Actual vs. Predicted Moisture Performance of a Highly Insulated Wall

-Lois Arena, Senior Building Systems Engineer, Steven Winter Associates, Inc.

Excess interior moisture, bulk water intrusion, and capillary action can all act separately or in concert to create moisture problems within the building shell. Once moisture enters the shell, whether through actors like vapor drive, wind driven rain, or through a wood to concrete connection, its duration of stay can mean the success or failure of the shell. Trapped moisture translates into mold growth and material decay.

The potential for moisture to cause problems becomes even more pertinent with the increasing trend of highly insulated and “High-R” wall assemblies. While some hygrothermal analysis has been conducted on these high performance walls, there are few published works on moisture performance of high R-value walls and there has been even less field research to validate predicted results. In response to this, a team from Steven Winter Associates, Inc., under funding from the US Department of Energy’s (DOE) Building America™ program, set out to verify measured performance of highly insulated walls in the field. The goals were to monitor an actual high R-value wall assembly to determine the accuracy of the moisture modeling and make recommendations to ensure durable, efficient assemblies.

Data Collection
The wall assembly monitored and analyzed in this study was an R-40, double-stud cellulose assembly in Climate Zone 5A (see Figure 1). Two test bays were identified in the newly constructed home: one on the North and one on the South facade. Data recorded during the study included:

- temperature, relative humidity (RH), and moisture content (MC) of the studs at different heights and depths within the exterior walls;
- MC, temperature, and RH of the sheathing in the center of the bay as well as temperature and RH in the center of the wall cavity and just behind the sheetrock;
- interior temperature and RH;
- exterior temperature and RH;
- and, insolation on the South wall.

The section in Figure 1 shows the wall construction and location of the sensors.

During the sensor install in March of 2012, a handheld moisture meter was used to take multiple measurements of the studs and sheathing. According to these tests, initial MC in the sheathing ranged from 7.5% to 9.0%, and averaged 9.5% in the above grade studs, indicating that the materials were very dry and had been protected from wetting during construction.
In July 2012, the data logging equipment was installed and interior conditions recorded (Figure 2) including interior temperature and RH, MC of the sheetrock, and MC of the exposed framing in the basement.

As indicated, the interior RH and MC levels were quite high. This was due to the fact that the house had been closed up since completion of construction. The air conditioning system was turned off and no additional dehumidification equipment was present to remove construction moisture. Typical sources of construction moisture include freshly poured concrete, drywall compound, and painting. These components can supply significant amounts of moisture to the inside of the building during the first year after completion.

Modeling

Hygrothermal modeling of the test home wall assembly was conducted using WUFI 5.2. The interior conditions were determined in accordance with the criteria for design parameters (intermediate method) as outlined in ASHRAE Standard 160 (2009) and all current, applicable addenda. Interior and exterior boundary conditions are displayed in Figure 3.

Standard permeance values from WUFI’s data files were used for the majority of the building materials with the exception of the sheathing and the interior surface. According to the manufacturer’s data, the permeance for the exterior sheathing ranges from 0.3 perms at 0% RH to 13 perms at 100% RH. The interior of the drywall was coated with a vapor retarder primer with a rated water vapor permeance of 0.5 perms when the coating has dried. The exterior vinyl siding is applied directly to the sheathing and is considered by code to be a vented cladding. Therefore, an air change rate of 10 ACH per hour was assumed behind the siding.

Failure Criteria

Several failure criteria were identified, against which the wall assemblies were evaluated, including moisture content thresholds and drying potential of the assembly. It is often quoted that the minimum moisture content (MC) requirement for the growth of fungi is approximately 20% in wood corresponding to about

![Figure 1. Double-stud, dense-packed, cellulose wall assembly and sensor locations. Graphic courtesy Steven Winter Associates, Inc.](image)

Failure indicators were also measured against long term and short term drying potential. Overall, assembly moisture content should never increase over time and should ideally decrease. Individual components should dry to safe levels annually and the time spent at high levels minimized. Thresholds for decay – MC levels above 28% – should be completely avoided.

**Drawing Comparisons: Modeled Results vs. Field Data**

Overall, field data collected from the various monitoring positions in the walls show the assembly drying out from July until the end of September, at which time the sensors located in the sheathing and exterior studs show an increase in MC. The sensors on the interior studs show a decrease in MC in both bays during the entire monitoring period. The bottom plate sensors (exterior and interior) were the wettest of all the locations at the beginning of the monitoring period. For both walls, actual MC levels in the sheathing peaked higher than predicted in the software given the chosen boundary conditions. The actual versus predicted sheathing MC levels are displayed in Figure 4.

While the difference between the measured results of the two facades is significantly different, predicted peaks in MC are lower than actual for both walls. The actual results for the South bay sheathing show the MC values peaking around 17% and decreasing rapidly to 10% by
the middle of April. The North bay sheathing, however, peaks at just over 21% MC and drying of the assembly didn’t begin until late March. At the end of the monitoring period, the MC in the North sheathing was still above 15%. Another concern is that several of the sensors in the North wall’s exterior studs show increasing MC levels through the end of the monitoring period.

To evaluate whether or not the differences between the actual and predicted results were due to differences in actual and predicted interior and exterior conditions, the actual conditions were imported into WUFI and used in the simulation, however, doing so resulted in predicted MC levels that were even lower than those predicted using the WUFI weather file. This is due to the fact that the actual interior RH was significantly lower than assumed in the model. Winter RH levels fell under 30% for several months, while the assumptions used in the model resulted in levels between 40% and 60%. Therefore, using the actual interior conditions resulted in even lower predicted MC levels, even though exterior boundary conditions were less favorable for drying.

Further investigation into the reasons for the differences between actual and predicted results was conducted by altering several different parameters in the model, including permeance of the VR paint, permeance of the WRB on the exterior sheathing, moisture penetration into the wall assembly, and various combinations of these values. The most significant match occurred when assuming a 1% moisture leak – a possibility, given the sensor’s location beneath a window. When the North wall was modeled with a 1% leak behind the WRB onto the OSB, the predicted results very closely mapped the measured performance.

Reasons for the difference between actual and predicted performance for the South were not clearly identified. Little effect was seen from varying the perm rating of the WRB or from decreasing the perm rating of the interior VR paint. Increasing the permeance of the VR paint, on the other hand, resulted in even lower MC predictions and, therefore, was determined not to be likely considering the measured results.

Figure 4. Predicted vs. actual sheathing moisture content levels for the North and South walls. Graphic courtesy Steven Winter Associates, Inc.

Figure 5. Predicted sheathing moisture content levels over three years. Graphic courtesy Steven Winter Associates, Inc.
When evaluating this assembly over a 3 year period using the initial modeling assumptions and the ASHRAE 160 method, it is predicted that the sheathing will dry out seasonally and peak MC levels will decrease over time (Figure 5). Field data taken from the South bay support this conclusion.

**Lessons from the Study**

Overall, data collected from July 2012 to mid-April of 2013 indicated reasonable agreement with the modeling. Long term modeling results indicate that the test wall assembly should dry out over the course of the year and experience decreasing peak moisture content levels for the following years. These are major indicators that a wall is durable and shows good hygrothermal performance. Measured data for the South wall showed good agreement with predicted peak MC levels using the ASHRAE 160 design criteria. The increase and decrease of MC over the monitoring period was faster for the actual wall than predicted, resulting in less time spent at elevated moisture conditions than predicted, a positive for that wall assembly.

At the North wall, collected field data indicated a similar rate of response for moisture build-up and drying compared to predicted response from WUFI. However, peak MC levels were higher than predicted and reached approximately 21%, leading to concerns about potential mold growth. A more vapor open interior surface (10 perm) on this high-R assembly results in lower predicted peak MC levels and faster drying than the initial assumption of 0.5 perm for the VR paint.

Energy Design Update thanks Lois Arena and her team for sharing their research and report with us.

Lois Arena is a Certified Passive House Designer. She serves at Steven Winter Associates, Inc., where she also works on the Department of Energy’s Building America program and conducts advanced systems research. She received her MS in engineering from the University of Colorado’s Building Science Program and possesses over 17 years experience in the building science field. Arena may be reached at Steven Winter Associates, Inc, 61 Washington Street, Norwalk, CT 06854, via phone at 203-857-0200, ext. 214, or via email at larena@swinter.com.

**Pushing Boundaries on Performance & Design: the ClimateMaster Trilogy® 40 Q-Mode™ Geothermal Heat Pump (Part 2)**

The ClimateMaster Trilogy® 40 Q-Mode™ Geothermal Heat Pump is the outcome of a 5 year collaboration between ClimateMaster, Inc., and Oak Ridge National Laboratory (ORNL). The Trilogy 40 Q-Mode is an ultra-high-efficiency geothermal heat pump that provides space heating, cooling, and water heating. Laboratory evaluation and modeling by ORNL predicted that the Trilogy 40 Q-Mode could save 55% to 61% of annual energy use and cost for space conditioning and water heating in residential applications versus new minimum efficiency (SEER 13) air-source heat pumps and electric resistance storage water heaters. These savings results were confirmed in field trials. The Trilogy series also became the first geothermal heat pumps ever certified by the Air Conditioning, Heating, and Refrigeration Institute (AHRI) to exceed 40 EER at ground-loop (GLHP) conditions.

The Trilogy 40 Q-Mode reduces energy consumption by combining 3 variable speed technologies: an inverter-driven compressor, indoor air blower, and water pump, all of which feature permanent magnet electric motor technology, enabling greater efficiency at part-load conditions. This system concept uses one variable-speed (VS) modulating compressor, a VS indoor blower, a VS pump for ground heat exchanger (GHX) fluid circulation, and a VS pump for hot water circulation. A 50 gallon (~189 l) WH tank is included. (For further details on this system, please refer to “Pushing Boundaries on Performance & Design: the ClimateMaster Trilogy® 40 Q-Mode™ Geothermal Heat Pump (Part 1),” Energy Design Update, August 2013, Vol. 33 No. 8.)

**Measuring Innovation: Proposed ASHRAE Standard 206**

As equipment pushes the envelope, standards and ratings struggle to keep up, as well as to paint an accurate comparative performance picture for consumers. In parallel with Trilogy’s development and manufacture and availability to the public, ORNL participated in the push to develop a standard test method for integrated heat pumps.

“Once final, the new standard would be the basis for a certified rating program for this new category of product, and would enable consumers to understand the value of the product,” said Patrick Hughes.

For the team, ASHRAE Standard 137 and AHRI Standard 470 offered only partial solutions. With support from numerous participants, including ORNL,

The new metrics for integrated appliances would also allow easy comparison to metrics for individual appliances: for air source equipment: SEERca; HSPFca; EFca, while for ground source equipment: EERca; COPca; EFca. The “ca” in these descriptors means “combined appliance.”

“Standard 206 was out for public review for 45 days, and the period ended with no comments,” said Wayne Reedy, Chairman of ASHRAE SPC 206. “It is now moving forward in ASHRAE to be published. 206 was officially approved for publication by ASHRAE’s Standards Committee in and Board of Directors Denver in June 2013. Publication is expected by fall 2013.”

**Final Details**

Made available in limited quantities beginning December 2012, the ClimateMaster Trilogy 40 Q-Mode is offered in two sizes, with space heating and cooling capacities ranging between 9,000–30,000 Btu/h (2.65–8.8 kW) for the smaller model and 18,000–60,000 Btu/h (5.3–17.6 kW) for the larger (see Figure 6). The list price for the Trilogy is between $14,300 and $16,800. This places the system as one of the most expensive home heating, cooling, and hot water systems. However, CM maintains it can still be competitive on a first cost basis when compared to a traditional two-stage geothermal heat-cool system combined with a separate dedicated hot water unit that delivers similar capacities, even before energy and operating cost savings are taken into account.

Through 2016, builders and consumers can also apply for a 30% federal tax credit on the full installed cost of geothermal systems. Like any geothermal system, the Trilogy 40 Q-Mode does require installation of a ground loop heat exchanger, which adds to the system cost.

Given the number of operation modes and variables, the Trilogy 40 Q-Mode built significantly more intelligence into the unit to simplify diagnostics. The equipment carries an additional option to be paired with an Internet-enabled thermostat, further allowing for remote diagnostics of the unit.

“The Trilogy has a significant number of sensors and data points, almost a mini laboratory worth of sensors on the system that the user can pull up and look at data easily, and help troubleshoot what’s happening in the unit,” stressed Shawn Hern.

“This is not the first time integrated heat pump products have been tried,” Van D. Baxter summarized. “This initiative builds upon the past experience, technology advancements since then, and innovation. The compact heat exchangers ClimateMaster used, the built-in diagnostics, optimizing control of the air and water flows, and developing management of the refrigerant charge between different modes in a system doing several jobs – there is significant innovation there. The inverter cooling design is very innovative. There have been some enabling technologies developed between earlier IHP attempts and today that enabled
this design, like a more effective inverter-driven compressor, and improvements in fan motor technology. The pumps for ground loop and water are really state of the art, with top tier efficiency on levels not used widely as of yet in the US.”

The ClimateMaster Trilogy 40 Q-Mode Geothermal Heat Pump will be widely available to the public in the fall of 2013. Interested builders may contact their local ClimateMaster distributor prior to full release to check on availability. To visit ClimateMaster online, go to http://www.lsbindustries.com/climatemaster.

Wayne R. Reedy, FASHRAE, is the retired engineering manager at Carrier Corp., in Indianapolis, Indiana. Reedy is the recipient of the 2006 Richard C. Schulze Distinguished Service Award for his outstanding service and contributions both within AHRI and the industry. He has served as chairman of AHRI’s Unitary Small Equipment Section, the subcommittee on AHRI Standard 290P, and the subcommittee for the integration of heat pump equipment standards. Reedy, who holds 17 patents and has authored 15 technical papers, was named an ASHRAE Fellow in 2005, and received the ASHRAE distinguished service award in 2009. Reedy was a long time voting member of ASHRAE SSCP 90.2 for residential buildings, a past chair of ASHRAE’s Research Administration Committee, and past ASHRAE Director-at-Large. Reedy was named Outstanding Mechanical Engineer by Purdue University in 1996, and in 2005, Reedy received the International Energy Agency’s Peter Ritter von Rittinger International Heat Pump Medal.

Van D. Baxter has over 35 years’ experience in research and development in building heating, ventilation, air-conditioning, and refrigeration (HVAC&R) equipment with emphasis on vapor compression refrigeration and heat pump systems, water heating heat pumps, supermarket refrigeration systems, alternative refrigerants, and project management. He has published more than 50 papers and reports in the area of buildings energy efficiency improvement. Baxter is a member of ASME and ASHRAE. During his 30+ years as a member of ASHRAE he has held numerous positions, including chair, Research Administration Committee, 1998/1999; voting member Technical Activities Committee, 2008-2011; and, member ASHRAE Standards Appeals Board, 2011-present. He is active on the technical committees (TCs 2.5, 8.11, 10.7) for global climate change and heat pump and refrigeration equipment and systems, and the standards project committee (147) on refrigerant emissions. In 2012 he became an ASHRAE Fellow.
Baxter is also active in international collaborative R&D activities with the International Energy Agency (IEA) and the International Institute of Refrigeration (IIR). He coordinates the US National Team for the IEA Heat Pump Programme (HPP) on behalf of DOE/BTP and is the current chair (2012-2015 term) of the US National Committee for the IIR (USNC/IIR).

Dr. C. Keith Rice has 35 years of experience in energy efficiency R&D at ORNL, with particular emphasis on thermal systems modeling and analysis, performance-based cycle models, and equipment seasonal performance modeling. He has led the development of the hardware-based DOE/ORNL Heat Pump Design Model (HPDM), which is used extensively by both researchers and private industry. He has significant experience in the use of the DOE/ORNL HPDM for variable-capacity heat pump design and performance mapping. More recently, he has focused on the simulation of ground-source and water heating heat pumps and has used these modeling capabilities extensively in the design of integrated heat pumps for application to high performance residential buildings. Rice also leads the annual performance evaluation of these designs in the TRNSYS building energy use simulation program. He is co-holder of three patents, has been a member of teams winning two R&D 100 awards, and has more than 35 technical publications in energy efficiency R&D.

Edward A. Vineyard, P.E., FASHRAE, is the Group Leader for Building Equipment Research at Oak Ridge National Laboratory. He has over 30 years of experience in research and development of high-efficiency appliances, HVAC systems, and alternative refrigerants. He has published more than 50 technical papers and reports involving all aspects of improving efficiency for residential and commercial HVAC systems and appliances. He is an active member of the American Society of Heating, Refrigerating and Air Conditioning Engineers (ASHRAE) and has held numerous positions, including program chair of TC 8.4, Air-to-Refrigerant Heat Exchangers, vice chair of TC 9.1, Large Building Air Conditioning Systems, and chair of TC 7.1, Domestic Refrigerators and Food Freezers. He has received four ASHRAE Best Paper awards and both the ASHRAE Distinguished Service and Exceptional Service awards. In 2011, he was elected to ASHRAE Fellow. Vineyard also participated on team that received a DOE Energy 23 award for the highest rated national laboratory program in DOE’s history and has led or been a member of teams that have been awarded two R&D 100 awards for the NextAire Gas Heat Pump (2011) and the ClimateMaster Trilogy 40 Q-Mode Geothermal Heat Pump (2013).

**IN DEVELOPMENT**

**Goal Net Zero: Harnessing Energy with Greater Efficiency from the Sun**

“Approximately 15% of the sun’s energy can be captured by solar PV; most of the remainder is absorbed as heat,” Tim Merrigan, Senior Project Leader, Residential Buildings Research Staff at NREL, summarized. What to do with the other 85%?

The Echo® Solar System by SunEdison®, a photovoltaic and thermal combination system, proposes to answer that dilemma by capturing and using more of the sun’s potential energy. With two to three times greater efficiency than the average solar system, the Echo Solar System was developed by EchoFirst under a National Renewable Energy Laboratory (NREL) research subcontract, funded by the Department of Energy’s (DOE) Building Technologies Office, from 2005 to 2012.

The Echo Solar System’s innovative photovoltaic (PV)/(T) thermal system provides increased electrical energy performance over conventional PV systems due to the thermal cooling of the PV modules, especially in hot climates. The Echo PV/T system also uses a unique two-stage heating approach to provide renewable thermal energy for year-round water heating and winter
space heating, as well as utilizing its air-based system to run automatically on cool summer nights, to provide space cooling. The system additionally meets ASHRAE 62.2 criteria, with its ability to provide year-round residential ventilation (see Figure 7).

Funding and research for the Echo PV/T system were spurred by the DOE’s goal of reaching zero energy cost-effectively. To realize Zero Net-Energy Homes, the homebuilding industry needs low-cost renewable energy systems to provide necessary on-site electricity and thermal energy. While solar power obviously represents renewable technology, the new, highly efficient EchoFirst solar system proposed was revolutionary both in its efficiency and combination of components. Developers also sought a design combining PV and solar thermal components into one system to lower the overall equipment and installation cost, as well as to provide dual functionality, maximizing the available roof area.

**Product Genesis**

Between 2004 and 2005, under the zero energy DOE directive, NREL engaged in a competitive solicitation for technology to enable zero net-energy homes. The nascence of Echo PV/T came from this solicitation.

“We had 4 different groups working on ideas for zero energy homes. After our first phase – the ‘proof of concept’ phase, demonstrating that the idea works – we selected down to 2 teams. SunEarth Inc. had submitted a proposal to develop a combined PV/solar thermal system to generate electricity and hot water. In 2005/2006, SunEarth was 1 of those teams selected to develop a prototype,” Merrigan said. “The system was the brain child of bright engineer Josh Plaisted.”

After SunEarth built its first prototype, the group tested it at their Southern California facility, and based on testing, NREL decided to go to the third phase to commercialize the prototype (see Figure 8). At the same time, SunEarth spun off the PV/thermal company, initially called PVT Solar, and it received venture capital funding to support the PV/thermal design.

Simply described, the Echo system is designed so that as its panels operate to capture solar energy and
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convert it to electricity, the design also draws air beneath the solar panels. Captured heat from the sun is transferred from the solar panels to the air flowing beneath. This hot air is directed below the roof through an intake to an Energy Transfer Module (ETM). The ETM contains an air filter, heat exchanger, and high efficiency fan. The hot air is filtered and drawn across the heat exchanger, and then the heat is transferred to the hot water storage tank (refer to Figure 9). During heating season, the system can also provide excess heat to space condition a home. At night, the solar array can be used to draw cool air into a home, through radiative night sky cooling under the panels. There are 6 to 8 whole home air changes per day with this system.

After further testing, product development, and design optimization, PVT Solar came into the market aimed at new homebuilders. With an additional capital investment from Khosla Ventures, PVT Solar ramped up production, entered into a partnership with Meritage Homes in Arizona, and became EchoFirst. Today, EchoFirst systems are used by Meritage, Joseph Carl Homes, Toll Brothers, and other homebuilders in California, Nevada, Florida, Texas, North Carolina, Utah, and Arizona.

Making Performance a Reality

Electricity, home heating, home cooling, hot water, and fresh air ventilation – a weighty promise to be fulfilled by one system. Echo PV/T generates electricity by capturing energy from sunlight through its PV panels, in an operation comparable to any standard PV system. However, Echo PV panels, or modules, are designed to incorporate airflow beneath the PV system.

“It is so hot in the Southwest, and most PV cells themselves have a negative temperature coefficient – as they get hotter they lose some of their efficiency,” Merrigan explained about the reasoning behind the design. “In most situations, this is not a big deal, you expect it. Your PV panels are not going to produce the same amount of electricity as under standard test conditions. For example, a 200 watt panel rated at 25°C or 77 °F, during normal installed operation may produce 160 watts, rather than 200 watts. Now, if you do the same installation in Arizona, when it’s 110° outside and panels are heating up even more, maybe you only generate 140 watts, which is a big difference. By introducing air flow beneath and around the panels, you are cooling the PV system down, and you can bring it back up to normal performance.”

What to do with this super-heated air? Through capture of excess heat generated by solar energy, Echo also provides heating for domestic hot water, supplying up to 90% of a home’s hot water heating needs. Solar home heating is provided by utilizing any thermal energy available after water heating. The solar heated air is directed into the home’s HVAC ducting system or connected to a dedicated space register. A mechanical damper controls air flow into the home and opens when the temperature of the air leaving the heat exchanger coil is greater than the indoor temperature energy. For use in home cooling, the system captures radiative night cooling from the solar modules. During nighttime, the PV units act as heat radiators to the night sky and emit long-wave radiation. Air traveling beneath the units in the evening is cooled, and can be used to cool a home’s interior. Through the mechanical damper, a home is also provided with intermittent fresh air ventilation.

“Basically, the Echo idea is a 2-stage system,” clarified Merrigan. “To enhance the performance of the PV modules, Echo designed their placement so that air is sucked under the modules to cool them down and thus increase their capacity to produce electricity. Instead of wasting this air, Echo captures it and takes the heated air through an air-to-water heat exchanger. This same air can be used for space heating. If you have a cool enough night in the summertime, you can run air through the same system and cool the house air at night.”

Figure 9. The system at work. Captured heat from the sun is transferred from the solar panels to the air flowing beneath. This hot air is directed below the roof through an intake to an Energy Transfer Module (ETM). Graphic from EchoFirst, http://www.echofirst.com/get-to-know-echo.php.
Along with combining multiple functions, Echo PV/T systems use real-time performance monitoring, direct system and remote control communication with a home’s wall thermostat, and a web-based interface called Echo Control. Through Echo Control, a homeowner can select and activate ENERGY STAR® thermostat savings settings. Remote system monitoring for peak system performance is enabled on each unit, allowing the factory to obtain feedback and troubleshoot the system.

“That remote control is the other neat thing about this system,” stated Merrigan. “Every system that goes in is connected to the internet; the whole control scheme is very sophisticated, with an iPhone application that can set the thermostat, and web-enabled interaction. Echo can access the performance of every system they’ve installed to make sure everything is performing right, and is in range. This also enables collection of performance data on systems.”

The Echo Building Integrated Photovoltaic (BIPV) Roofing System is also a UL standard certified Class A Rated roofing system.

EchoFirst ran an analysis of the actual performance versus the predicted performance of the Echo+ solar system on 37 systems in the greater Phoenix, Arizona area, installed on single family detached homes (see http://www.echofirst.com/media/pdf/Echo-Solar-System-Performance-Analysis.pdf). The systems were installed on 4:12 pitched roofs (18 degrees) and were oriented from due east to due west. According to Echo, 2 sets of 20 systems each were analyzed for a 90-day period beginning January 1, 2011 and ending March 31 2011. Performance data from a separate 20 systems was also collected and analyzed from the period March 1, 2011 to March 31, 2011 (refer to http://pld.iapmo.org/file_info.asp?file_no=0007027 for system certifications). For solar electricity generation, performance against maximum California Energy Commission (CEC) AC nameplate was 94%. Performance against expected PV Watts (NREL) kWh AC output was 100%. For solar thermal generation, performance against OG-100 peak power nameplate was 124%.

According to the white paper released by Echo, the “Echo+ solar systems analyzed used either eight or nine SolarWorld SW230 Modules, each with a PTC Rating of 205.2 watts, and a Kaco ‘02’ Series inverter with 95.5% CEC rated efficiency. Each individual module therefore had a CEC AC watt peak nameplate of 196 AC watts and the solar arrays themselves were CEC AC watt peak rated at either 1,764 AC watt peak (9 PV module system) or 1,568 AC watt peak (8 PV module system).”

“To compare the measured energy performance against expected performance, the National Renewable Energy Laboratory’s ‘PV Watts’ model of solar performance was used. A DC-AC conversion factor of 84.8% was used as an input into PV Watts to coincide with the CEC DC to AC de-rate factor. The average performance was 100% of expected performance as predicted by PV Watts. For this analysis, PV Watts actual system orientation was used.”

While broadly found in new construction, with funding through SunEdison and WGL Holdings, Echo hopes to expand its influence into retrofits.

“Certainly the system can be used in a remodel,” said Merrigan. “Initial field tests were done using this system as a retrofit.”

“The DOE has been very supportive of this system concept,” Merrigan concluded. “This type of all-inclusive, renewables-driven system could be easily added to new home construction, especially to highly energy efficient homes, to make them net zero energy.”

To interact with a live system online, and to learn more, visit http://www.echofirst.com/.

Energy Design Update thanks Tim Merrigan for sharing his insights and expertise with us. Merrigan is a senior project leader at the US Department of Energy’s (DOE) National Renewable Energy Laboratory (NREL) in Golden, Colorado. Prior to joining NREL in 1999, he was with the Florida Solar Energy Center (FSEC) for 20 years. Tim has a Masters in Mechanical Engineering from the University of Central Florida (UCF) as well as a B.S.M.E. from Columbia University and a B.A. from Rollins College in physics.

Combating Quality Control Issues in the Field

What we’re seeing in the field is that our current model of training isn’t working... once trained contractors and subcontractors get out in the field, they’re still doing the work wrong. What can we do to make the training work, and get the job done correctly?

Taking Stock of the Problem

Heating, ventilation, and air-conditioning (HVAC) performance factors are affected by multiple variables: duct leakage, duct conduction, refrigerant charge, air flow, sizing, room-to-room air delivery, equip-
ment efficiency, and equipment defects. In a 2010 California research study, *Efficiency Characteristics and Opportunities for New California Homes*, lead by California Energy Commission’s Public Interest Energy Research (PIER) program, with significant support provided by Pacific Gas & Electric Company, Southern California Edison and Sempra Utilities, room airflow (in CFM) was found to be correct only 17% of the time; supply grill velocity was correct 25%; and, delivering the air to the unoccupied portion of the room was correct in less than 1% of homes evaluated. Bruce Wilcox led the project and John Proctor authored the report, with Rick Chitwood conducting field research. The project’s ultimate goal was to reduce end-use energy consumption and peak electrical demand in California by developing a baseline data set to support more accurate life cycle cost and energy savings calculations for efficiency measures to improve the California Building Energy Efficiency Standards for Residential Buildings (Title 24).

Among noted equipment defects in the CEC study were TXV’s not working, mis-specified orifices; mis-specified TXV’s; non-adjustable TXV’s; small refrigerant leaks; and, inaccurate air flow specifications. Across evaluated homes, Building Enclosure Tightness, Combustion Safety, Air Handler Static Pressure, HVAC Air Flow, HVAC Fan Watts, HVAC Duct Leakage, Delivered Cooling Capacity, and Delivered Heating Capacity all received “F” grades. Overall, Chitwood found 50% failures in the study sample.

### Aspiring Toward Better Solutions

“Chitwood’s work revealed that huge numbers, something like 60% of systems are 40% less efficient than they could be if they would just be tuned up correctly. There’s a problem that can be solved,” said Craig Savage of Building Media Inc. (BMI). “Clearly, what we’re seeing in the field is that our current model of training isn’t working. Once the training gets out in the field, contractors are still doing the work wrong. What can we do to make the training work, and get the job done correctly?

We began to ask what automated or cloud-based tools we could leverage to hopefully promote better compliance, quality assurance, and quality control, and as a result gain more efficiency and performance from energy efficient systems.”

To answer the dilemma of making training readily accessible and increasing compliance, Building Media is developing ENERGY STAR® in the Cloud (ESC), a cloud-based education and reporting package that will offer complete online training coupled with instruction-embedded checklists and real-time, smart-form reporting (see Figure 10). The comprehensive online training program is currently planned to be entirely free to ENERGY STAR Partners, paid for by a consortium of ENERGY STAR manufacturer partners. Builders would pay a nominal fee for each house they verify using the cloud-based reporting system.

The design plan calls for the ESC system to be composed of three interconnected parts: Training, QA/QC, and Reporting.

- **Training** is currently planned to include a comprehensive, online curriculum with 6 courses and 18 lessons. Consisting of 20+ hours of interactive presentations, experienced learners will be able to “test-in”...
through a Knowledge Verifier which will re-constitute the curriculum based on the user’s understanding of the topics. Online Lessons, typically under 15 minutes, will be filled with onsite photos, animated illustrations and site-produced videos that ultimately will find their way as interactive “explainers,” into part two, the cloud-based QA/QC ENERGY STAR checklists. Students completing the entire course will not only understand how to build an ENERGY STAR Home, but the building science behind why.

- Quality Assurance and Quality Control: Case studies, research, and third party verification reports all indicate that training – without jobsite quality controls – doesn’t assure proper installation and compliance in the field. “What is needed in addition to training, are tools that integrate the training directly into the quality control processes,” Savage said. The ESC system aims to provide cloud-based, checklist-driven processes that guide the builder step-by-step through the ENERGY STAR qualification process, from the first registration through the last verification. Every step is “checked off,” self-inspected, and recorded via audio notes, text, photos, and/or video, before moving on to the next task. In addition, embedded video “explainer” segments aligned to each task act as a refresher to the training, making clear the best practices, and work standards, with the aim of “right first time” quality control (see Figure 11).

- Recording: Built into the ESC system is a cloud-based reporting system that securely records and stores jobsite checklists and reports generated from the field. Documents stored on secure cloud servers are accessible with password protected access through a browser and an internet connection. To facilitate the verification and field-tests in accordance with Home Energy Rating System (HERS) Standards by a Rater, the system continues the unbroken flow of project information that began at the first task on the first checklist.

“Essentially, we are proposing a new, blended approach to training, a series that starts by flipping the classroom. Initial online training is supported by laboratory experience, more oriented towards real world problems an HVAC contractor will face. He or she will be presented with questions that arise in the field. The cloud-based training means a participant will have a constantly accessible tool box to help form a decision tree and proceed through a problem,” Savage remarked.

Savage further outlined the methods BMI hopes to encompass with ESC. “This tool needs to be oriented not just to general contractors, but also to subcontractors. When a subcontractor comes out to tune a furnace, they are provided with a checklist-driven, embedded training, that mimics what they have already taken. As part of the learning process, we propose to have them photograph their steps, and embed a series of photos from their handheld, so that their work is validated. Because the system is cloud-based, this checklist can be sent anywhere, and can be signed off and sent on to a rater, trainer, or contractor, for review.”

Currently, BMI is in initial negotiations with Home Performance with ENERGY STAR (HPwES) in...
Nevada to pilot the training tool. “With the increase in certification programs, there is a ready-made market for a simple-to-use, inexpensive system that eases the contractor’s and rater’s paperwork and logistics while increasing compliance and rating scores,” Savage emphasized.

Upon release, the ENERGY STAR in the Cloud training and interactive checklists will be available for free through a downloadable application for iOS and Android operating systems, with a small per-house fee to store checklists and documents. The costs of creating the comprehensive online training series will be covered by sponsorship fees paid by manufacturers, associations, and others who want to have visibility in the program. Sponsor’s logos, links, and product videos will be accessible, but not be part of the curriculum.

For further information on the program, contact Tami Svarfvar or Craig Savage at Building Media, Inc., at 1-802-476-8584 or 1-805-963-4353. They may be reached via email at: tsvarfvar@buildingmedia.com or csavage@buildingmedia.com. BMI may be visited online at http://www.buildingmedia.com

**IN BRIEF**

**Zero Home Opens to Public in Utah**

The result of collaboration between Vivint®, Garbett Homes, and KTGY Group, Inc., Architecture + Planning, the Zero Home in Herriman, Utah achieved a net-zero rating and scored a zero on the Home Efficiency Rating System (HERS). Heralded as the first affordable net-zero home in Climate Zone 5, the Zero Home model is also scalable and replicable, with the partnership planning homes for sale at $350,000. Zero Home is also the first residence to receive the US Department of Energy (DOE) Challenge Home status in the state of Utah, and is designated as both an Environmental Protection Agency (EPA) Indoor airPLUS Home and an EPA ENERGY STAR® Home.

Scoring a HERS 28 before installation of the Vivint Solar 10.29 kilowatt solar array, the home design incorporates sophisticated insulation, advanced framing techniques, and pre-cut floor joists and pre-built trusses. Exterior wall insulation is rated at R-31, with R-60 attics, and R-24 foundations and basements. DuPont™ Tyvek® Home Energy wrap, 2’x6’ exterior walls, 24’ on-center framing, spray foam and blown-in fiber insulation, and an Owens-Corning™ EnergyComplete® air sealing system, are some of the components within the 4,300 square foot home. Zero Home also utilizes Vivint CT clamps, lighting and small appliance controls, a programmable thermostat, and real-time energy analytics to give consumers insight into how they’re using energy so they can make their habits more environmentally friendly. Solar hot water and natural gas condensing tankless water heaters serve the home. The home’s furnace and air conditioner are expected to be needed only 3 to 5 days each year, leaving the homeowner with a predicted monthly utility bill near zero.

To learn more, go to http://www.thezerohome.com/en/.

**Michigan Saves Joins DOE Residential Network**

Based on work through BetterBuildings for Michigan (http://betterbuildingsformichigan.org/), part of a Department of Energy (DOE) grant, Michigan Saves has been accepted into the Better Buildings Residential Network. BetterBuildings for Michigan brings incentives and affordable loans to improve the energy performance of housing stock while lowering energy costs. Engineered to take a community-based approach, BetterBuildings for Michigan helps homeowners and businesses save money and creates a sustainable energy efficiency market. The program delivers energy efficiency improvements and affordable loans in key targeted areas throughout the state. The program aims to reach over 11,000 homes throughout Michigan and over 130 commercial buildings in the city of Detroit while creating over 2000 new jobs.

Beyond its work with BetterBuildings for Michigan, Michigan Saves also has a Home Energy Loan Program, which provides up to $20,000 to homeowners for energy- and renewable-energy improvements. The Loan program was launched in November 2012. No home appraisal or equity is required due to the organization’s non-profit status. A homeowner can choose from a list of qualified improvements, such as a new furnace or replacement windows. A homeowner may also get a home-energy assessment to find out how they can spend less money on energy at home. Participating lenders offer an unsecured loan at a fixed annual percentage rate no higher than 7%. Michigan Saves can also provide energy loans for businesses, which reduce costs by funding energy-efficient lighting, heating and cooling systems, refrigeration, and other applicable upgrades.

DOE is currently expanding its network of residential energy efficiency programs and part-
Inaugural members of the Better Buildings Residential Network include AFC First, Austin Energy, Boulder County, Clean Energy Durham, Clean Energy Works, CNT Energy, City & County of Denver, GTECH Strategies, LEAP (Local Energy Alliance Program), Metropolitan Washington Council of Governments, Michigan Saves, Mountain Association for Community Economic Development (MACED), and the New York State Energy Research & Development Authority. The Better Buildings Residential Network connects energy efficiency programs and partners to share best practices and learn from one another to dramatically increase the number of American homes that are energy efficient.

Since 2010, the US Department of Energy (DOE), local Better Buildings Neighborhood Program partners, and Home Performance with ENERGY STAR® Sponsors have leveraged over $1 billion in federal funding and local resources to build more energy efficient communities.


ASHRAE Unveils Recipients of Inaugural Innovative Research Grants
On August 1, 2013, in Atlanta, Georgia, the American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE) announced that it has awarded projects at Purdue University and Oklahoma State University with its newly created research grants. The grants provide funding for research having the potential to significantly advance the state-of-the-art in HVAC&R. The first two grants were awarded to fund research into nanolubricants and biowall technology.

According to the official ASHRAE press release, the ASHRAE Innovative Research Grant carries a base grant of $50,000 per year for two years, with an additional $25,000 available in the third year if matched by an industrial contributor.

“Our goal with the new grant is to encourage more out-of-the-box research to complement the research proposed and guided now by ASHRAE technical committees,” T. Agami Reddi, chair of ASHRAE’s Research Administration Committee, said. “We see it as providing seed money to encourage ‘blue sky research’ that may otherwise not be funded initially through other means.”

Recipients are Lorenzo Cremaschi, Ph.D., associate professor, School of Mechanical and Aerospace Engineering, Oklahoma State University; and William Hutzel, P.E., professor, Mechanical Engineering Technology Department, Purdue University.

Cremaschi’s project, “Smart Nanolubricants for HVAC&R Systems,” focuses on nanoparticles with purposely different conductivity, size, and shape. The research will advance the understanding of the interactions of the nanoparticles with refrigerant and lubricant flow boiling at the nano- and micro-scale levels, for which no previous studies exist.

“This research opens a new frontier for nanotechnology applied to air conditioning and refrigeration systems,” he said. “Driven by higher energy efficiency targets, there is critical need of major heat transfer enhancements in heat exchangers and nanolubricants, which are defined as nanoparticles suspended in high-viscosity suspensions, have the potential to address such need in a cost-neutral manner for both new and retrofitting residential air conditioning applications.”

Hutzel’s project, “Biowall Research,” will evaluate a biowall, which integrates plants with the return air of a residential or light commercial HVAC system to remove CO₂ and volatile organic compounds. Americans spend 90% to 95% of their time indoors, where levels of pollutants may run 2 to 5 times, and occasionally more than 100 times, higher than outdoor levels, according to Hutzel. Many of these pollutants cause adverse health reactions in building occupants, which can contribute to lower worker productivity and increased sick leave.

Traditional methods of indoor pollutant control in sealed buildings typically use some form of dilution ventilation using outdoor air. The outdoor air must be heated or cooled to meet indoor temperature and humidity requirements and represents a major thermal load of a building.

“This research will demonstrate and evaluate a novel biofiltration system that improves indoor air quality and has the potential for decreasing overall energy use by,” he said.

Content taken with permission from ASHRAE. To access the ASHRAE press release, go to https://www.ashrae.org/news/2013.
First Net-Zero North American Leadership Summit Announced
Touted as the first-of-its-kind gathering of industry leaders in the growing net-zero energy (NZE) movement, the Net-Zero North American Leadership Summit will be held in Irvine, California, October 8-10, 2013, in conjunction with the US Department of Energy (DOE) Solar Decathlon 2013. Hosted by the Net-Zero Energy Home Coalition, a multi-stakeholder not-for-profit organization federally incorporated in Canada, the Summit hopes to examine and debate model policies, finance and real estate solutions, technology gaps, and to foster data sharing. Ultimately, the meeting seeks to identify opportunities for collaboration in North America, and develop a “tangible, actionable, and aligned plan for catalyzing the market toward shared NZE goals.”

According to organizers, the Summit’s 3-day agenda has been designed to engage participants in an active dialogue, focused on the key issues. Day 1 sessions will focus on Big Picture issues; Day 2: Implementation Nuts and Bolts is categorized into three tracks: Evolving Practice, Building the Market, and Supporting Pillars. Day 3 will culminate with participants collectively mapping the path to zero. Attendees will also tour the DOE Solar Decathlon. Participants have been asked to read a “Collective Impact” article, available at http://www.netzeroenergysummit.com/collective-impact. For more information on the conference, go to http://www.netzeroenergysummit.com/agenda.

2013 Greenbuild® International Conference and Expo
The 2013 Greenbuild® International Conference and Expo will be held in Philadelphia, Pennsylvania, at the Pennsylvania Convention Center, November 20-22, 2013. The opening night keynote is scheduled to be given by former Secretary of State Hillary Rodham Clinton.

The Greenbuild 2013 Master Series speakers will include Avery Bang, Ron Finley, Scot Horst discussing Leed v4 and Performance, Ed Mazzia, Joe Van Belleghem, and Sheryl WuDunn.

To register, and for more information, go to http://www.greenbuildexpo.org/faqs/Cost-and-Registration.aspx.

DOE Releases Funding for New Space Conditioning and Insulation Technologies
On August 14, 2013, the US Department of Energy (DOE) announced $9 million in funding for 12 projects to develop new heating, cooling, and insulation technologies. The projects will also receive $1 million in matching private sector funding.

The DOE will invest $6 million into nine projects aimed at development of new, more efficient heating, ventilation, and air conditioning (HVAC) systems, and building insulation. Projects are also required to curb emissions of hydrofluorocarbons (HFCs). Of the grantees, the National Renewable Energy Laboratory (NREL) will receive funds to develop affordable vacuum insulation for windows; Sandia National Laboratories and United Technologies Research Center will help demonstrate a rotating heat exchanger technology for residential HVAC systems; and, Oak Ridge National Laboratory, along with Thermolift, Stony Brook University, and National Grid, will help commercialize their natural gas heat pump to provide heating, cooling, and hot water for homes and commercial buildings. Berkeley Lab and PPG were awarded funds to further study fluorescent pigments for high-performance cool roofing and façades; Argonne National Laboratory and the Illinois Institute of Technology will receive money to study acoustic building infiltration measurements; and, the Pacific Northwest National Laboratory will put funds towards dynamically responsive IR window coatings. Rounding out the projects, Industrial Science & Technology Network will study a new generation of building insulation, made from foaming polymer blend materials incorporating CO₂. For a full description of each project, visit http://www.eere.energy.gov/pdfs/et_selections_0823.pdf.

DOE also slated $3 million for 3 projects focused on open-source energy efficiency software. The University of California, Virginia Tech, and Carnegie Mellon University will develop software that helps building owners and operators measure, monitor, and adjust lighting, HVAC, and water heating energy use to save energy.

To access the DOE press release, go to http://energy.gov/articles/energy-department-invests-save-heating-cooling-and-lighting.