Energy Design Update

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IN DEPTH

Good Intentions, Unintended Consequences

Florida Retrofit Challenge Mechanical Standard Offers Perspective and Lessons on Raising the Bar for Retrofit Codes (Part One)

On the surface, subjecting existing homes to the same standards as new homes looks like a good idea. But focusing on numeric results and efficiency specifications without facing the reality of field conditions only tells one part of the story.

Janet McIlvaine, Senior Researcher at Florida Solar Energy Center (FSEC), and others, see a serious performance gap, especially when examining an aging housing population in the Southern US; one heavily populated by starts from the 1970's through the 1990's. To address this divide, the Building America[SM] Partnership for Improved Residential Construction (BA-PIRC), led by FSEC, launched The Retrofit Challenge Initiative. This Initiative is currently focused on affordable housing programs conducting whole house renovations. The Retrofit Challenge selects key building science principles commonly seen in new homes for occupant health and safety, building durability, and thermal comfort and targets these best 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. (For more on the Challenge, see ***Energy Design Update***, March 2014, In Practice, "How Do We Solve A Problem Like Retrofit Performance?")

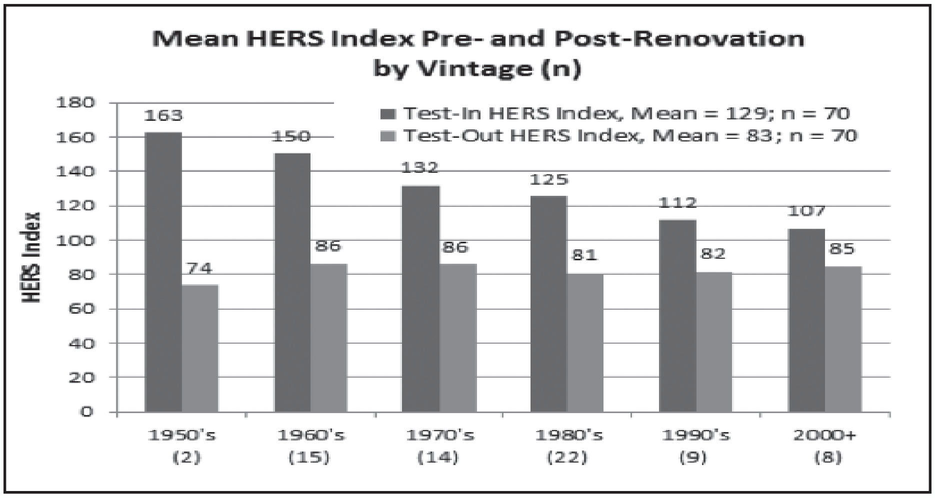

Figure 1. Mean Home Energy Rating System (HERS) Index at pre- and post-retrofit by decade. Data courtesy Janet McIlvaine and Karen Sutherland, and the Building America[SM] Partnership for Improved Residential Construction.

To date, the Retrofit Challenge field study has seen some great wins: A key finding was that by applying an analogous set of replacement specifications, efficiency enhancements, and systems engineering strategies, similar post-retrofit whole house efficiencies were achieved in homes of widely disparate pre-retrofit efficiencies (see Figure 1). On average, the homes in the study posted a Home Energy Rating System (HERS) Index score improvement of 34%. The average HERS Index score was 83 – similar to Florida homes built from 2000 to 2010. In essence, Florida homes from the 60's and older can be made "as good as new," at least from a whole house efficiency perspective.

Mechanical system improvements played a major role in this whole house efficiency improvement. For example, the average SEER Equipment Efficiency increase seen was 49%. Heating efficiency, though less important in Florida than in other parts of the country, rose radically as well. Eighteen of the 20 homes with electric resistance heating were retrofitted with heat pumps. Duct air tightness improved also with 75% of the homes achieving test results on par with the Energy Star for New Homes Standard Version 2 in force at the time of the study in 2009-11.

Retrofit Challenge measures are experiencing performance success in the field. Yet the burgeoning promise of "old as new again" performance must meet the harsh reality of code and existing home conditions. These things often result in troublesome consequences, despite the best of intentions.

Mechanical Systems Pinpoint Code Divide

"Our starting point for evaluating mechanical system replacement recommendations for the Retrofit Challenge was our Building America experience with high performance new homes and Florida's new construction building codes," said McIlvaine. "The Florida Building Commission has really done a good job of slowly integrating proven building science strategies into the code over the past 20 years backed by extensive research and practical experience."

For example, the Florida Building Code for new homes requires sealed return plenums, bans the use of building cavities for air distribution, and requires passive return air pathways from bedrooms. New homes also must adhere to Manual J sizing and air handlers must be installed to have 4" or more clearance on all sides for access and sealing.

"Yet these requirements do not apply to HVAC changeouts," McIlvaine stated. "It makes for a bit of a double standard. If it's right and reasonable for new homes, why isn't the same standard there for existing homes? The differences contribute significantly to the energy efficiency and performance of existing homes when compared to new ones."

Under the Florida Building Code, standards set for replacement heating, ventilation, and air-conditioning (HVAC) equipment are minimal. Contractors are required to leave replacement equipment in a condition that is equivalent to what was originally approved at the time of the first installation. "So if a house was built before codes were instituted, or the HVAC system was retrofitted, there are essentially no requirements, which results in basically an anything goes approach."

"FSEC encountered a wide variety of how this was actually handled by program managers and mechanical contractors in the field," said McIlvaine. "We saw retrofit installations done by certified HVAC contractors who achieved results similar to high performance new construction and met some or all of the requirements imposed on new construction in Florida. This proves feasibility, especially since this was done in the affordable housing arena. On the other end of the spectrum, we saw contractors simply remove the old air handler, vacuum out the closet, then install the new one without addressing uncontrolled air flow pathways, such as open wall cavities in the return plenum. There is a huge range in conventional practice." (Refer to Figure 2, 3, and 4 for examples from the field.)

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Figure 2. Framed or "platform" return air plenum in an air handler closet in the conditioned space. Plenum had no air barrier, thereby connecting it to the walls and attic, and had dirt, debris, and fiberglass in the space. Photo courtesy Janet McIlvaine and the Building America℠ Partnership for Improved Residential Construction.

The vagueness of retrofit accountability also means that contractors doing a high quality job must compete with low quality installations in a market where the consumer doesn't have the information to differentiate between levels of quality. "Consumers don't even know they have a choice," McIlvaine said. "If certain quality guidelines were instituted into the mechanical code for existing homes, it would bring the competition more in line. The contractors achieving high performance levels wouldn't be cutting themselves short to compete."

Implications of Mandating New Construction Standards Hit Home

"That said, there are quite a few reasons that mandating any new requirements for retrofits sounds good conceptually but may actually lead to major problems," McIlvaine stated.

Focusing on mechanical system requirements, consider the following relevant characteristics: the vast majority of Florida homes have central cooling with central returns, rather than fully ducted returns. In Florida, almost all homes are either slab-on-grade construction, or have a small crawlspace. There are virtually no basements. The primary location for an air handler is either within the conditioned space in an interior closet with a central return, or, in newer construction, in the garage. Orchestrating a mechanical system change-out means dealing with factors already set in stone, like placement of ductwork, air handler closet (AHC), and return locations (see Figure 5).

"If you demand that new construction mechanical system requirements be met in every existing home, you could be in for real trouble and expense," stressed McIlvaine. Mandating the AHC clearances around the air handler found in new construction would mean moving entire walls and adjusting ductwork in certain existing homes. This represents a greater cost and increased scope of work outside of the mechanical contractor's range, as well as a financial burden and much higher "hassle factor" for the consumer.

"For one house in a related FSEC field study funded by the Florida Code Commission, in order to enlarge the existing air handling closet so that we could increase clearance for sealing, the homeowner either had to lose about 1/3 of their master bedroom closet or move the main electrical panel," McIlvaine said. "Changing out heating and cooling components already means a major financial investment for the homeowner. Adding an entire renovation to that picture rules out the possibility of replacement for many."

The ultimate lesson in practicality from the field study? "When we look at requiring a measure as part of a renovation program, we need to quantify the cost and improvement, and look at an array of solutions that contractors are already using. This is a step in understanding the implications of our decision," McIlvaine summarized. "For example, if a program requires sealing return plenums (see Figures 6 and 7), which is one of the best practices, program managers need to know what the major barriers are to achieving it,

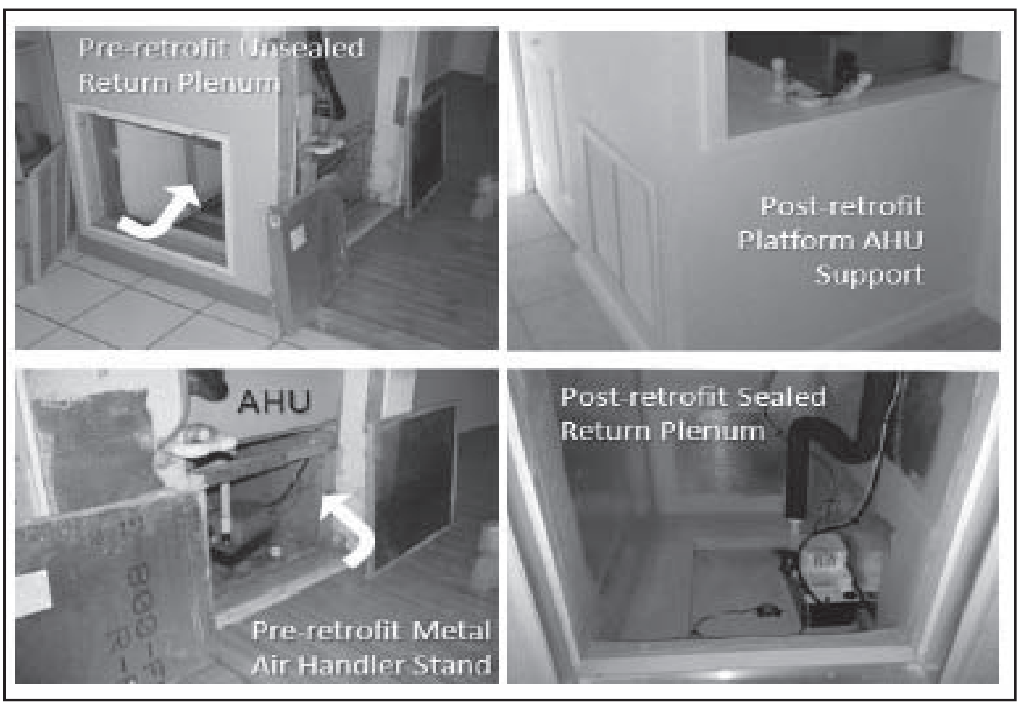

Figure 3. Pre-retrofit metal AHU stand with no dedicated return air path (left); post-retrofit platform AHU support with dedicated, mastic sealed return air path (right). Photo from *Applying Best Practices to Florida Local Government Retrofit Programs*, J. McIlvaine and K. Sutherland, Building America Partnership for Improved Residential Construction (BA-PIRC), December 2013.

Figure 4. AHU closet with side wall return grille: pre-retrofit (left) and post-retrofit (right). Photo from *Applying Best Practices to Florida Local Government Retrofit Programs*, J. McIlvaine and K. Sutherland, Building America Partnership for Improved Residential Construction (BA-PIRC), December 2013.

how prevalent the barriers are (2% of houses or 60%), and how their contractors would achieve the requirement. This requires commitment and interest – two important elements necessary for meeting high performance standards."

"Although this may seem like a straight forward requirement on paper, the reality is that it means something different in every house," continued McIlvaine. "If we want to step existing standards towards new construction codes, we need to be very sure we're not placing an excessive burden on the homeowner."

Balancing Desire and Reality: The Retrofit Challenge HVAC Standard

For the Retrofit Challenge mechanical system and infiltration standards, the team at BA-PIRC and FSEC sought to balance performance improvement for retrofits against these all-too-real barriers in performance present in the field. "In our Retrofit Challenge we are providing language and recommendations to encourage affordable housing programs, primarily, to adopt master specifications based on the findings of our field and pilot studies. Programs often have master specifications for other aspects of renovation such as plumbing fixtures, cabinets, floor finishes. We're fostering expansion of those to include specifications for occupant health and safety, building durability, thermal comfort, and energy efficiency," said McIlvaine.

Having clear, standardized language for communicating specifications has played a key part in the success of BA-PIRC's affordable housing partners. In Phase 1 of the BA-PIRC field study, researchers often observed scopes of work and bid documents written by local government partners that stated "all work shall be executed in accordance with prevailing codes." Program managers expected to get installations comparable to new construction. However, there are separate codes for existing homes that only require work comparable to the original approved installation. One of the refinements crafted after the field study for the Retrofit Challenge pilot was to add specific language modeled after individual provisions of the code requirements for new construction. For example, the criteria include system sizing using Manual J (1.2.b), AHU closet and return plenum construction, air distribution system sealing 1.2.c), R-6 ducts at replacement (1.2.e), and passive return air pathways (1.3.k), among others that are all required for new construction.

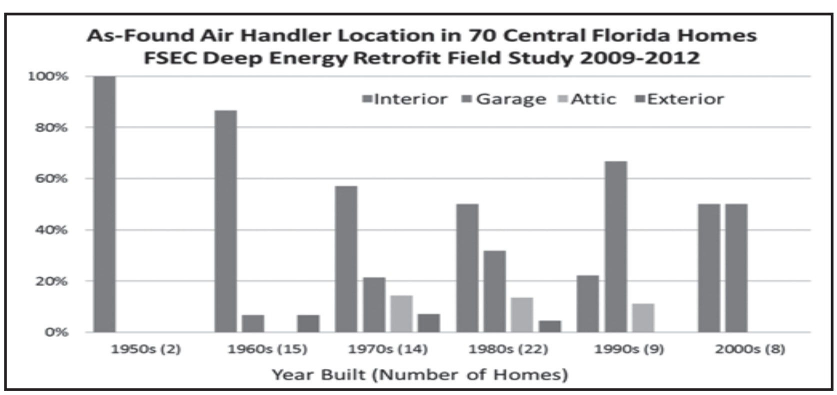

Figure 5. In a recent FSEC field study (McIlvaine, et al. 2012), 40 of the 70 homes had an interior air handler closet with a platform or full closet return plenum. These interior air handler closets generally manifested in the field study in two configurations: a framed platform supporting an up-flow air handler with through wall filter-back return grilles or a metal or frame air handler stand where the closet functions as the return plenum with return air pathways through louvered doors or door mounted grilles. Data courtesy Janet McIlvaine and the Building America℠ Partnership for Improved Residential Construction.

Figure 6. Framed Return Plenum retrofitted with ducted return air path formed by duct board sealed on the air barrier (foil) side. Note sealant at floor penetration. Photo courtesy Janet McIlvaine and the Building America Partnership for Improved Residential Construction.

The following is the list of HVAC and Whole House Air Tightness criteria for partner groups created by BA-PIRC based on the 70 house field study and the Retrofit Challenge pilot study:

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

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

1.1 Existing HVAC Equipment Not Being Replaced

a. Check/Service if needed: charge, condition of coils, condensate lines, exhaust flues, combustion air supply, gas lines, and other components.

1.2 Full or Partial HVAC System Replacement

b. ENERGY STAR heat pump

c. ACCA Manual J calculations

d. Seal accessible ducts

e. Modify AHU closets to create sealed return plenum with wall or ceiling return air grille

f. Duct Replacement: Install new ducts with R-value ≥ 6

g. When equipment and ducts are replaced, relocate AHU into conditioned space

h. Perform ACCA Manual S equipment selection

i. Perform ACCA Manual D duct sizing

j. Produce a schematic duct design for field crew

k. Conduct rough-in inspection

1.3 All Homes Regardless of HVAC System Replacement

a. Seal all duct connections in supply and return runs, return plenum, connections to AHU.

b. Conduct a duct airtightness test.

c. Eliminate louvered doors that serve as returns. Eliminate metal AHU stands.

d. Install and seal an air barrier to separate return from adjacent wall cavities.

e. Provide partial door above return.

f. Flex duct insulation covers all collar and boot connections.

g. Flex duct runs should not be kinked or have sharp bends.

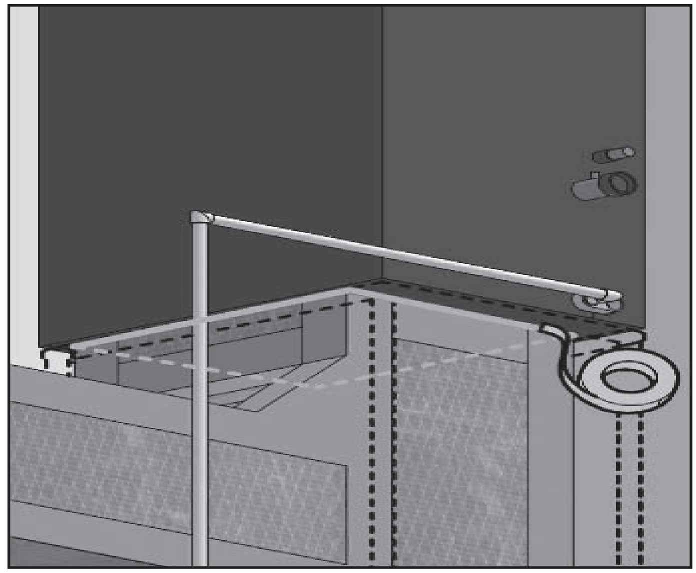

Figure 7. Detail for sealing the return plenum to the air handler. Image from Building America Measure Guideline: *Air Sealing Mechanical Closets in Slab-On-Grade Homes*, Bruce Dickson, February 2012.

h. Strap flex ducts to trusses every 5'.

i. Install MERV 6 filter.

j. Bathroom, kitchen exhaust fans and dryer ducted to outside.

k. Verify Bedroom Return Air per guidelines in Florida Mechanical Code Section 601.4.

I. Install a bath fan timer.

2 Whole-House Airtightness

a. Ensure whole-house air leakage of 6 or less ACH at the test pressure of 50 pascals (ACH50 ≤ 6.0).

b. Seal common air infiltration points with code-approved sealant.

(Source: McIlvaine et al 2013.)

Rubber, Meet Road: Lessons from the Retrofit Challenge

McIlvaine shared several key takeaways from the Retrofit Challenge pilot program and field studies:

- Learn climate appropriate strategies – both the theory and implementation. If the reasoning behind a practice is not well understood, there is a risk that it will receive a lower priority or be ignored, possibly increasing risk. Do a few trial installations of unfamiliar details and strategies before mandating them.
- Develop clear, standardized language for communicating specifications and expectations to contractors and subcontractors and other program stakeholders.
- Clear communication is necessary to ensure that high performance specifications translate into high performance results.

Energy Design Update thanks Janet McIlvaine, the Building America℠ Partnership for Improved Residential Construction (BA-PIRC), and the Florida Solar Energy Center (FSEC) for sharing their research and expertise with us.

In the final installation of this series, ***EDU*** will take an in-depth look at practical lessons for subcontractors and how these can affect outcomes.

Groups interested in taking The Retrofit Challenge may go to *http://www.ba-pirc.org/retrofit/PDFs/Pledge%20 1-27-14.pdf* to take the pledge. The Retrofit Challenge website is online at *http://www.ba-pirc.org/retrofit/index.htm*. FSEC and BA-PIRC invite partners from the remodeling, renovation, and affordable housing sectors to join them in this research.

IN DEVELOPMENT

Making Ventilation Control Smart

A much-anticipated development in ventilation, Lawrence Berkeley National Laboratory's (LBNL) Residential Integrated Ventilation Controller (RIVEC) *(http://homes.lbl.gov/projects/rivec)* will roll out later this year, becoming commercially available across the US.

RIVEC was developed by a team at LBNL led by Iain Walker, Max Sherman, and Darryl Dickerhoff. Funded by the US Department of Energy (DOE) and the California Energy Commission (CEC) Public Interest Energy Research Program (PIER), the goal set before RIVEC was to moderate the ventilation tug-of-war that ensues when ensuring indoor air quality (IAQ) and avoiding energy penalties. By using a dynamic algorithm that takes into account floor area, volume, number of bedrooms, infiltration, target ventilation rate, peak demand hours, and airflow capacities, RIVEC eases both energy consumption and conditioning losses while keeping contaminant exposure low (see Figure 8).

Simulations support RIVEC's energy savings potential. In a study of homes in 16 California climate zones, RIVEC was shown to reduce the energy penalty from adding whole-house ventilation by more than 40%.

To learn more about RIVEC, ***Energy Design Update*** spoke with Iain Walker.

What is the history of RIVEC at LBNL?

IW: The basic idea behind RIVEC goes back quite a long time. However, it is only recently that mechanically ventilating homes has been a big issue in the US. Part of the resistance to setting minimum ventilation rates, like ASHRAE 62.2, has been concern about the energy and conditioning penalties of ventilation. ASHRAE 62.2 essentially calls for a continuous flow of air through the home, based on size and occupancy. While we need to ventilate for IAQ, we don't want to pay for it with energy penalties.

So how do you minimize this conflict? Of course there are already devices that help, like Energy Recovery Ventilators (ERVs), but they are expensive and can be complicated to install. We began asking how we could minimize energy losses and maintain healthy air without the hassle.

First, we have to look at the impact of ventilation. The impact of ventilation depends on when you do it – you may have no impacts ventilating on a nice day. Conversely, in Minneapolis in January, the energy penalties for bringing in outdoor air are massive, because of the cold. So when you ventilate matters. If we can adapt that "when," we can minimize energy use.

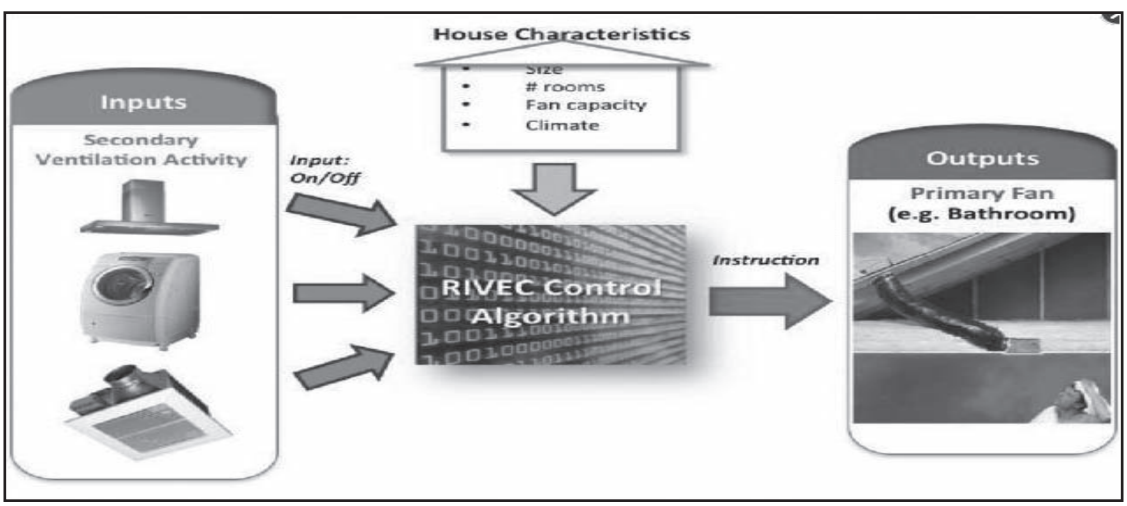

Figure 8. How the Residential Integrated Ventilation Controller (RIVEC) interfaces with home appliances and the building envelope. Image courtesy Lawrence Berkeley National Laboratory, from *Residential Integrated Ventilation Controller (RIVEC) Cleantech-to-Market*, Spring 2011, UC Berkeley Haas School of Business. Available online at *http://homes.lbl.gov/projects/rivec*.

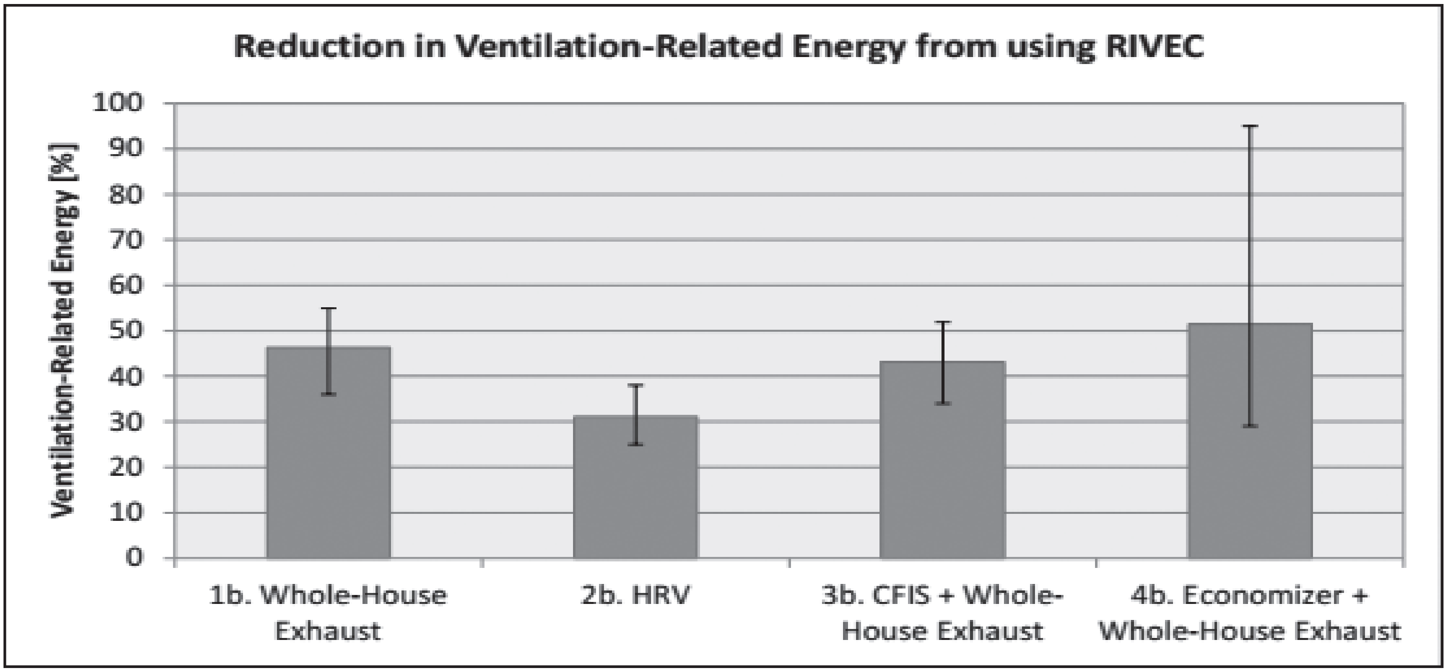

Figure 9. The reduction in ventilation-related energy from using RIVEC averaged across all house sizes, envelopes leakages, and climate zones. Graph and data courtesy Iain Walker and the Lawrence Berkeley National Laboratory.

That brings us to our next research question: How do you change the time you ventilate, but still maintain adequate IAQ? This is the principle of equivalent ventilation, or how ventilation changes with time to change pollutant levels. Because the concentration of pollutants is not proportional to the ventilation rate, you can't simply average to estimate exposure. The equivalency calculations are used to integrate the effects of changing ventilation rates on the pollutants and compare that to the concentration of pollutants found using a continuous ventilation rate.

The main issue is to ventilate the smart way – figure out what things are moving air, shift the times to minimize energy impact, and integrate the fan with non-mechanical ventilation paths.

So equivalent ventilation is the foundational concept underlying RIVEC's calculations. What were your parameters when you developed the algorithm?

IW: The key thing is to create simple representations of the problem that allow you to do calculations on the fly in the control system. One of the main things we wanted to capture in our control system was to ventilate when the energy penalty is the least. If we are in winter, what would the impact be if we turned the vent off from 4:00 a.m. to 8:00 a.m. when its colder, and instead ventilated more as the day warms up? How would ventilating in early morning hours during the summer look, both in terms of indoor conditioning and pollutant exposure? That was our "Mark 1" idea.

To support the added ventilation needed during more ideal weather conditions, we experimented with oversizing the system's fan by 25%, to compensate for time off. Our equivalent ventilation calculations let us figure out the appropriate sizing that is needed. For example, if the system was off for 4 hours, then we need to have that fan running about 25% more when it is in operation to compensate.

In our "Mark 2" iteration, we began asking whether we could account for the air flows in the equivalency calculations from other fans in the house, such as kitchen, bathroom, and clothes dryer exhausts, and save even more energy. These Mark 1 and 2 ideas were first evaluated in work for the California Energy Commission.

That's how we got started with smart ventilation.

What simulation and testing efforts are underway? How has the system performed in the field?

IW: Currently we are only evaluating RIVEC in research situations. We have a few tests in study homes, as well as extensive simulation efforts. Next year, we plan to expand the evaluations to include strategies to minimize humidity effects in humid climates.

We are currently working with Building America teams on a house outside of Chicago, Illinois to test temperature control strategies.

Trekking back to ASHRAE 62.2, the standard lets you take a credit for house leakage. We incorporated this leakage credit into RIVEC. By including this factor in the controller, the system can sense outside temperature and wind, and can estimate simple infiltration rates. If infiltration jumps, RIVEC can shut the mechanical fan off when it obtains enough filtration from leakage.

In testing we want to see confirmation of our controls and algorithms. The meat and potatoes is how it performs related to energy savings.

What benefits are you seeing from RIVEC? Did your hypothesis of energy savings hold up?

IW: Simulations demonstrate a 40% savings of ventilation related energy, which would equate to around a 5% to 10% energy savings from the whole house bill. Especially in a modern, high performance, energy efficient home, ventilation is proportionally more important, so these factors could go up (see Figure 9).

During peak periods, our research also indicates a 2kW peak load reduction for a typical home.

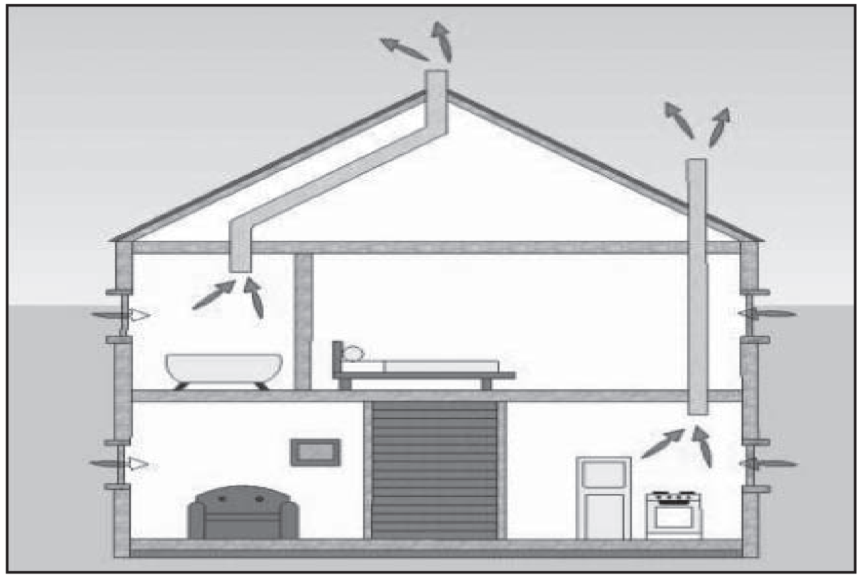

Figure 10. Passive stack ventilation. Image courtesy Iain Walker and the Lawrence Berkeley National Laboratory.

What can we expect as RIVEC comes to market later this year?

IW: The first generation of RIVEC will revolve around equivalent ventilation equations, making sure air is brought in efficiently while avoiding exceeding pollutant dose and exposure levels relative to a constantly operating fan. The control will operate based on time and sensors indicating which fans are on or off. Every few minutes the algorithm will weigh how much dilution there is from the current air flow and match that answer against the equation. RIVEC then makes the decision to turn on the whole house system based on dose and exposure. The concept of smart ventilation involves a bunch of things; however, it will always revolve around equivalent ventilation calculations of dose and exposure.

What's next for RIVEC?

Since proofing our initial algorithm, we have looked at accounting for occupied hours versus unoccupied. Would adding occupancy controls help lower energy use even more? We are also exploring the effects of passive stacks, like those used in Europe for ventilation.

Passive stacks take a pipe that opens into the kitchen or bath and goes up and out of the roof, constantly allowing for exhaust and removal of pollutants from the home (see Figure 10). We are working on adding controls that sense the airflow in a passive stack and would shut off the whole house ventilation system. For example, if we had a day with a minimal temperature difference and no wind, RIVEC could sense the lack of flow in the passive stack and then turn on the mechanical system. We would only need to intervene mechanically at times when the passive stack doesn't supply adequate exhaust. We also want to experiment with flow limiters on a passive stack, so on windy, cold days we can avoid too much air flow.

Our algorithm for occupancy will weigh reducing contaminant filtration for pollutants when people are absent against maintaining both acute and chronic exposure below the limits. When the homeowner is gone, can we allow the exposure ratio to rise slightly, but not beyond the acceptable point? Can we set calculations so that the fan runs just enough to keep the house below cumulative limits? Would we save energy by lessening run time while the home is unoccupied, and bumping ventilation up during occupied hours? Calculating exposure rates with an occupancy setting is a next step for our research.

EDU would like to thank Iain Walker and LBNL for letting us peek behind the curtain at RIVEC. To learn more about the system, visit *http://homes.lbl.gov/projects/rivec* or contact Walker at *ISWalker@lbl.gov.*

Dr. Iain Walker is a scientist at Lawrence Berkeley National Laboratory (LBNL). He has more than 20 years of experience as a building scientist and consultant, conducting research on energy use, ventilation, moisture, performance simulation, and commissioning/diagnostic issues in residential buildings. His current work focuses on retrofits, Zero/Low Energy Homes and heating, ventilation, and air-conditioning (HVAC) systems in residential buildings through field and laboratory evaluations, modeling and simulation activities, and standards setting.

IN PRACTICE

CEE Releases Heat Pump Water Heater Calculator

On May 13, 2014, the Center for Energy and Environment (CEE) unveiled its Heat Pump Water Heater (HPWH) Calculator (access at *http://www.mncee.org/Innovation-Exchange/Resource-Center/Data-and-Reference/Heat-Pump-Water-Heater-Calculator/*; see Figure 11), allowing homeowners and builders to easily evaluate total savings and simple paybacks from installation of a HPWH in their individual home. The data fueling the calculator has been gathered over several years, culminating in a white paper study evaluating how heat pumps affect houses from a whole house perspective (available at *http://www.mncee.org/Innovation-Exchange/Projects/Current/Heat-Pump-Water-Heaters--Savings-Potential-in-Minn/*.).

"Heat pump water heaters have been shown to save 50% on water heating," noted Ben Schoenbauer, Senior Research Engineer at CEE. "We wanted to know how they perform in cold climates." Unique factors in colder zones could play havoc with HPWH mechanics. Questions addressed by the research looked at what impact HPWH might have on space conditioning in a cold climate, how home characteristics interface with the equipment, and what a cold climate would do to the necessary heat transfer.

Water heating is the second largest energy user in residential homes in the US, and often this equipment can be very inefficient, with some unit efficiencies rated at only 60%. The promise of HPWH efficiencies was too great to ignore.

There is a Growing Need for More Efficient, Combustion-Safe Equipment in Cold Climate Water Heating.

According to Schoenbauer, 30% of homes in the midwest use electric water heating in some form. Not only are homeowners looking at more efficient ways to provide hot water, utilities are looking to reduce peak loads, and new construction codes are driving more interest in electric water heating to avoid combustion safety issues. The standard equipment found in this area is an electric storage water heater of 40 to 60 gallon capacity, with Energy Factor (EF) ratings between 0.89 and 0.95.

HPWH considered for the study are ENERGY STAR® integrated HPWH with storage of between 50 and 80 gallons, and a Coefficient of Performance (COP) at 2 to 2.5. These units rate greater than 1 in efficiency as they produce more hot water than they consume in electrical energy. The units have multiple modes of operation: heat pump only, hybrid, or resistance heat only. The units also have a measured cooling capacity of between 1.2 to 2 tons.

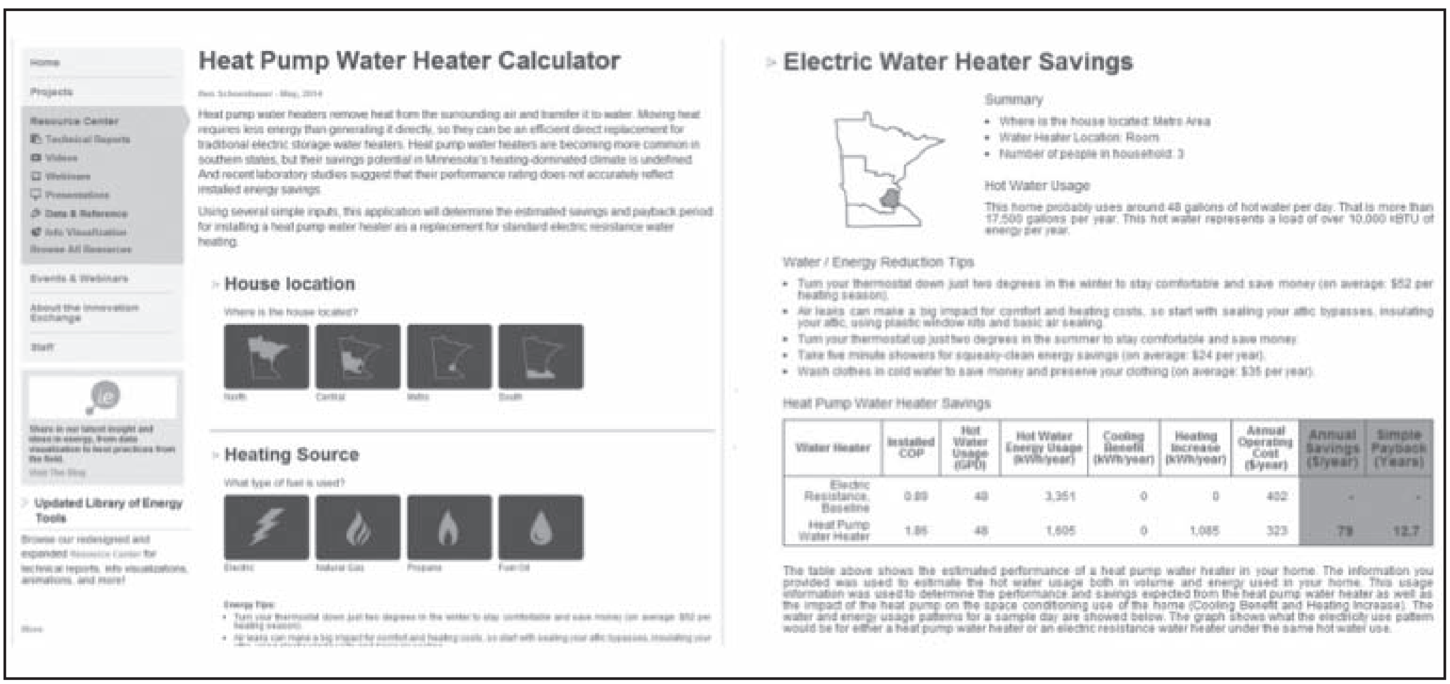

Figure 11. Heat Pump Water Heater Calculator tool homeowner example outputs. Visit the tool online at *http://www.mncee.org/Innovation-Exchange/Resource-Center/Data-and-Reference/Heat-Pump-Water-Heater-Calculator/*. Image courtesy Ben Schoenbauer and the Center for Energy and Environment.

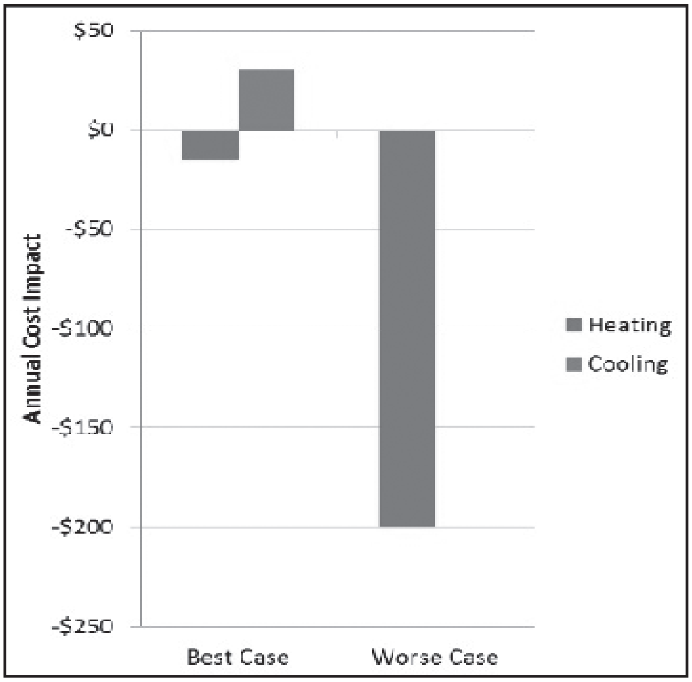

Figure 12. Best and worst case energy penalty simulation results from heat pump water heaters in cold climates, measured in dollar costs. Image courtesy Ben Schoenbauer and the Center for Energy and Environment.

Are We Losing Space Conditioning for Gains in Water Heating Efficiency?

Using HPWH in cold climate zones, despite the equipment efficiencies, raises a number of concerns. What is the impact of HPWH on the space conditioning load? Is there an impact from cooler ambient temperatures on HPWH efficiency and capacity?

Typically, water heaters in Minnesota are installed in the basement, which is considered an unconditioned or partially conditioned mechanical space. Temperatures in these spaces can range from 50 to 60°F. In 2011, Steven Winter Associates, Inc., issued a measure guideline for the performance of HPWH in HP mode only. At lower temperatures, where the average ambient temperature is 50°F, performance is lower than when the ambient temperature is near 80°F.

"If the heat pump water heater is in 50°F air and is producing 50 gallons of hot water daily, its COP is at 2; if you bump that temperature to 80°F, the COP goes to 3," stated Schoenbauer.

However, relocating HPWH into the kitchen or next to the living room, while introducing them to warmer air, has other impacts. A significant one to consider is the heat transfer impact of a HPWH. The efficiency of a HPWH is achieved by pulling heat out of the surrounding air and putting it directly into the water supply. In a cold climate, if a HPWH is installed in a conditioned space, those stolen BTU's must be replaced to maintain overall space conditioning, especially during heating season. Simply put, the HPWH has a heating penalty in the winter and a cooling benefit in the summer.

Although HPWH can produce significant cooling benefits – lab data shows HPWH delivery of 1 ton of cooling for production of 50 gallons of hot water per day – these benefits are minimal in northern climate zones.

The CEE team saw a best case scenario of a $10 increase in heating bills, if HPWH were installed within the conditioned envelope in a northern climate zone home. In the worst case, homes experience a heating penalty of $200 per year. This was especially true in homes with inefficient heating equipment and HPWH installed in a main living space (see Figure 12).

"You can minimize impacts by looking at installing HPWH in unfinished basements and by having efficient heating, ventilating, and air conditioning (HVAC)systems," Schoenbauer said."The question for us became how to characterize these losses and benefits accurately? Not only did we need to weigh the equipment in the house used for space heating, but also its efficiency and set points."

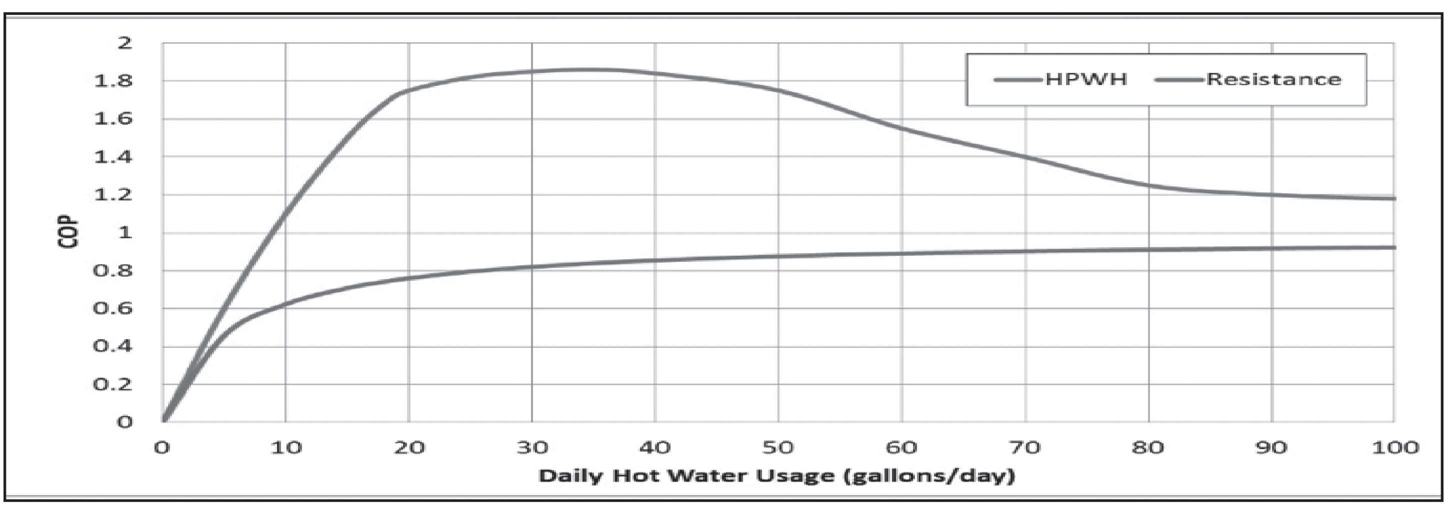

Figure 13. Coefficient of Performance (COP) for electric water heaters: resistance electric compared to heat pump water heaters, based on daily hot water usage in gallons. Image courtesy Ben Schoenbauer and the Center for Energy and Environment.

HPWH Efficiencies Justify Their Use in Most Homes, Despite Climate Zone Impacts.

Despite the challenges presented by cold climates, just changing water equipment efficiencies from a COP of 0.9 to 2 equals $250 per year in savings for a house using 60 gallons of hot water per day. This equates to a 3 to 6 year simple payback for HPWH.

Calculating actual savings is more complex. This number is based on installed location, ambient temperatures, the impact on space heating load, and how much domestic hot water (DHW) is used.

Daily hot water usage can dramatically alter savings profiles. For very low water usage, electric resistance and HPWH units perform much the same; above 15 gallons a day usage, HPWH provide great benefits. Yet this efficient effect is reduced at high usage rates, beyond 100 gallons per day. According to Schoenbauer, a HPWH peaks in performance at 20 to 40 gallons daily DHW usage (see Figure 13).

Despite heating energy penalties, the CEE team found that in the average Minnesota home, HPWH still make sense, and in most situations, result in an overall energy savings. HPWHs are not recommended in situations where they will be installed in occupied space or where the removed heat will be made up, i.e., where a thermostat controls.

Taking Accumulated Data Into the CEE Calculator Offers an Individualized Picture of HPWH Performance.

Actual savings is derived from balancing positive and negative impacts from the equipment. Taking aggregated simulation and field data, CEE developed the Heat Pump Water Heater Calculator, allowing builders and retrofitters to weigh whether or not HPWH make sense in an individual home. The Calculator takes into consideration home location, home heating source, equipment efficiency, home cooling source, frequency of cooling demand, water heater location, number of people in the household, and energy costs. It then projects expected energy savings for the home if a HPWH is installed.

The Calculator also offers simple payback information. HPWH are more expensive, and though more durable in the long run, can require plumbing modifications and new ducting when installed. According to the National Renewable Energy Laboratory (NREL), installed costs for HPWH are between $1400 to $2600; for electric resistance tanks the installed costs are $400 to $800.

Beyond individual homes, CEE is developing a Calculator for utilities to weigh benefits of HPWH adoption on peak load energy consumption. A HPWH at maximum draw uses 600 watts as compared to the 4000 watts or more used by electric resistance units. Outputs from the utility calculator will provide savings per day estimates as well as peak load impacts. In addition to HPWH, CEE will incorporate datas on electrical thermal storage water heater strategies, which heat water at off peak times, another method to reduce peak loads. These savings factors can be used to evaluate utility incentive and rebate programs.

Upcoming Research Will Evaluate Alternate Ways to Maximize HPWH.

Research teams within Building America are looking at several new ways to increase savings with HPWH, including optimizing HPWH for thermal storage. This method would run heat pumps to overheat the tank during the night, minimizing or alleviating the need for the unit to operate during the day.

Other research efforts will look into ducting and mechanical ventilation. Can a HPWH be linked with mechanical ventilation in the home? Could it be planned to capture waste heat in a home, and integrated with a mechanical room or bathroom?

The Northwest Energy Efficiency Alliance (NEEA) is also releasing new water heater ratings which may impact set-points. NEEA developed cold climate specifications for HPWH testing at colder ambient conditions. Work from NEEA has helped to drive manufacturers to look at cold climate impacts for HPWH.

Energy Design Update thanks Ben Schoenbauer, Senior Research Engineer at CEE, and the Center for Energy and Environment. Access the calculator online at *http://mncee.org/Innovation-Exchange/Resource-Center/Data-and-Reference/Heat-Pump-Water-Heater-Calculator/*. To view Schoenbauer's latest presentation, "Quantifying Energy Savings from Heat Pump Water Heaters in Cold Climates," go to *http://www.mncee.org/Innovation-Exchange/Resource-Center/Webinars/Quantifying-Energy-Savings-from-Heat-Pump-Water-He/*.

IN REFERENCE

Building America Solution Center Adds Mobile Apps, Support for Zero Energy Ready Program, Help for Code Compliance

Spearheaded by the Pacific Northwest National Laboratory (PNNL), the Building America Solution Center launched Building America Solutions, new mobile applications for Android and Apple programs. The apps were developed to render the Solution Center more customizable and accessible. Registered users of the Solution Center can organize relevant content into customized Field Kits. The Solutions app then synchronizes Field Kits to a mobile device with the push of a button. Once synchronized, users can access their customized content anytime, anywhere, with or without cell or Wi-Fi coverage.

"The key here is that users can take valuable, project-specific knowledge easily into the field, organized by their preference. We want this content accessible at any jobsite," noted Michael Baechler, Senior Program Manager, PNNL.

Solution Center content includes guides on topics from advanced framing, to installation of ducts and insulation, and over 125 specific measures for constructing high-performance, energy-efficient buildings.

The Solutions mobile app is available for Android tablets and smart phones running Android 4.0 or higher, and for iPad and iPhone devices running iOS 7.0 or higher. Android users can download the installer from *https://basc.pnnl.gov/* solutions, and iOS users can download from the Apple App Store using the search words: "Building America Solutions."

In addition to making the Solution Center mobile, PNNL has added a live checklist to help builders work with the Department of Energy's (DOE) Zero Energy Ready Home program. The Solution Center checklist will match the program checklist at each step, and includes provisions for pertinent parts of the Environmental Protection Agency's Indoor airPLUS and WaterSense programs. Beyond the checklist, the Solution Center also offers technical and installation support for the programs. The Solution Center already provides technical support for ENERGY STAR® for new homes program.

"The exciting thing here is not only that we now have Zero Energy Ready Home structure and content, we also have a lot of content for associated programs, like Indoor airPLUS," said Baechler. "Where we're headed is, by Fall 2014, we will build out checklists for these associated programs. We will be able to offer the builder a truly comprehensive site in terms of subject matter and support programs."

To visit the Building America Solution Center online, go to *https://basc.energy.gov*.

Launching in June 2014, Building America is taking aim at barriers to innovations from codes. Building America (BA) will release Code Compliance Briefs to facilitate the conversation between builders, installers, and code officials when an innovative product or technique is used in the field. The new content will reside under the Compliance Tab in the Building America Solution Center labeled "Code Compliance Brief."

The BA Guidance for Identifying and Overcoming Code, Standard, and Rating Method Barriers will be used as the baseline for determining if existing or new measure guides for the Building America Solution Center have a barrier. Resolving Code and Standard Barriers to Building America Innovations (CSI) barriers are defined as any requirement in a code, standard, or rating method that:

1. requires the wrong thing,
2. prohibits the BA innovation,
3. discourages a BA innovation, or
4. does not encourage a BA innovation that would lead to better, more efficient homes.

The intent for Code Compliance Briefs is to provide additional information to help assure the measure will be deemed in acceptance with the code or standard. Briefs will include notes for codes officials on how to plan review and field inspect and can also help the builder or remodeler with the proposed designs and provide the jurisdiction with information for acceptance. As part of the CSI efforts, the need was identified to develop additional guidance to builders, remodelers, and code officials through the Building America Solution Center measure guidelines.

"We already see a fair amount of traffic on the Building America Solution Center from code officials," stated Michael Baechler, Senior Program Manager at Pacific Northwest National Laboratory (PNNL). "At the same time, however, we want code officials to understand innovations coming out of Building America research programs. If code officials can't understand it and installers can't understand what innovations are, that's a barrier to them being implemented."

By providing the same information to all interested parties, the Solution Center hopes for increased compliance and fewer innovations being questioned at the time of plan review and field inspection.

"Code compliance briefs will focus on targeted technologies and provide bite-sized information on that product. The briefs are focused to provide a builder with information before a code official, and to feel confident talking about the innovation. The verbiage is compatible with official code language, and is written to provide information on how to perform a field evaluation of the innovation," Baechler added.

Two briefs have already been developed and can be viewed at the following links: *https://basc.pnnl.gov/code-compliance/double-wall-framing-code-compliance-brief*, *https://basc.pnnl.gov/code-compliance/bathroom-fan-ratings-code-compliance-brief*.

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