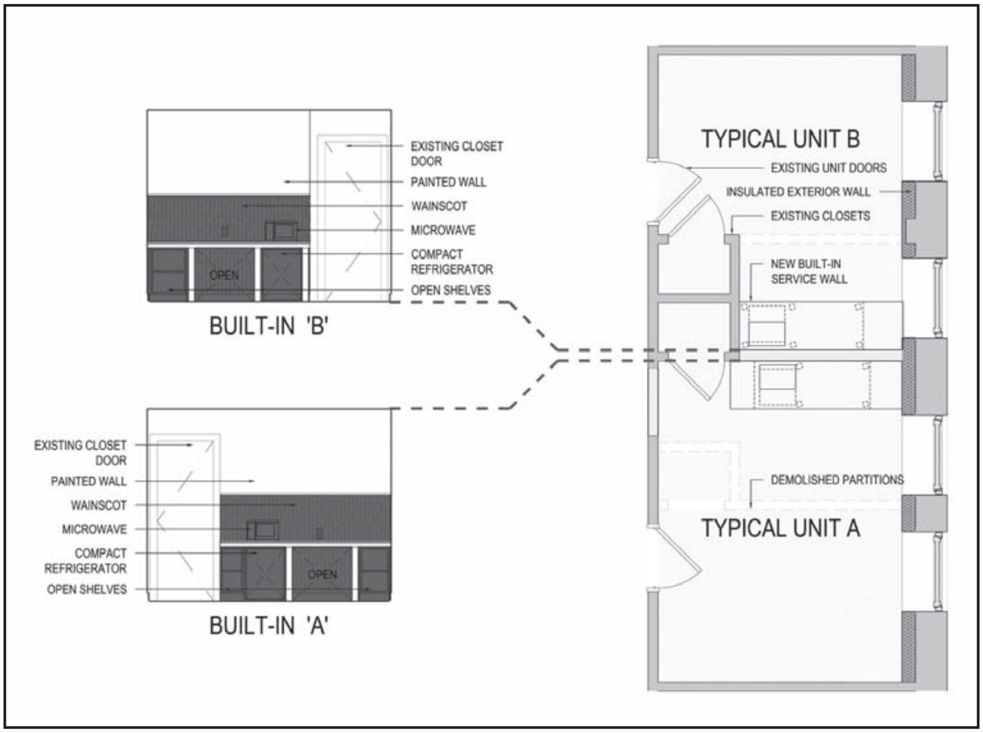

Figure 3. A diagram showing how existing single occupancy rooms were expanded during the retrofit. A built-in Service Wall was also added. Graphic courtesy Michael Whartnaby of Thoughtful Balance, Inc.

weighing what kind of recovery ventilation system to select, we were faced with a massive building and the need to move a pretty good amount of air. Most ERV and heat recovery ventilators (HRVs) were not really large enough. UltimateAir offered a 2000 cfm capacity unit, so we had to install only 3 in the end. Each unit can go up to 6000 cfm of fresh air, but we don't need that. If we went to another supplier with the next size down in unit, we would have had to install many more units. We give credit to UltimateAir for having a product aimed at the larger market.

MW: For the size they are and the amount of air they move, the ERVs are very quiet. Each unit has a 6' diameter filtration and energy recovery wheel, and you would never expect the minimal noise level they are able to maintain.

With the project wrapping up in December 2013, how are the first results looking?

LM: We successfully earned our pre-certification with Passive House, and are waiting on final certification this month.

During construction, we took what were 84 units on the third and fourth floors and expanded each unit by 50% (refer back to Figure 3). For ACTION, that was one of the best things; we created spaces that were much larger for SRO units. We also added kitchen facilities and many new bathrooms, as well as an indoor bicycle room, computer room, and bed bug eradication room. Bed bugs are an endemic problem everywhere, and are very much an issue in homeless shelters. We created the room after seeing a similar idea in Portland, Oregon. People place their belongings in the room, which is then heated up, killing off the bugs. All it took was creating a tightly sealed room, and putting in a sauna heater to raise the temperature so that bugs are killed.

By following Passive House, our building got a wonderful envelope (see Figure 4 and Figure 5), we introduced a geothermal well field, and significantly drove down projected energy costs. For our 60,000 square foot building, our energy bills used to be $60,000 a year just in heating and electricity. The Passive House model is telling us be we should be at $30,000 annually, with air conditioning and make-up air added as new loads. Going back to our main issue of how to keep housing affordable, we have to drive down utility costs.

Figure 4. The most common wall at McKeesport YMCA, an existing wall of 14" thick masonry, with the addition inside of an additional 8" close cell spray foam. The typical wall is now an R-57. Photo courtesy Michael Whartnaby of Thoughtful Balance, Inc.

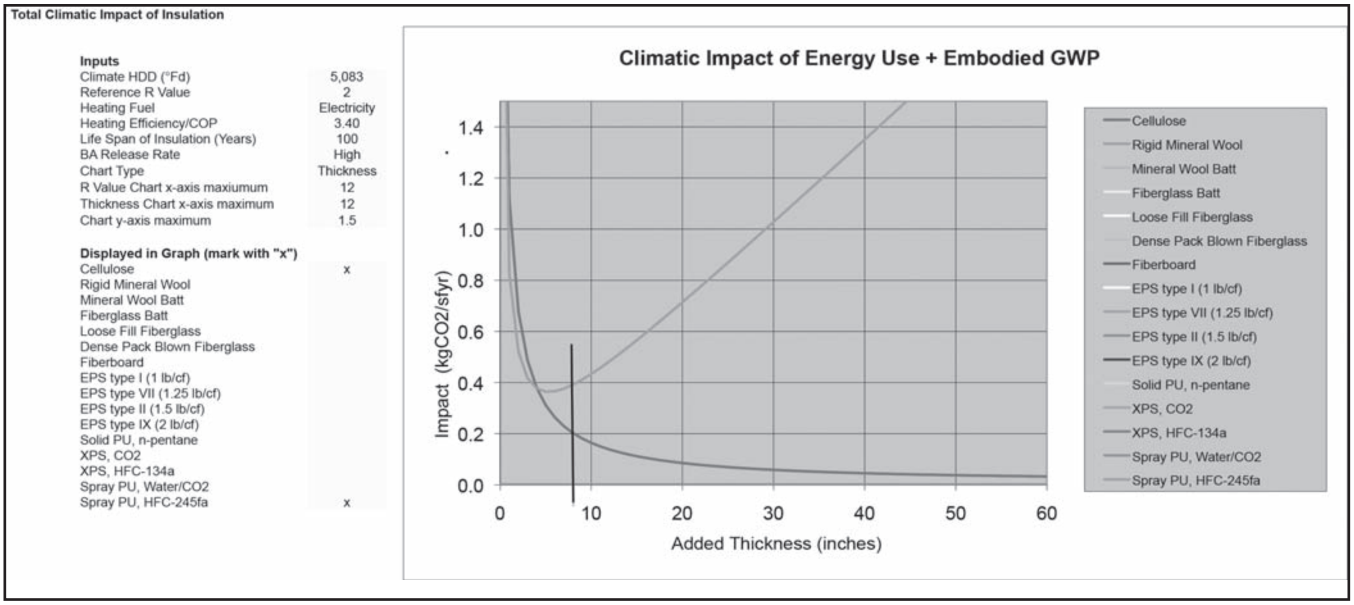

Figure 5. Addressing sustainability issues from close cell spray foam: Thoughtful Balance consulted with Graham Wright to balance the potential benefit of the product's insulation against its carbon footprint, shown plotted here. The curve shows the value of the insulation based on the amount increased against the detriment to the environment that that amount might present. Image courtesy Graham S. Wright.

LN: Calculations show that the YMCA will use 66% less energy than a standard renovation would have used.

But the real story goes back to cost. On a project of this size, we spent a lot of money on the envelope and windows, much more than we would have in a normal budget. But those upgrades enabled us to reduce the money spent on heat pumps to a third of what we expected. We also incorporated geothermal wells for McKeesport to pre-heat and pre-cool air. In early estimations, we planned to have 30 to 36 wells.

LM: Because of reduced loads, we were able to size down, and drill less wells than expected. Due to site conditions, we ended up drilling 21 wells to a more shallow depth.

LN: Each well costs money to drill. In total, we were able to cut mechanicals costs down by 60% which offset cost of improvements to the envelope.

What are the big lessons you'd like for us to take away from this project?

LN: This is still an arena where we're learning things under trial by fire. I would stress the importance for design professionals of getting an engineering team on board to really understand the goals of the project. This is a key, key piece and links to the ultimate success of the project.

MW: Think in terms of buy-in. For such a daunting building overhaul to be successful, you need it to be the goal of the client or owner, and you need buy in from the architect and engineering team. Your architects and engineers are the ones who will sort through details, specific systems, and really fine-tune the job. You need contractor buy-in, too. When we think about the recipe for success at McKeesport, it's not products that come to mind so much as the actual manpower on the jobsite. A specific example that comes to mind occurred with our doors. While we were able to purchase high performance Zola windows, it wasn't in the cards to get Passive House performance doors in the building. We specified the best American insulated door product we could get, with a thermally broken jamb, but the downfall of domestic doors is that we haven't paid enough attention to air tightness. The foreman on the jobsite special-ordered weatherstripping and gaskets and went around to all doors that came in, post-installation, and adjusted every single piece and replaced pieces to get a better air seal at each door. I think we'll get better than expected performance from the product because our foreman understood the goals of the project. He had a sense of the unique performance that he could engineer in the field. There is no product which could replace that attention to detail.

LN: It's also important to have quality control in place, and to accompany that with the education of all subcontractors.

MW: Subs have to understand what will undermine performance. Think twice before you drill once!

What was your experience with Passive House?

Figure 6. A photo of the rear section of the building. In confronting performance in retrofits, addressing unique details inherent to the building are vital. Photo courtesy Michael Whartnaby of Thoughtful Balance, Inc.

MW: Building professionals, as a group, are so used to prescriptive requirements: dominant programs in the market, such as Leadership in Energy and Environmental Design® (LEED) are so prescriptive. When you're doing Passive House, especially in a retrofit situation, it could never be prescriptive (see Figure 6). Passive House is so performance based; we would use different wall sections and make totally different decisions if we were presented with a different building. It is really about looking for and being open minded toward all the ways you can get to that energy goal, finding the one that is the best, and is also a best fit for the building and its goals. Retrofits are even again a little different than new construction, where you can choose all your materials and work with new and known variables. The "perfect" Passive House wall for new construction is very different from, and probably not an ideal fit, when it gets applied to a retrofit. As an architect, an engineer, and a builder, you have to shift away from the approach that there is one right way to do something. You have to be willing to look at what you're given and do research; you also have to check out the materials you're thinking of using.

LM: ACTION-Housing is a 57-year old non-profit based in Pittsburgh that helps those with limited incomes have sustainable housing solutions. Thirty years ago, we started running the weatherization assistance program for Allegheny County. One of the things we have recognized for a long time is that to keep homes affordable, you have to help people control their energy use. The next largest expense after a mortgage are utilities. We have always understood that for people to stay in homes, they have to be given the tools to weatherize and economize. We understand the connection between affordability and sustainability. Three years ago, we had the chance to go on a tour in Europe with other housing developers from around the world, and ended in Germany to view Passive House buildings. We came back hoping to work on our own projects, and bring Passive House to affordable multifamily buildings. We partnered with Kat Klingenberg at PHIUS to start serious work on understanding the Passive House strategy. Affordability and sustainability are so synchronistic.

LN: In thinking of affordable housing in general, as a culture we have skimped on the building envelope. Typically, we bought cheap windows with a limited lifespan of 5 to 10 years and used minimal insulation. The thing we've loved about Passive House criteria is that Passive House means no more poor decisions in the shell. Especially as seen in the McKeesport YMCA case, from a performance standpoint that's a really important aspect of Passive House. Additionally, having that superior shell means you are able to economize in other areas. The ability to put money into the envelope means smaller mechanicals, less maintenance, more affordability, and less utilities.

Energy Design Update would like to thank Linda Metropulos, Laura Nettleton, and Michael Whartnaby for sharing their data and perspectives from this project. The McKeesport YMCA retrofit is scheduled for final testing and certification this month. ACTION-Housing and Thoughtful Balance are allowing ***EDU*** to follow the building's performance and report data back at the end of 2014.

For further details on the brick assessment and thermal bridge evaluation at McKeesport YMCA, done in partnership with Building Science Corporation (BSC), visit *http://www.buildingscienceconsulting.com/presentations/documents/2013-10-17%20PassivHaus%20Masonry%20Presentation_Ueno.pdf*.

IN BRIEF

Student Design Teams "Race for Zero" in Energy-Efficient Homes

As part of its Building America Program, the US Department of Energy (DOE) engaged college students across the United States to participate in the DOE Challenge Home Student Design Competition and become part of the leadership movement to achieve truly sustainable homes. This competition provides the next generation of architects, engineers, construction managers, and entrepreneurs with skills and experience to start careers in the field of clean energy and generate creative solutions to real-world problems. The program is being administered and technically supported by Home Innovation Research Labs.

Teams from colleges, universities, and technical schools across the country were invited to register for the competition through the middle of December 2013. Students were encouraged to create multidisciplinary teams and include industry advisors, such as local home builders, to help inform their decision-making processes and ground their solutions in real-world terms to overcome barriers to innovation impacting our nation's housing industry. Student entries will demonstrate the teams' knowledge and skills to design, analyze, and plan the construction of quality, high-performance homes that meet or exceed the DOE Challenge Home requirements.

Participating teams are:

- Bulldog Builders (California State University – Fresno)
- Cal Poly SLO 1 (California Polytechnic State University)
- Clemson DOE Challenge Home Competition Team (Clemson University)
- Energy Javelinas (Texas A&M University – Kingsville)
- gt. 5 (Georgia Institute of Technology)
- [habit]at (Iowa State University, College of Design)
- Illinois State University
- Invent the Future (Virginia Tech)
- KCC Industrial Technologies (Kirkwood Community College, Industrial Technologies)
- KU 609 (University of Kansas)
- Legends of the Phog (University of Kansas)
- LSC-Architectural Technology (Lake Superior College)
- MIDC – Blue (Auburn University College of Architecture, Design & Construction)
- MIDC – Orange (Auburn University College of Architecture, Design & Construction)
- Montage Builders – Syracuse (SUNY College of Environmental Science & Forestry, Syracuse University, Onondaga Community College)
- Nittany Lions E-den (Penn State University)
- Panther Innovations (University of Pittsburgh)
- PCT Team Blue (Pennsylvania College of Technology)
- PCT Team Gray (Pennsylvania College of Technology)
- ProjectZero (Roger Williams University)
- Ryerson ThresholdHouse (Ryerson University)
- Ryerson Urban Harvest (Ryerson University)
- Team Mojave (University of Nevada Las Vegas)
- Team Rutgers (Rutgers University)
- Team UIUC (University of Illinois at Urbana-Champaign)
- Team UofT (University of Toronto)
- The IIT Crowd (Illinois Institute of Technology)
- UCD Advanced Green Building Studio (University of Colorado Denver)
- UMass Lowell Design Team (University of Massachusetts Lowell)
- University of Minnesota – Race to Zero (University of Minnesota)
- University of Wyoming Architectural Engineering
- Utah Lab House (School of Architecture, University of Utah)

Designs for the 2013/2014 inaugural competition will be submitted by March 30, 2014, and winners will be announced and recognized during a ceremony before the end of the spring 2014 semester. Winners will also be featured at upcoming industry events, including NAHB's 2015 International Builders' Show, and through forums like GreenExpo365.com.

Going forward, the competition will be held on a two-year cycle that alternates with the Solar Decathlon. The Decathlon's off year in the United States serves as the award-year for the Challenge Home competition, providing a two-year timeframe for teams to prepare their submissions.

This year's competition was sponsored by the DOE, Building America Program; Architectural Energy Corporation (AEC); National Consortium of Housing Research Centers' Joint Committee on Building Science Education; Energy & Environmental Building Alliance (EEBA); and the National Association of Home Builders (NAHB). Primary student references include Excellence in Building Science Education; DOE Challenge Home requirements; EEBA Houses That Work Online Education; and, REM/Rate™ Simulation Software, by Architectural Energy Corporation.

To learn more, visit *http://www.homeinnovation.com/DOEChallengeHomeStudentDesignCompetition.*

Stafford Manufacturing To Offer Customized Flange Mounting Collars

Custom-made flange mounting collars that are perfectly square for mounting a shaft, tube, or pipe to a flat surface or for attaching components to them, are now available from Stafford Manufacturing Corp. of Wilmington, Massachusetts. The Stafford Custom Flange Mounting collars can be manufactured from steel, stainless steel, alloys, aluminum, and thermoplastics in a wide range of flange designs, hole patterns, and sizes. Incorporating the Accu-Clamp™ non-marring and perfectly square clamping feature, these one-piece collars can be machined into flat and stable mounting flanges, hubs, or pulleys.

Featuring flatness and perpendicularity held to < 0.001 TIR, Stafford Custom Flange Mounting Collars can be manufactured in bore sizes from ½" to 6" I.D. with flanges up to 14" O.D. and also as two-piece designs. Typical applications include conveying, converting, and packaging equipment as well as various power transmission, drive, and structural applications.

Stafford Custom Flange Mounting Collars are priced according to configuration and quantity. Price quotations are available upon request.

For more information, contact: Stafford Manufacturing Corp., Jim Swiezynski, Technical Director, at P.O. Box 277, North Reading, MA 01864-0277; via telephone at 1-800-695-5551, via fax 1-978-657-4731; or, by e-mail: *jswiezynski@staffordmfg.com*.

Diversified Technologies Upgrades UK ISIS Linear Accelerator

Diversified Technologies, Inc., (DTI) developer of PowerMod™ high voltage, high power pulse modulators, DC power supplies, and process control systems, has recently installed two solid-state switches at the Rutherford Appleton Laboratory (RAL), in the United Kingdom, to eliminate numerous operating difficulties with their legacy systems and reduce operating costs.

RAL, one of the national scientific research laboratories in the UK, has been operating the ISIS Linear Accelerator since 1984. Recent tetrode switch tube failures, however, prompted them to replace their legacy, low-power cathode modulators used on the 2 MW RF triodes with high power, solid-state anode modulators from DTI.

DTI installed the solid-state switches between the power supplies and tetrode which prevented high fault energy from destroying the tetrode, saved approximately 25% in electricity costs, and increased the overall reliability of their older generation ISIS Linear Accelerator.

According to Michael Kempkes, DTI VP, "The solid-state switches are drop-in replacements. DTI specializes in modernizing any vacuum tube RF amplifier or transmitter such as Klystrons, TWTs, and magnetrons."

For more information, contact: Michael A. Kempkes, VP of Marketing, 35 Wiggins Ave. Bedford, MA 01730-2345; via phone at 1-781-275-9444 x211, or by e-mail: *kempkes@divtecs.com*.

IN PRACTICE

How Do We Solve a Problem Like Retrofit Performance?

New Florida Retrofit Challenge Sets Sights on Making Old New Again (Part 1)

New home performance improves under the pressure of more demanding codes. But what happens to existing housing stock? Are older homes doomed to languish in the dust from newer construction, or can an old home be taught new tricks? From the 1970's through the 2000's, housing starts were strongest in the South and ranged from 4.6 to 5.9 million, nearly twice as many starts as any other region across all decades, according to Janet McIlvaine, Senior Researcher at Florida Solar Energy Center (FSEC). For McIlvaine, all those aging homes represented a serious performance gap. But she also contends this performance gap doesn't have to be the end of the story.

The Retrofit Challenge Initiative, launched by the Building America® Partnership for Improved Residential Construction (BA-PIRC) at the FSEC in 2014, selects key building science principles seen in new homes and targets these practices toward retrofits. The Retrofit Challenge's Best Practices Checklist (*http://www.ba-pirc.org/retrofit*) was compiled after a 4-year study that completed 70 comprehensive affordable housing renovations.

From the study, BA-PIRC researchers concentrated a checklist of practical, accessible best practices for renovations in typical Florida (Climate Zone 2) homes, focused on health, safety – most notably, combustion safety –, and durability measures. On average, a home in the study posted a Home Energy Rating System (HERS) Index improvement of 34% (refer to Figure 7). When fully implemented in homes with HERS Index scores around 129, the field study average, projected savings will likely be about 25%.

The Retrofit Challenge best practice measures include moderately higher performance specifications at equipment replacement for elements including heating, ventilation, and air-conditioning (HVAC), appliances, and water heating; efficiency enhancements like insulation; and building science measures that address combustion safety, durability, and moisture management. HERS Index improvement from the 70 test homes ranged from 6% to 60% for an average of 34% (see Figure 8); incremental costs ranged from $780 to $8,382, averaging $3,854; and 61 homes had a heating, ventilation, and air-conditioning (HVAC) change-out during the renovation. Average SEER Equipment Efficiency increase was 49% (see Figure 9). As-found, 20 homes had electric resistance heating with the elements integrated with the air conditioning coil in the central air handler, a very common system in Florida existing homes. Of the 20, 18 were replaced with heat pumps, representing a major whole house efficiency improvement and a a major shift in market norms over the past 15 years.

Summarized Retrofit Challenge Best Practices Checklist:

Health, Safety, and Durability Measures (Risk Reduction):

- Combustion safety
- Whole house pressure balance

Moderately higher performance replacements:

- Heating & cooling system (>=SEER 15 heat pump)
- Windows (Low-E)
- Water heating (>=EF 0.92)
- ENERGY STAR® lighting, appliances, and ceiling fans
- Light or white exterior finishes
- Meet new construction code for heating and cooling

Efficiency Enhancements:

- Substantially leak free duct system
- R 38 attic insulation
- Window film
- Air sealing at plumbing and fixtures openings

To access the full Checklist document, visit *http://www.ba-pirc.org/retrofit/PDFs/Current%20Best%20Practices%20-%209-9-13-Version%202.0%20Final.pdf.* The most common choices have been consolidated from the field study results and a City of Melbourne pilot and turned into a checklist as a separate, living document, updated based on program feedback.

Checklist Development

"These best practices in the Retrofit Challenge are not from an optimization study," stressed Janet McIlvaine, Senior Researcher at FSEC and project lead. "Instead the best practices reflect the choices made by the affordable housing providers in our 70 home field study which were influenced by many economic and market factors."

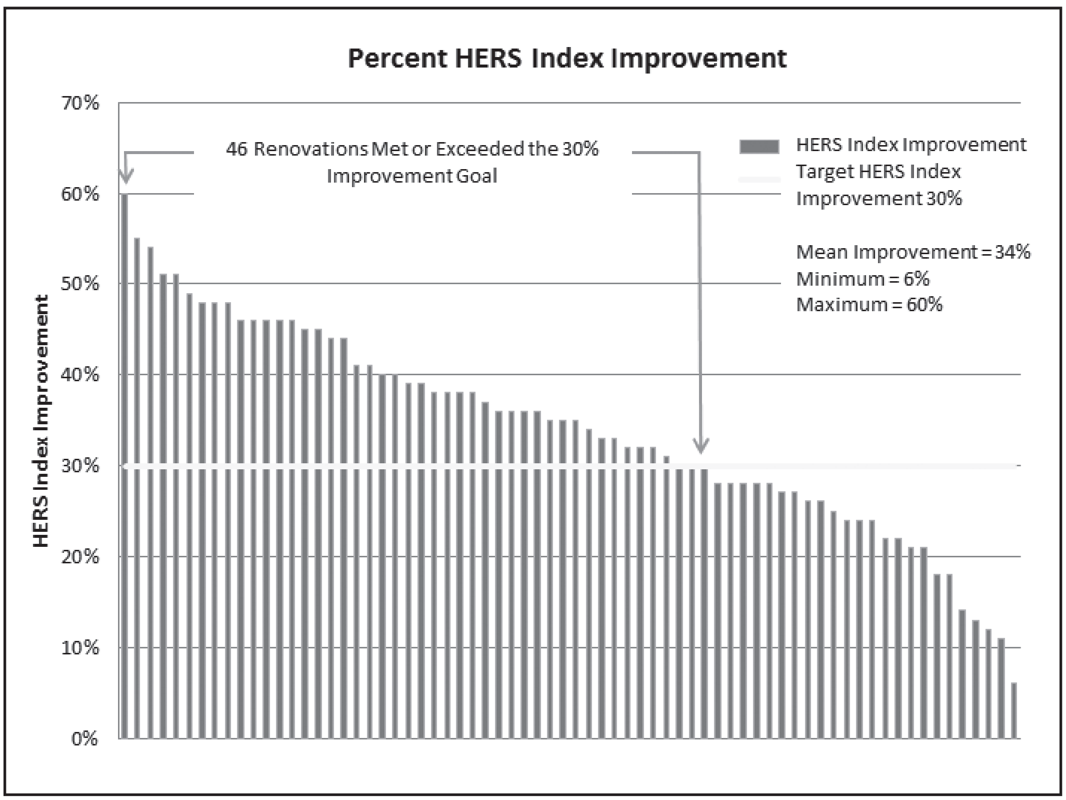

Figure 7. Home Energy Rating System (HERS) Index improvement goal of 30% was met in 46 deep retrofits. Data courtesy Janet McIlvaine and Karen Sutherland, and the Building America® Partnership for Improved Residential Construction.

The existing housing stock can vary dramatically even among houses of the same age, even in the same neighborhood. No single package of improvements will work for every existing house. Parts of the Retrofit Challenge checklist apply to all homes, others apply only at the time of replacement, and the remaining items apply to components/equipment being retained.

For each distressed

Vintage	Partner A (n = 20)	Partner B (n = 22)	Partner C (n = 20)	Overall Mean (n = 70)
1950s	48%	60%		54%
1960s	40%	48%	42%	42%
1970s	38%	28%	37%	34%
1980s	36%	36%	33%	35%
1990s	25%	29%	33%	28%
2000s	18%	9%	26%	20%
Overall Mean	36%	34%	34%	34%

Figure 8. Average Home Energy Rating System (HERS) Index improvement for top partners by vintage. Data courtesy Janet McIlvaine and Karen Sutherland, and the Building America® Partnership for Improved Residential Construction.

home taking part in the project, a pre-audit was first conducted, weighing the scope of work at each house based upon what it needed. The BA-PIRC team then assembled all the energy-related changes the affordable housing partner was already planning to make and did simulation analysis for each change, while also proposing additional improvements. (For more in-depth information on the project, see reports at *http://www.fsec.ucf.edu/en/publications/pdf/FSEC-RR-404-13.pdf* and *http://fsec.ucf.edu/en/publications/pdf/BA-PIRC-florida_retrofit_best_practices.pdf*.) "For example, if the partner was already changing out the mechanical system, we provided analysis to help the partner weigh whether a higher efficiency unit with duct sealing would make more sense, based on projected savings and estimated costs," McIlvaine clarified. "Decision making at the partner level largely produced our collective list."

The goal underlying the Retrofit Challenge is to give program managers a starting point of realistic recommended practices and to further document what contractors are willing to adopt as standard practice on availability in the marketplace, costs, and labor capabilities. "This initiative really boiled out of application rather than simulation, which encompasses a wide variety of decision points. We are driving toward a base level of improvement for all renovations in central Florida. Whether major or minor, portions of the Retrofit Challenge likely apply," McIlvaine said.

Real World Retrofits

"Doing any field study you are in the trenches and that really helps you stay grounded," McIlvaine laughed. BA-PIRC was anxious to see whether the effort of bringing older homes up to approximate new construction performance standards was even feasible. The program went to the toughest testing ground possible – distressed affordable housing. Pre-retrofit HERS Indices for selected field study homes ranged from 95 to 184, with an average of 129. The typical configuration was a three-bedroom, two-bath, ranch-style floor plan with shingle roof, with a slab-on-grade foundation (see Figure 10). Painted stucco over wood frame or concrete block was the most common exterior wall finish. Estimated annual pre-retrofit energy costs ranged from $1,437 to $3,101 for the 70-home dataset.

Homes needed multiple energy-related replacements and improvements. Potential risks in the building type were pinpointed. The team then identified 13 key

		Replacement SEER Rating			
		13–13.9	14–14.9	15–15.9	16–16.2
Pre-Retrofit SEER Rating	<10	1		7	4
	10–10.9	4	2	16	9
	11–11.9				1
	12–12.9		2	4	4
	13–13.9			4	2
	14–14.9			1	
Total Replaced (n = 61)		5	4	32	20

Figure 9. Pre-renovation and post-renovation AC efficiencies. Data courtesy Janet McIlvaine and Karen Sutherland, and the Building America® Partnership for Improved Residential Construction.

Figure 10. An example of a typical home in the study. Data courtesy Janet McIlvaine and Karen Sutherland, and the Building America® Partnership for Improved Residential Construction.

efficiency measures related to equipment, appliance, and lighting efficiency and envelope components. Additionally, BA-PIRC stressed combustion safety and adherence to the Florida Residential Mechanical Code for new construction, which addresses system design, quality installation, duct integrity, durability issues, and system accessibility. Performance criteria were set out to raise awareness about whole-house and duct airtightness. These measures laid the foundation for an eventual best practice checklist, and aimed to push each retrofit to reach the Building America 30% energy-saving renovation goal for the hot-humid climate.

According to McIlvaine, the test-in audit included a sketch of the home; envelope measurements; characteristics of all energy-related equipment, materials, and components; whole-house and duct airtightness testing; whole house pressure mapping; and extensive photographs. This audit data were used to build a pre-retrofit simulation model, and allowed BA-PIRC to make additional or enhanced improvement and upgrade suggestions.

Once recommendations were made, BA-PIRC analyzed what actually went on in the field. Which recommendations would be selected and put into action (see Figure 11)? Most all (96%) of deep retrofits included a mechanical system replacement, 93% included additional ceiling insulation, and 92% included infiltration reduction. Most also included duct tightening (86%) and window replacement or film (80%). Additionally, contractors selected R-6 replacement ductwork (39% of deep retrofits), light color exterior paint (30%), and light color shingles (30%).

In addition to measures chosen to reduce space conditioning energy use, retrofit contractors focused on appliance, water heating, and lighting improvements: 76% of the deep retrofits included an ENERGY STAR refrigerator and 70% included a higher efficiency water heater. About half the retrofits increased the number of fluorescent lighting fixtures by 30% or more and a similar number added programmable thermostats. ENERGY STAR-labeled ceiling fans were incorporated into only 15% of the deep retrofits.

Sorting Through Results: What Actually Happened in the Field

Overall, McIlvaine and her team saw that deep retrofits in the field study included a combination of major improvements supplemented with multiple minor improvements.

"This was the guiding force behind developing a best practice list: we looked at post-retrofit audits, and asked which specification the most partners had implemented," McIlvaine said. BA-PIRC's affordable housing partners faced a very tight economic formula to work within when refurbishing distressed homes. "First cost was definitely a factor at the partner level," emphasized McIlvaine. "But also, because it's affordable housing, our partners had an eye on long-term costs and benefits."

Affordability became the trump card. To help partners, the team showed how much each recommended efficiency step would save, projected on an annual basis, based on cost estimates. Only options that could show a first-year positive cash flow were recommended with the exceptions of high performance windows and whole house ventilation. Projected annual cost savings were used instead of actual utility bills or monitored data as most homes were unoccupied, foreclosed homes.

In cases where roofs had to be replaced and exteriors refinished, BA-PIRC selected white or very light colors as a best practice. These options were cost neutral and selecting a light roof and paint meant additional cooling benefits for the home.

Windows were the only area where partners repeatedly choose high performance over cost effectiveness. The most typical pre-retrofit scenario, a single-pane window with clear glass and a metal frame, carried an estimated solar heat gain coefficient (SHGC) of 0.80 and a U-value of 1.20. The most common replacement window type was a double-pane, Low-E, vinyl frame, single-hung with an SHGC of 0.20 - 0.40. Despite individual analysis revealing a much longer payback period than other measures, contractors chose ENERGY STAR windows given their impact not only on energy and performance, but also on livability. BA-PIRC took note of this preference and carried it into the final best practice list.

13 Key Efficiency Strategies	Deep Retrofits (n = 46)	Non-Deep Retrofits (n = 24)	All Houses (n = 70)
1. Higher cooling and/or heating efficiency at replacement	96%	71%	87%
2. Additional ceiling insulation	93%	63%	83%
3. Better whole-house airtightness (ACH50[a])	92%	77%	88%
4. Better measured[3] air distribution (duct) tightness (Qn,out)	86%	68%	80%
5. Lower solar heat gain coefficient (SHGC) window film or windows at replacement windows	80%	46%	67%
6. ENERGY STAR® refrigerator at replacement	76%	71%	74%
7. Slightly higher efficiency water heater at replacement (electric EF=0.92)	70%	38%	59%
8. 30% more fluorescent fixtures/bulbs	52%	42%	49%
9. Programmable thermostat	48%	42%	46%
10. Replaced duct system	39%	13%	30%
11. Higher reflectivity exterior wall color at replacement	30%	8%	23%
12. Higher reflectivity roof shingles at replacement	30%	13%	24%
13. Higher efficiency ceiling fan(s) at replacement	15%	13%	14%

a. Air changes per hour at a standard test pressure difference of 50 Pascals.

[3] Duct leakage to the outside measured under depressurization conditions according to ASTM test results normalized for conditioned square footage (ASTM International 2013).

Figure 11. Prevalence of 13 key efficiency strategies implemented. Data courtesy Janet McIlvaine and Karen Sutherland, and the Building America® Partnership for Improved Residential Construction.

Real World Results Yield Best Practices List

The best pre-retrofit HERS Index score from the 70-home dataset was 95. Post-retrofit HERS results from the study homes ranged from 65 to 135, with an average of 83 (see Figure 12). The average decrease in HERS from the homes was 34%. Projected annual energy savings ranged from $35 to $1,338, with an average energy cost savings of 25%. According to McIlvaine, all but 4 homes achieved a HERS Index of equal to or less than 95, which is similar to new Florida homes built in the early 2000s, "a remarkable reversal."

By characterizing typical houses in the program, BA-PIRC started seeing consistencies and pinpointing strategies that could work across the central Florida housing stock.

"In our work with partners on individual homes, we asked what the state of each building was, what measures were going to be done regardless of energy efficiency, and then we looked within those plans to find moderately higher performance improvements," McIlvaine said. "Where can we make tweaks? What opportunities do we have to add on efficiency enhancements?" While McIlvaine stressed the value of evaluating efficiency measures for a specific house with a home energy rater, but asserts the best practices based on partner choices in the field study analysis can for a basis for setting master specifications applied to many houses.

What advice did McIlvaine have for those looking to jumpstart their own retrofit challenge? "Health, safety, and durability measures are key elements, and these should be the first tier of measures considered by anyone as they evaluate each retrofit," McIlvaine stated. "Where can we spend money on replacements to gain moderately higher performance cost effectively? For this climate zone, what efficiency enhancements notwithstanding replacements should we implement? That three-pronged approach is a recipe for success." A home

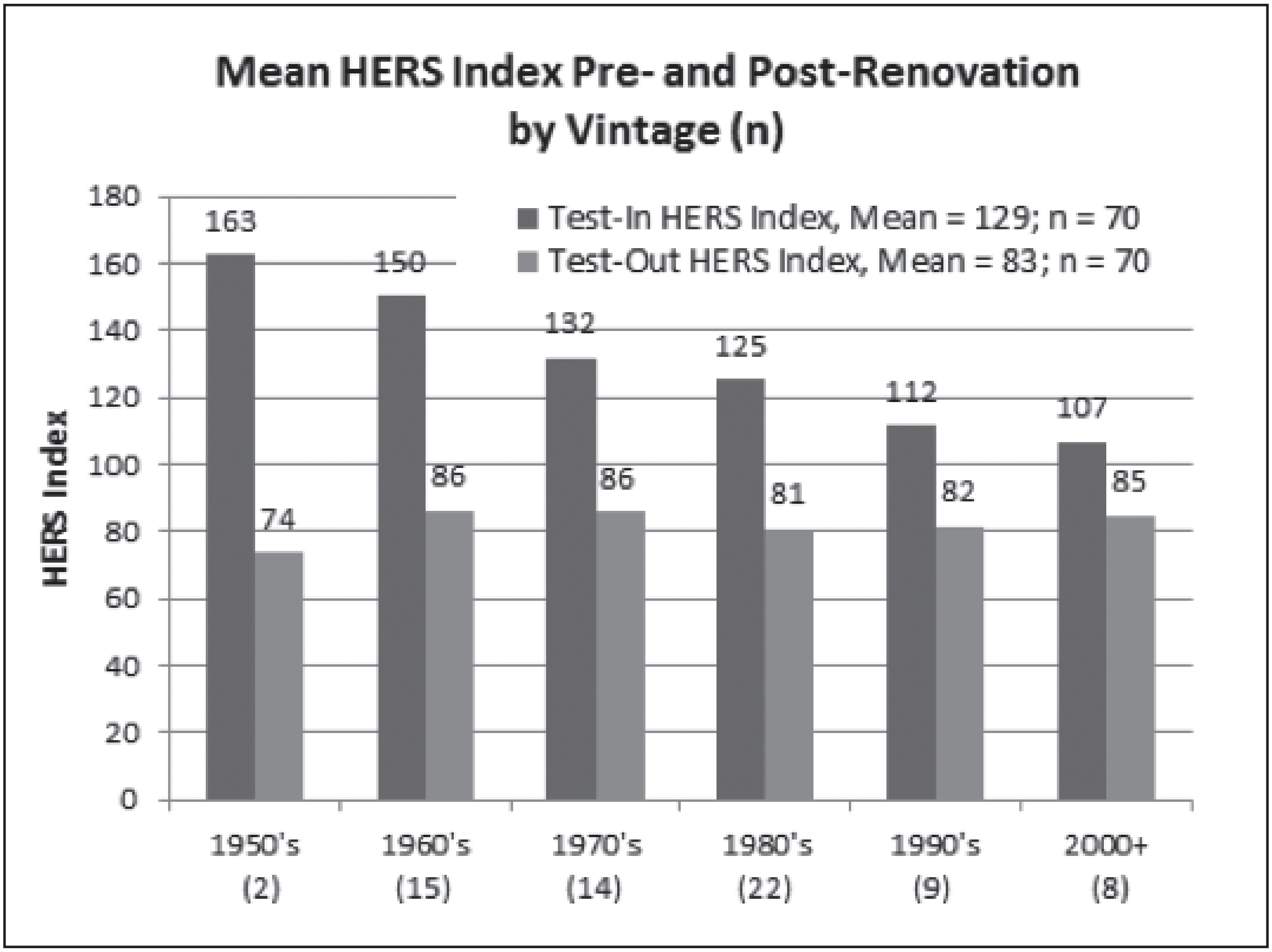

Figure 12. Mean Home Energy Rating System (HERS) Index at pre- and post-retrofit by decade vintage. Data courtesy Janet McIlvaine and Karen Sutherland, and the Building America® Partnership for Improved Residential Construction.

energy rater can help program managers answer these questions for typical anticipated as-found conditions.

Why retrofits? Why now? "We're hearing a lot from the new construction industry that they promote the energy efficiency of new construction as a major advantage over existing homes," said McIlvaine. "Yet with application of these best practices, many existing homes can be brought up to current new construction code levels cost effectively. We saw homes from every decade, from the 1950's on, reach new home performance levels on the HERS Index."

"The big question is what should we be aiming for?" McIlvaine asked. "What percentage of improvement? Should our goal be a certain energy use per square foot? Movement down on the HERS index? A percentage of annual energy use reduction? We feel that a good target is to aim for performance levels on par with new homes in the area within the scope of work needed. Having this goal in mind can give us all a mental picture of transferring new construction practices to existing homes. It helps us think about integrating the good building science incorporated in the new construction code at replacement, beyond simple enhancement."

Energy Design Update thanks Janet McIlvaine, the Building America® Partnership for Improved Residential Construction (BA-PIRC), at the Florida Solar Energy Center (FSEC) for sharing their research and expertise with us. Groups interested in taking The Retrofit Challenge may go to *http://www.ba-pirc.org/retrofit/PDFs/Pledge%201-27-14.pdf* to take the pledge. The Retrofit Challenge website is online at *http://www.ba-pirc.org/retrofit/index.htm*. BA-PIRC invites partners from the remodeling, renovation, and affordable housing sectors to join them in this research.

In upcoming articles in this series, ***EDU*** will take an in-depth look at a subset of the program's best practice recommendations, and will also explore how best practice language can effect outcomes.