Energy Design Update®

The Monthly Newsletter on Energy-Efficient Housing

ASPEN PUBLISHERS

Vol. 33, No. 6 June 2013

IN DEPTH

CEE's Home Energy Improvement Index

Over the past 5 years, the use of home energy ratings as a tool to promote energy retrofits in existing homes has expanded rapidly. A home energy rating program typically provides a quantitative appraisal of a home's asset performance, with most models employing a benchmark such as the average energy use of similar homes in the same region. To affect change, a rating must not only inform, but also motivate homeowners. Home energy tools utilize several different motivation strategies. First, a rating may clearly communicate a home's achievable energy efficiency potential, spurring a homeowner to take action toward that new efficiency goal. Tools can provide a quantitative assessment of energy savings after retrofits are completed, creating a type of cost benefit analysis, helping a homeowner decide how best to invest in their home. Tools can also be designed to communicate how an individual residence compares to neighboring homes, creating pressure to conform to a social standard.

IN THIS ISSUE

Wolters Kluwer
Law & Business

With the proliferation of ratings tools, is there an ideal set of best practices when it comes to retrofit evaluation and motivational psychology?

In 2012, after 3 years of research, the Center for Energy and Environment (CEE), located in Minneapolis, Minnesota, launched their own ratings tool, geared specifically at their cold climate region. ***Energy Design Update*** spoke with Jennifer Edwards, Program Manager at CEE Innovation Exchange to learn more about the Home Energy Improvement Index, and lessons CEE learned along the way.

"We get asked, 'Why did we create another rating system?'," Edwards commented. "During our pilot testing of the Department of Energy's Home Energy Score, we watched homeowners fulfill all recommended upgrades yet still fail to achieve what they perceived as a good score. We watched a 'zone of unattainability' develop (refer to Figure 1). When overlaying the distribution of current scores under Home Energy Score with the predicted

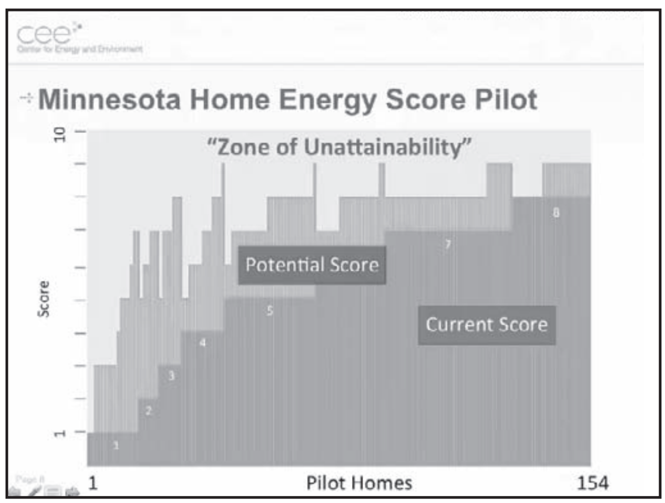

Figure 1. The "Zone of Unattainability," a glass ceiling on performance scores for existing homes that occurs in home energy rating tools. Graphic courtesy Center for Energy and Environment.

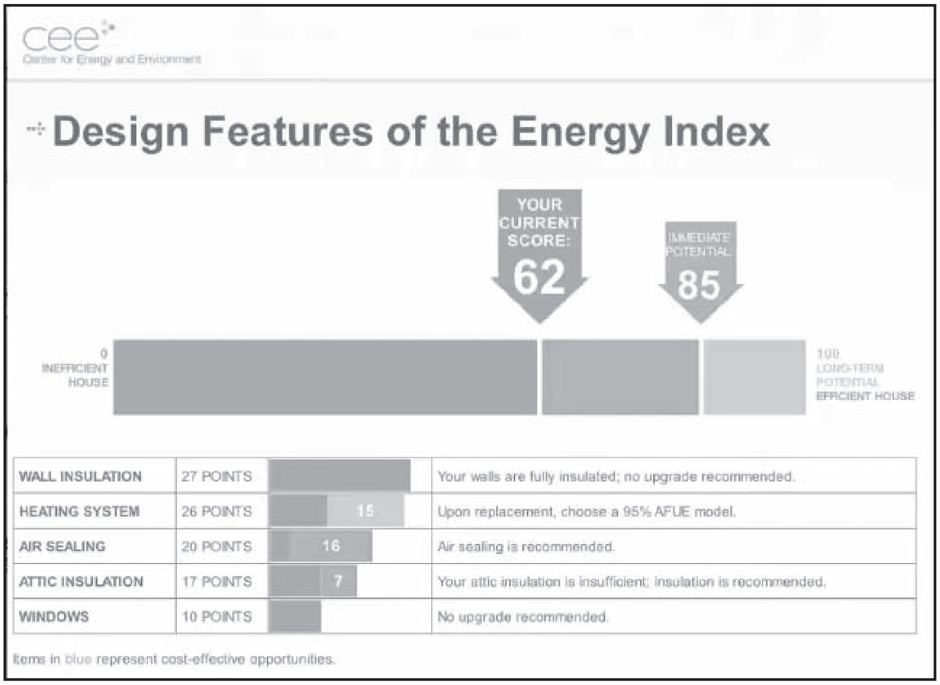

Figure 2. An example of a report generated by the Home Energy Improvement Index. Graphic courtesy Center for Energy and Environment.

increase of score, if all recommendations were completed, we see that no home is able to be perfect, thus the 'zone of unattainability.' While this is by design, so that only high performance and new homes can attain the highest score of 10, it does not help with motivating homeowners to do the upgrades. So we decided to design our own tool. We wanted a customizable rating to specific conditions we see in the home, which is different in Minnesota than from other parts of the country. For example, we typically we do not have ducts outside the conditioned space here."

The common approach to building a home asset rating incorporates site data collection, occupancy assumptions, building energy simulation models, and estimated energy use to calculate a rating or score. Generally, estimated energy use is compared across a similar population of homes and gauged by where an individual home's use lands.

"This does allow you to compare homes across a broad population. But we wanted to compare a home against what its fullest achievement level would be," said Edwards. "Other methods take a lot of extra time, involve a lot of data collection, and penalize lots of things that the homeowner can't change, such as color of roof, or orientation of windows. Also, the ability to predict energy use has to be based on perfect information; currently, estimated energy use predictions when compared to reality are not perfect, though getting better."

CEE research, and the resultant design, for a specific residential retrofit program encompassing a home visit, energy audit, and scoring tool, began in 2009 through Community Energy Services (CES). Over 5,000 homes in Minneapolis participated in CES during its first 3 years, a comprehensive home performance program, which uses community engagement in marketing by partnering with neighborhoods and local government organizations to raise homeowner awareness. The Services program was designed to be a pathway to energy savings for homeowners, which would address all aspects of energy use, including habits, direct installation of materials, and major energy upgrades. To ensure maximum follow through on Services recommendations, CEE also added a contractor program with quality assurance, as well as financing, funded by local utilities. In February 2013, the CES program was picked up by Xcel Energy® and CenterPoint

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Energy Design Update (ISSN 0741-3629) is published monthly by Aspen Publishers, 76 Ninth Avenue, New York, NY 10011. (212) 771-0600. One-year subscription costs $595. *To subscribe, call 1-800-638-8437. For customer service, call 1-800-234-1660. POSTMASTER: Send address changes to **Energy Design Update,** Aspen Publishers, 7201 McKinney Circle, Frederick, MD 21704.* **Permission requests:** For information on how to obtain permission to reproduce content, please go to the Aspen Publishers website at *www.aspenpublishers.com/permissions.* Printed in the U.S.A.

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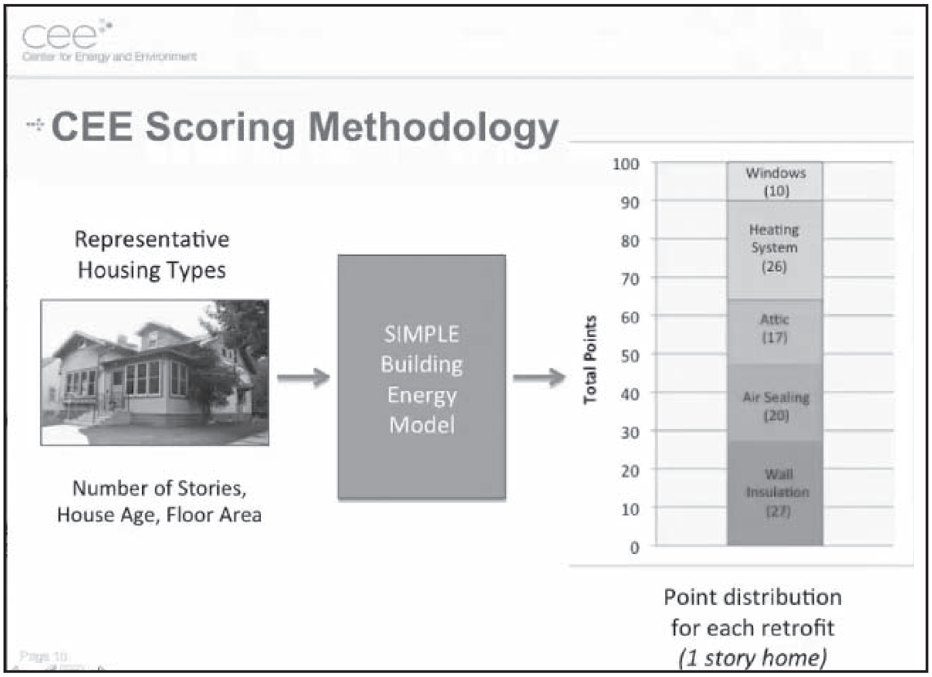

Figure 3. The CEE model sought a quantitative score, and influenced by the SIMPLE building energy model, modeled representative housing types categorized by number of stories, house age, and floor area. Graphic courtesy Center for Energy and Environment.

Energy®, and is now branded as the "Home Energy Squad Enhanced" program.

Based on data and experience gathered through CES, as well as interaction and study with national ratings tools, CEE developed the Home Energy Improvement Index. To date, CEE has delivered almost 1,000 scores in the Minneapolis and surrounding suburbs.

"What we ended up doing was using the SIMPLE model to develop our own home score, and make the tool a lot simpler and more relevant for homes in the Minnesota area," Edwards said. "Instead of rating a home on how it compares across the population, our program rates a home on how close it is to its fullest cost-effective efficiency potential. If a homeowner completes everything recommended, they get a perfect score."

SIMPLE, developed by Michael Blasnik and Associates, is a spreadsheet-based home energy model that runs on fewer than 50 streamlined inputs. It uses broad classifications for certain home characteristics and allows field technicians to switch between estimations or diagnostic measurements, depending on the scenario.

"For the energy retrofit market, it's all about getting cost down, and getting a usable tool. Comprehensive tools such as REM/Rate™ can be cumbersome, and take a lot of time and cost a lot. There are many good applications for that approach, but for the average homeowner, it is very consuming," stated Edwards.

CEE's Home Energy Improvement Index begins with a home energy visit, a 1 ½ to 2 hour visit with 2 energy experts, a counselor and a technician. The CEE counselor can perform direct installation of products like CFLs or LED bulbs and door weatherstripping while onsite. The technician conducts data gathering, performing blower door tests and insulation checks. An iPad is used on location for data collection, with a printed report generated at the end of the visit and given directly to the homeowner (see Figure 2 for an example of this report).

"In the field, the technician feeds data collection for a specific house through an API, which develops the score on site. This score tells us where that specific home actually is, based upon the 20 to 30 data points we collect," clarified Edwards.

The score is related to site energy use through a points system based on heating intensity of the home. But it is not meant to correlate with actual energy use, since it does not track all gas loads, and a score depends on *what remains to be saved*, rather than what is actually used. Nonetheless, when correlation was checked, asking whether homes with high scores did in fact show lower gas use intensity based on their historical energy usage data, the correlation was an R^2 of 0.31.

The CEE model sought a quantitative score, and influenced by the SIMPLE building energy model, modeled representative housing types categorized by number of stories, house age, and floor area. Using this typology, the data point distribution for 5 prioritized retrofit measures – air sealing, attic insulation, wall insulation, furnace upgrades, and windows – was quantified to display what the full potential would be for each housing type (see Figure 3).

For example, a single story 1920's home, with 2x4 walls typical of the period, would offer a maximum insulation level recommendation of R-11, based on constraints of the building type. If the total potential for wall insulation is 27 points, and the technician measures the existing wall cavity at R-3, the home has only achieved 1/3 of its wall insulation potential.

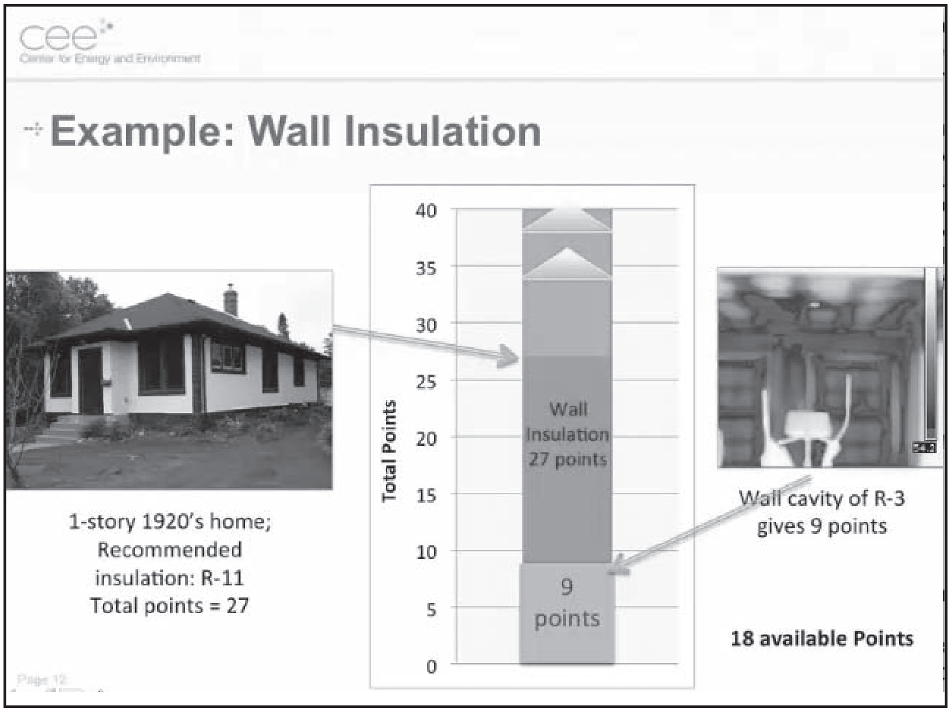

Figure 4. An example of Home Energy Improvement Index scoring. A single story 1920's home, with 2x4 walls typical of the period, would offer a maximum insulation level recommendation of R-11, based on constraints of the building type. If the total potential for wall insulation is 27 points, and the technician measures the existing wall cavity at R-3, the home has only achieved 1/3 of its wall insulation potential. For wall insulation, the homeowner would receive a score of 9, with a potential to earn all 18 remaining points if insulation levels are upgraded to reach R-11. Information and graphic courtesy Center for Energy and Environment.

For wall insulation, the homeowner would receive a score of 9, with a potential to earn all 18 remaining points if insulation levels are upgraded to reach R-11 (refer to Figure 4).

Based on the most recent data collected, there is a noticeable trend that older homes receive lower Energy Index scores. Homes built before 1920 received 56% of the scores below 40, and only 16% of the scores above 90. CEE believes that this is not due to structural conditions, but because these older homes have lower existing levels of wall and attic insulation.

"How different housing types score means you don't disadvantage certain housing types," Edwards said. "Which upgrades offer the most points? About 76% of points people can get come from completing near term cost effective recommendations, and within that wall insulation is the highest. Windows, in our area, represent less than 1% of available upgrade points. Future points are mostly from heating upgrades."

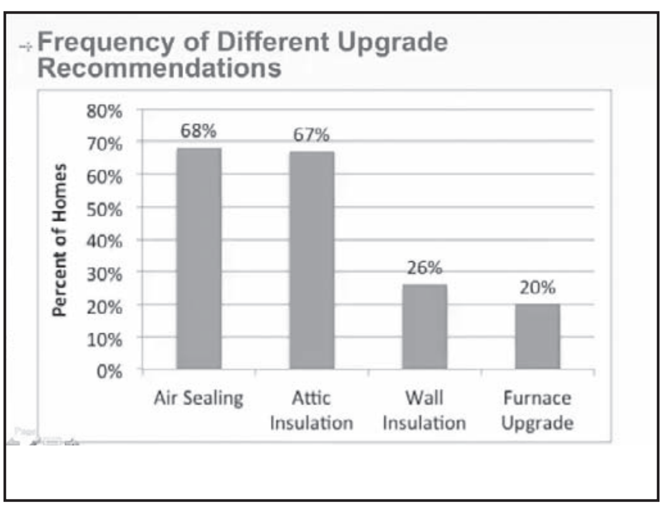

Figure 5. Recommendations distribution from the initial homes evaluated. Graphic courtesy Center for Energy and Environment.

CEE has applied the Home Energy Improvement Index rating to 788 homes to date. From initial data collected on the first 447 homes, 68% of all homes have had additional air sealing recommended, 67% of homes have had upgrades recommended to attic insulation, 26% have received recommendations to upgrade wall insulation, and 20% of all homes have had a furnace upgrade recommended. Air sealing, attic insulation, wall insulation, and furnace upgrades are the top 4 upgrades recommended (refer to Figure 5). Based on the most recent data collected from 788 homes, wall insulation holds the highest immediate potential for performance gains, followed by the heating system, air sealing, and attic insulation. CEE found that very few points are available from window upgrades. The dominant long-term opportunity remains upgrading to an efficient heating system upon replacement. Overall, most recent data maintains that 76%, a majority, of the available points are available from immediate actions.

For Edwards and CEE, the primary objective for the Index is to help increase the number of participants that complete recommended upgrades. Design features of the Energy Index are geared with that in mind.

"We want to create a tool that creates a clear prioritization and visualization of what to achieve, and why,"

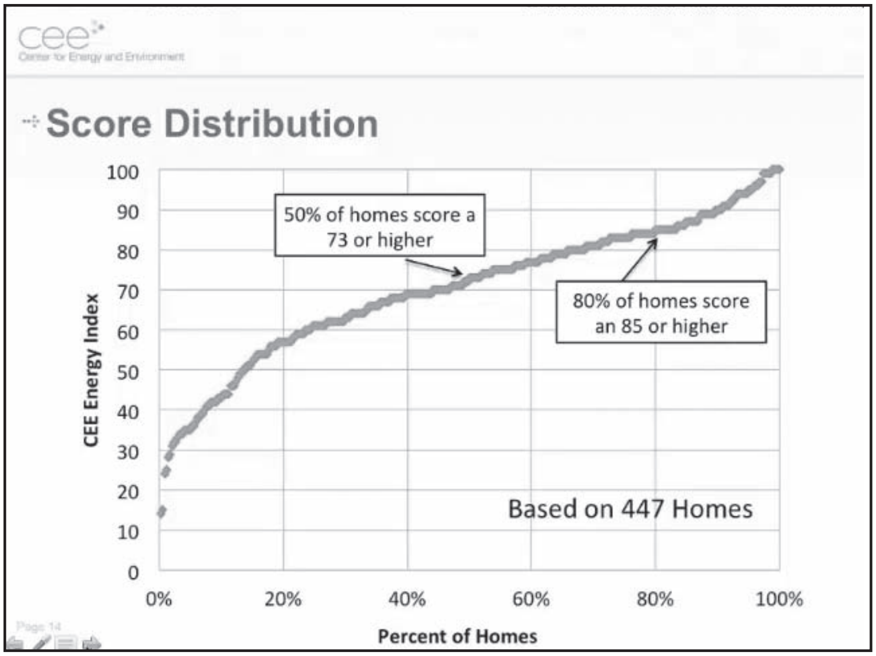

Figure 6. Of the first 447 assessed homes during the first phase, 50% scored a 73 or higher, on a scale of 1-100. Graphic courtesy Center for Energy and Environment.

Edwards said. The Index provides mechanisms to persuade the homeowner to complete recommendations by giving "credits" so that the homeowner can achieve a 100, or a perfect score (refer back to Figure 2). The Index creates actionable information about upgrades needed in the home both immediately, and over the long term. The rating focuses on the home, not on occupant behavior. The program does not discriminate by type or age of home, allowing every homeowner who completes the full recommendation checklist to get to a perfect score.

"This is a tool to motivate," Edwards clarified. "We want the homeowner to feel satisfaction when they've done what is recommended. We wanted to make it easy, but we wanted something with efficient quantitative rigor to still have sound, science-based reasoning for the homeowner to their make decision on."

A home's score links directly to recommendations of the technician, and only includes what can be cost effectively done in that house. The Index report makes both immediate and long term recommendations: immediate recommendations are shown in blue, with future improvements displayed in green. Frequent long term, or future, recommendations are replacing existing heating systems, upon failure, with a higher efficiency unit.

Of the first 447 assessed homes, 50% scored a 73 or higher, on a scale of 1-100 (refer to Figure 6). Poorest performing homes have scored as low as 15. Along with scores for current performance, after immediate upgrades, and after future upgrades, The Home Energy Improvement Index report also includes more information on testing results, available rebates, and homeowner next steps.

The latest CEE Home Energy Improvement Index results encompass 788 homes that received a score as part of their home energy visit in 2012. Fifty percent of homes scored a 71 or higher based on their home's current state. Homes in the 75th percentile scored an 83, and homes in the 90th percentile scored a 91. The minimum score was a 14, though only 2% of homes scored a 30 or below. Eleven homes, or 1.4%, scored a perfect 100.

The Index seems to be offering the right type of motivation. "People get scores equated with a C or B grade, and desire to get to that A," Edwards said.

After the initial test, CEE next steps for the Index include partnering with other groups to deliver the score in new regions. CEE will also investigate the impact of the score on homeowner follow through, and is considering refinements such as accounting for "above and beyond" energy retrofits, for example adding photovoltaics to a home. CEE also plans to design and offer a certificate of completion when homeowners have made upgrades, which hopefully translates into a sales tool for the homeowner, if needed.

"Other providers are interested in our approach, and whether it can be used to reframe current scoring methods," Edwards noted.

Energy Design Update thanks Jennifer Edwards and CEE for sharing their work on the Home Energy Efficiency Index. ***EDU*** extends additional thanks to the Research & Development team: Carl Nelson, Residential Program Manager; Dave Bohac, Director of Research; and Isaac Smith, Residential Program Assistant.

Jenny Edwards is a Program Manager with CEE's Innovation Exchange. She has been working in the energy field for nearly 15 years, including at the University of Minnesota, Lawrence Berkeley National Lab, and UC Berkeley's Renewable and Appropriate Energy Lab.

The Center for Energy and Environment may be visited online at *http://www.mncee.org/*, or contacted via telephone at 1-612-335-5858 or 1-612-354-2108.

IN DEVELOPMENT

Lawrence Berkeley Unveils Plasmonic Electrochromic Window Coating

Figure 7. Delia Milliron, Staff Scientist at Lawrence Berkeley National Laboratory's Molecular Foundry. Photo courtesy Delia Milliron.

Lawrence Berkeley National Laboratory's (LBNL) Molecular Foundry announced groundbreaking research on a new transparent electrochromic film that modulates near-infrared (NIR) solar heat gain without affecting visible light transmission. While traditional dynamic window coatings – photochromic, thermochromic, gasochromic, and electrochromic – can provide a range of solar control, they primarily modulate visible light. LBL's prototype plasmonic electrochromic coatings may offer a unique opportunity to selectively control the transmission of NIR without affecting visible transparency.

Initiating the research internally, LBL's Molecular Foundry recently received a Department of Energy (DOE) Advanced Research Projects Agency – Energy (ARPA-E) grant to further develop the technology. The research team, led by the Delia Milliron, Staff Scientist at the Foundry (Figure 7), aims to create a low-cost electrochromic window coating technology, which can respond to changing weather conditions by regulating the visible light and heat entering a building through its windows, reducing energy usage. The Molecular Foundry team is working in partnership with Stephen Selkowitz's Windows Research and Development team and the Energy Analysis Group, both of LBNL's Environmental Energies Technologies Division (EETD), and with Heliotrope Technologies.

Energy Design Update interviewed Milliron to learn more about the new coating, current laboratory results, and the pathway of future testing. "Over the past 2 years we've developed a new electrochromic with functionality. The principle we came up with is to find way to use nanocrystals synthesized chemically to absorb NIR, yet that stay transparent so the coating does not interfere with visible light transmittance (VL). We can thus drive a better solar heat gain coefficient (SHGC) without affecting VL. We are also looking at incorporating the new nanocrystal coating with a more conventional electrochromic to control light, so that a homeowner can tune selectively for NIR transmittance and VL," Milliron said (see Figure 8).

"This research is driven by 3 key factors: the functionality of controlling heat and light; the opportunity to actually manufacture the technology inexpensively, and modeling results," Milliron explained. "Frankly, modeling results are helping guide technology development, such as defining which markets are best for this application. Modeling will also help us predict which of the possible solution process options are best, what are our branch points in the decision to manufacture, and which approach will give us the most cost savings. We need to have a full picture of lifecycle costs, embodied energy, and payback."

Figure 8. West facing windows absorb heat through the sun. The principle behind the proposed technology uses nanocrystals synthesized chemically to absorb near infrared light and inhibit solar heat gain, while staying transparent so that the coating does not interfere with visible light transmittance. Photo courtesy Delia Milliron and Lawrence Berkeley National Laboratory.

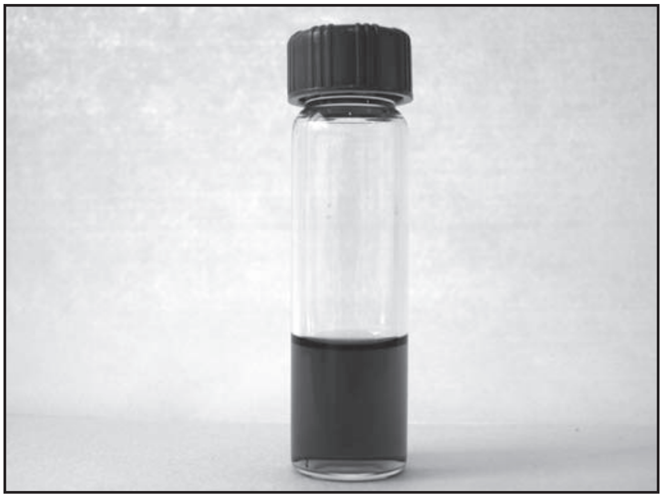

Figure 9. A vial containing the nanocrystal dispersion. Photo courtesy Delia Milliron and Lawrence Berkeley National Laboratory.

Because this approach can reduce solar gain without inhibiting daylighting, Milliron feels this technology may be better positioned against competing, traditional window glazings. By separately tuning the incoming NIR, which generates heat, and VL, which can provide daylighting, LBL hopes this technology will improve the energy efficiency of buildings by reducing the need for both air conditioning, heating, and electric lighting, and by enhancing the comfort of occupants, by managing the visible light that enters. LBL's breakthrough electrochromic nanotechnology is based on a plasmonic electrochromic effect that dynamically modulates the localized surface plasmon of doped semiconducting nanocrystals. An applied voltage is used to alter the optical properties of the glazing. In a dynamic window construction, voltage control strategies could be tied to HVAC setpoints to ensure effective operation. Based upon current laboratory testing results, the prototype phase technology can modulate up to 60% of solar NIR (Figure 9).

"We did a lot of materials development; these test units are all coated using a solution processing, making their eventual manufacturing process a lot cheaper, so that we can bring this technology into reach of the average consumer," Milliron clarified. "We are at the stage now where our team is building the materials into a complete prototype. Modeling will help us define the target dynamic range for NIR and VL modulation and to predict how dark and clear the tints can be. This development will take place over the next 3 years, funded by ARPA-E. Our goals will be to optimize optical and switching performance. We will be asking how much infrared we can manipulate, and maintain VL? These initial stages will also help us develop a scalable manufacturing approach. Techniques like spray coating – how do they translate to the large scale, and how can we bring manufacturing costs down?"

Milliron used degenerately doped semiconductor nanocrystals (NCs), such as tin doped indium oxide (ITO), that have a well defined localized surface plasmon resonance (LSPR) in the NIR region of the solar spectrum. When activated by an applied voltage, ITO NCs show a large spectral shift in their NIR LSPR due to electrochemical doping (Figure 10).

"The nanocrystals are synthesized using the standard chemical technique of colloidal chemistry; using a flask of solvent, we bring the components of the nanocrystals to a chemical reaction, and after growth in an organic solution, we isolate them with a standard purification technique to got a stable solution. Related procedures have been used for large area coatings and devices like static optical films, displays, or photovoltaic cells."

"I've always been interested in electrochromics as a nanomaterials chemist," Milliron said. "It was really through talking with my colleagues in window development that my perspective was informed, and I understood the need. One of the things that's really needed is a way to control IR transmittance. 10 years ago the community took a preliminary look at electrochromic properties of nanocrystals, but it was not suitable for windows. I figured that we had made a lot of progress in the last 10 years, and that maybe with a twist on chemistry and composition, we could move the spectral features into the wavelength range that really matters for solar radiation."

According to initial laboratory research (Refer to Guillermo Garcia, Raffaella Buonsanti, Evan L.

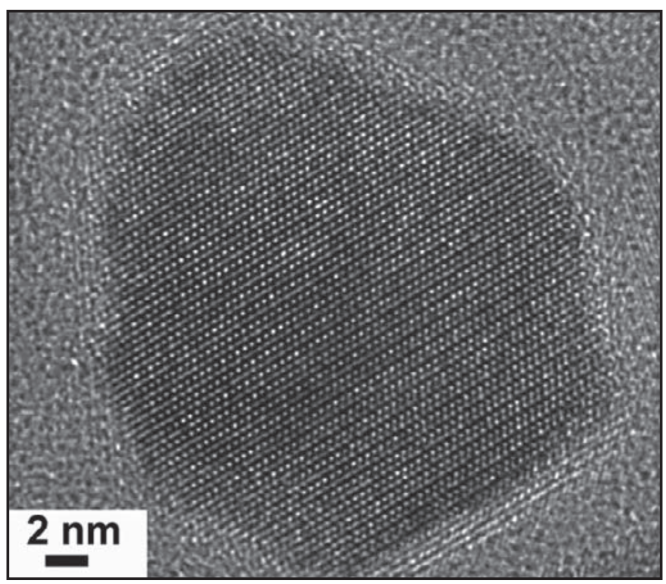

Figure 10. High-resolution transmission electron microscopy image of an electrochromic nanocrystal. Photo courtesy Delia Milliron and Lawrence Berkeley National Laboratory.

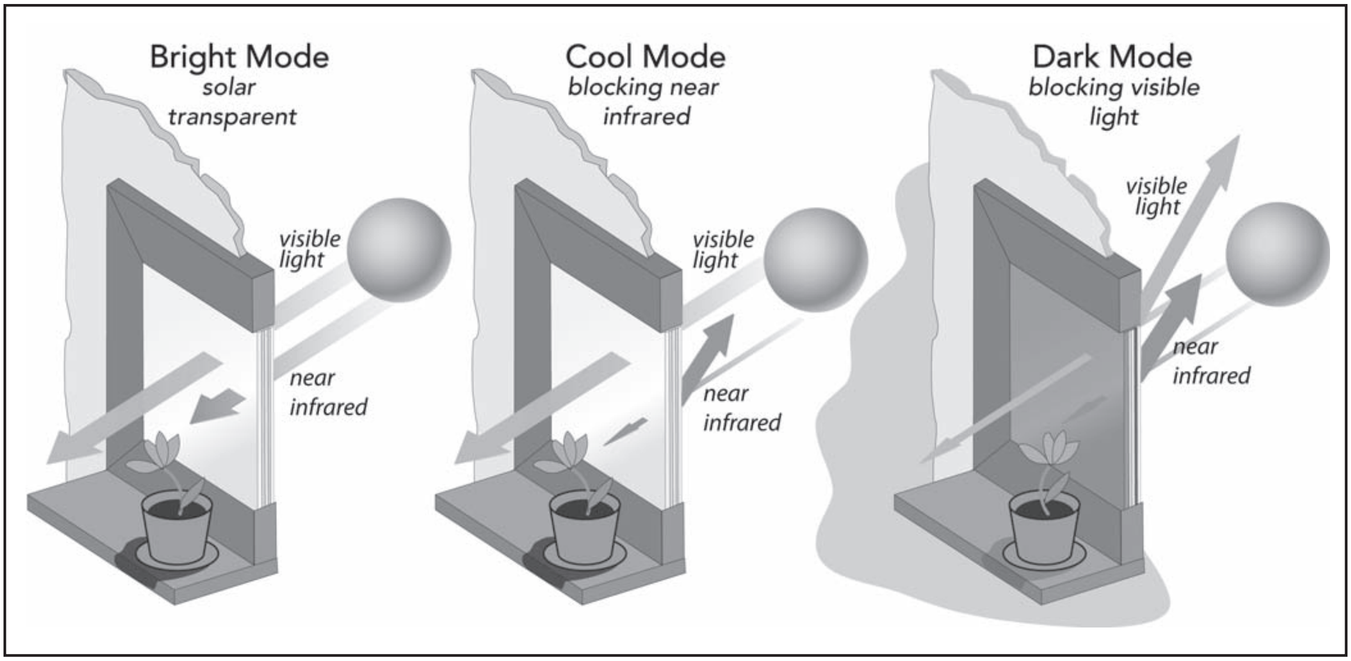

Figure 11. Milliron's team will also investigate coatings that combine the near infrared-selective plasmonic electrochromic effect with conventional electrochromic materials that can also modulate visible light, on demand. Photo courtesy Delia Milliron and Lawrence Berkeley National Laboratory.

Runnerstrom, Rueben J. Mendelsberg, Anna Llordes, Andre Anders,Thomas J. Richardson, and Delia J. Milliron, "Dynamically Modulating the Surface Plasmon Resonance of Doped Semiconductor Nanocrystals," Nano Letters, *http://pubs.acs.org/NanoLett*) by utilizing capacitive charging, plasmonic electrochromic coatings can achieve larger optical contrast with minimal charge requirements. Optimization of nanocrystal size, chemical doping level, and film thickness may enhance these results. VL was preserved in the tests, with over 92% of light transmittance preserved during the product's colored state to inhibit solar heat gain. The plasmonic electrochromic coatings also appear to maintain stability, with positive implications for the device's lifecycle. Durability test performance resulted in an 11% reduction in charge capacity after cycling 20,000 times between the applied voltage extremes. Nevertheless, this slight loss in charge did not seem to affect the optical performance. Milliron postulated that charge may have dropped due to solvent evaporation in the cell.

"We built some initial small-scale prototypes, about 1" square, to show that the coatings can switch, and carry out fundamental predicted properties. From there, we have collaborated with the energy analysis team, to get some initial modeling of possible energy savings," Milliron stated.

Actual savings from these technologies will depend heavily upon their performance in diverse climate and operational conditions. LBL used COMFEN 4 software, an EnergyPlus interface, to simulate a broad range of performance levels for commercial and residential buildings in 16 climate-representative reference cities. The software also models window to wall ratios, internal floorspace, and heating and cooling loads. The results will gauge performance of the prototype technology against existing static technologies.

Best-case results for LBL's new plasmonic electrochromic coating showed an annual heating, ventilation, and air-conditioning (HVAC) energy savings potential as high as 11 kWh/m² a year for commercial buildings, and 15 kWh/m² year for residential, over the highest performing static glazing. Due to schedule of occupancy, lighting and miscellaneous loads, which contribute to internal heat gains, the technology shows the most promise, and greatest energy savings, for residential application.

Among the 16 reference cities, the simulation showed that the technology performed worst in Miami, as increased transmitting functionality is nearly worthless, and even the highest transmitting SHGC enables little discernible performance reduction in the blocking state. Chicago, Boulder, Minneapolis, Helena, Duluth, and Fairbanks showed greatest promised, based on delta ratios between transmitting and blocking performance. San Francisco, while energy-savings favored blocking, was still viable. Energy analysis showed that, outside of a select few hot Southern regions, meaningful savings can be realized from the new glazing prototype. This study finds that outside of the hot, sunny region of the southern US, nanotechnology electrochromic glazings, defined as those that maintain high visible transmittance but switch over a wide range in the NIR, have significant potential to outperform static glazings on the basis of heating and cooling energy. The report concluded that, ultimately, it is the fixed, highly visible transparent nature of the nanotechnology that constrains its applicability, because the highest performing blocking state still transmits approximately 30% of the solar energy in the form of visible light. (To access the full energy analysis report, see "Regional performance targets for transparent near-infrared switching electrochromic window glazings," Nicholas DeForest, Arman Shehabi, Guillermo Garcia, Jeffery Greenblatt, Eric Masanet, Eleanor S. Lee, Stephen Selkowitz, Delia J. Milliron. Building and Environment 61 (2013) 160e168. *http://www.elsevier.com/locate/buildenv*.) For this reason, Milliron's team is currently investigating coatings that combine the NIR-selective plasmonic electrochromic effect with conventional electrochromic materials that can also modulate visible light, on demand (see Figure 11).

"Further improvements are currently being investigated to enhance the glazing performance and establish market deployment opportunities in the next 3 to 5 years," Milliron said. "Ultimately, the potential for success will depend on how effectively this technology performs in reducing building HVAC loads through blocking or transmitting NIR heat, and reducing lighting energy by transmitting visible light."

"Our research is now going to the next step from clear IR transmittance, to darkening the window to also control VL. We are adding a new functionality. Even just for NIR our energy analysis shows a pretty compelling market, with residential energy savings more significant, as the northern markets can really take advantage of solar heating in winter."

Energy Design Update would like to thank Delia Milliron and Lawrence Berkeley National Laboratory for sharing this research with us.

Delia J. Milliron is a Staff Scientist at Lawrence Berkeley National Laboratory, a research center and user facility for nanoscience supported by the U.S. Department of Energy. She received her PhD in Chemistry from the UC-Berkeley, in 2004. From 2004 to 2008 she worked for IBM's research division, investigating opportunities to use nanoparticle materials in next generation data storage technologies. Her current research is motivated by the potential for nanomaterials to introduce new functionality to and reduce manufacturing costs of energy technologies. Her group's activities span from the fundamental chemistry of nanomaterials to device integration and characterization. She is the recent recipient of an R&D 100 Award, an MDV Innovators Award, and a DOE Early Career Research Program grant.

IN BRIEF

Shining the Light on Green Roofs: Data From Photovoltaic Array Interaction

Over a 30 month period, from June 2008 through December 2010, environmental monitoring was conducted in downtown Denver, Colorado, on the Region 8 Environmental Protection Agency (EPA) Headquarter's green roof (20,000 sq ft). The vegetated portion of the green roof covers 20,000 square feet (1,858 m²) of the 33,000 total square ft (3,066 m²) roof. The study was lead by Thomas J. Slabe and former Colorado State University (CSU) doctoral student, (now Dr.) Jennifer Bousselot under the advisement of CSU Professor James E. Klett.

During data collection, the research team noted that shade structures, including photovoltaic arrays, influence the growth of green roof plants (refer to Figure 12).

Figure 12. Part of the photovoltaic structure at the Region 8 Environmental Protection Agency Headquarter's green roof. Photo courtesy Thomas J. Slabe.

Designing with moisture in mind is vital for the success of a green roof, structurally and biologically. For a region such as Metropolitan Denver, moisture may dissipate too rapidly with a thin substrate material designed for drainage. The concept of ecosystem structure, or designs with shading structures, was brought to the surface through unique data observations correlating benefits from the Region 8 EPA's photovoltaic panels, which are elevated on support structures to about 5 feet from the roof surface (see Figure 12), in helping cool and conserve moisture beneath the panels and diversifying green roof habitats.

A photovoltaic array (PV) system installed along the southeast edge of the EPA green roof research area allowed plants near the photovoltaic array to receive partial shade in the morning. Study results showed that these shaded plants performed better in comparison to similar plants without shade. The temperature of the substrate surface in these shaded areas was more steady, and ran 1.17°C cooler compared to surface temperatures in exposed areas. The research team theorized that the protection provided by the array created a microclimate that benefitted the plants by reducing the total daily solar radiation reaching the plants and therefore reducing the overall evapotranspiration demand and most likely reducing photorespiration. 98% of plants shaded by the PV system survived during the winter of the study, compared to a 60% survival rate of plants on other areas of the roof.

The PV array actually shades the plants just enough to cut down on the demand for water," Bousselot said. "We have temperature data to support that higher temperatures are a driver for the transpiration rate. This was the biggest unplanned observation that the research team noticed, the symbiosis that exists between the PV array and the green roof."

These data also suggest that the shade of the solar panels reduces the potential for heat flux into the building from the roof, as well as reducing the potential for loading into the atmosphere during summer months. The temperatures of the exposed surface of photovoltaic panels no doubt increase but the cool temperatures beneath the panels compensates for some of the heat contributed by the panels to the atmosphere even if in very small amounts.

The photovoltaic panels and the shade they create may mimic the canopy structure found in nature by producing gradients in temperature and solar irradiance. By blocking direct solar irradiance from reaching the substrate for at least a portion of each day, the panels help to conserve moisture and serve to extend habitat complexity with varying degrees of shading.

The temperature data loggers that were distributed across the green roof in diverse locations, including within the shade of a solar photovoltaic panel installation revealed an interesting if not obvious trend. The results show a spatial decrease in temperature variation between the exposed surface and shaded beneath the surface locations, as would be expected. The coolest daytime and warmest nighttime temperatures were recorded beneath the substrate surface in the shade of solar panels. These observations may have important design implications to enhance performance, energy efficiency, and water conservation attributes of green roof applications. The shading from the panels helps conserve moisture that would otherwise have evaporated at a faster rate with direct sun exposure.

"From an ecological standpoint, my argument is that you should make the roof structure as complicated as practicable so you get shade, and you get gradation of micro climates," Slabe said. "Overall, I think we need to start thinking out of the box when it comes to designing green roofs. Let's get out of the paradigm of covering the whole roof. Perhaps create a complex green roof area on part of your roof. A highly reflective roof is also a good roof; this could comprise the leftover space."

Energy Design Update wishes to thank Thomas Slabe and Jennifer Bousselot for allowing us into their project, and for sharing their data and expertise with us.

EDU also wishes to thank CitiesAlive and Green Roofs for Healthy Cities for encouraging greater research into green roof data and performance. You may visit these organizations online at: *http://www.citiesalive.org/* and *http://www.greenroofs.org/*.

Slabe may be reached at U.S. EPA Region 8 Laboratory, 16194 W 45th Drive, Golden, CO 80403; or via email at *Slabe.thomas@epa.gov*.

ASHRAE Releases New Residential IAQ Standard

On April 29, 2013, the American Society of Heating, Refrigerating and Air Conditioning Engineers (ASHRAE) released the newly published 2013 residential indoor air quality standard, which removes the default leakage rate assumption and also requires carbon monoxide alarms.

One of the biggest changes in the standard over the 2010 version was an increase in mechanical ventilation rates to 7.5 cfm per person plus 3 cfm per 100 square feet. This is due to the earlier removal of the earlier default assumption regarding natural infiltration.

The Standard 62.2 Committee had previously assumed homes got a minimum of 2 cfm, per 100 square feet, according to Don Stevens, committee chair.

"Because research shows houses have gotten tighter and apartments have always been tight, the 2013 edition drops this default assumption and calls for the entire amount to be provided mechanically," he said. "The only exception is when single family homes have a blower door test – then the predicted average annual leakage rate can be deducted."

Another major change is a requirement for carbon monoxide (CO) alarms in all dwelling units. CO poisoning leads to hundreds of deaths and thousands of injuries each year in homes, resulting from automobiles left running in attached garages as well as from portable generators, power tools and heaters, according to Paul Francisco, committee vice chair. A small fraction of poisonings also result from failed central heating combustion appliances.

"Residents have very little ability to sense the presence of CO without detectors, unlike many other indoor polluting events," he said.

Whether to include CO alarms as a requirement in the standard had been discussed since the standard was first proposed with debate focused on the unreliability and cost of alarms.

Francisco said the committee believes the time has come to make this change, noting that it brings the standard into closer alignment with the International Residential Code, which requires alarms if the house has combustion appliances or attached garages, and with many states that have passed laws requiring CO alarms.

The requirement goes a step further, expanding the protection to all homes, regardless of fuel type or garage configuration, reflecting the fact that many CO exposures occur due to causes completely independent of these factors, he said. It also requires that alarms be hard-wired with battery backup to address an increased likelihood of high CO exposure events during power outages.

Other significant new changes include the removal of the climate limitations on pressurization and depressurization; specifications related specifically to multifamily buildings; and new calculations and weather data for estimating annual leakage based on a blower door test.

The cost of Standard 62.2-2013, Ventilation and Acceptable Indoor Air Quality in Low-Rise Residential Buildings, is $58 ($48, ASHRAE members). ANSI/ASHRAE Standard 62.2-2013, Ventilation and Acceptable Indoor Air Quality in Low-Rise Residential Buildings, is the only nationally recognized indoor air quality standard developed solely for residences. It defines the roles of and minimum requirements for mechanical and natural ventilation systems and the building envelope intended to provide acceptable indoor air quality in low-rise residential buildings.

To order, contact ASHRAE Customer Contact Center at 1-800-527-4723 (United States and Canada) or 404-636-8400 (worldwide), fax 678-539-2129, or visit www.ashrae.org/bookstore. For further information, contact Jodi Scott, Public Relations, 1-678-539-1216 or *jscott@ashrae.org*. Visit the official press release online at *https://www.ashrae.org/news/2013/carbon-monoxide-alarms-required-default-leakage-rate-removed-in-new-ashrae-residential-iaq-standard*.

NREL Announces Plans for New Solar Database

The Department of Energy's (DOE) National Renewable Energy Laboratory (NREL) announced plans for the Open Solar Performance and Reliability Clearinghouse (O-SPaRC) on April 9, 2013. The NREL program, as part of DOE's SunShot Initiative, will build an open-source database of real-world performance from solar facilities across the country.

"The O-SPaRC dataset will provide the market with critical data on the long-term performance of residential and commercial solar facilities," NREL Senior Financial Analyst Michael Mendelsohn said in an NREL press release. "This is an important step to tapping the public capital markets and offers the potential to significantly lower the cost of solar energy." To read the full release, go to *http://www.nrel.gov/news/press/2013/2166.html*.

The project will also include standardization of solar contracts via the Solar Access to Public Capital (SAPC) working group and detailed analysis of the opportunities and barriers to finance solar energy development with public capital. To visit the O-SPaRC sign-up page go to *http://www.sunspec.org/nrel-has-contracts-build-solar-performance-dataset-sunspec-alliance/*.

Touted as 'Greenest in Canada,' Endeavour Home Opens to Public

Designed and built by the Endeavour Centre in Peterborough, Ontario, "Canada's Greenest Home" opened to the public on May 26, 2013. Going beyond traditional green home standards, Endeavour designed the home to generate all the power it requires, collect and filter its own water, and treat all its own waste. Energy modeling using Passive House software predicts that the house will use about 80% less energy than an identical house built to meet the building code.

Endeavour reported the following goals and data for the home:

- Extremely high energy efficiency: “The annual heating bill for the home, as determined by energy auditor Ross Elliott of Homesol Building Solutions, will be around $325 annually. The home will have net zero energy use if the occupants have ‘average’ power usage habits, and the photovoltaic panels will provide an income for the homeowners. We achieved a very high degree of air tightness, with the final test showing 0.63 ACH/50 (air changes per hour at a 50 Pascal pressure differential). An Energy Recovery Ventilator (ERV) supplies fresh, filtered air with minimal losses of heat and moisture from the building. A complete energy monitoring system with central touch-screen display will assist the owners in meeting their own energy consumption targets. A smart phone can monitor the system from anywhere in the world.”
- Extremely high indoor air quality: “Every finish and surface in the home meets the highest standards for being chemical free and non-toxic. Achieving this level of non-toxicity was a great challenge, and one we’re proud to have met.”
- All materials manufactured and sourced as locally as possible, with a target of a 250km radius.
- Very low embodied energy materials. The team choose NatureBuilt Wall’s straw bale walls, and recycled cellulose to reduce the home’s environmental footprint.
- Very law water use, with a rainwater collection and filtration system to enable the house to be water self-sufficient, as well as composting toilets. Composting toilets also eliminate sewage output.
- Zero fossil fuel usage.
- Very low construction waste: The team sent only 825 pounds of waste to landfill, rather than the average 10,000 pounds for a home of the same size.
- Make a reproducible home, and a home with street appeal: “We did not want this home to be a ‘one-off’ specialty home. Any contractor or homeowner can reproduce the results of this home with materials and products that are off-the-shelf. We intentionally did not choose materials or systems that would require skills, sourcing or maintenance that are outside the scope of any builder or homeowner. We wanted to create a home that fit into an existing neighborhood. The exterior is intended to be attractive without being ‘showy.’ The interior finishes are intended to bring a natural building slant to contemporary design, mixing clean lines and open spaces with natural materials and surfaces. Retraining and retooling is not required to build a home like this.”

To follow the construction blog and learn more about the home, go to *http://endeavourcentre.org/category/canadas-greenest-home/*.

Earth Day Brings Celebration of Greening of Home Industry

The National Association of Home Builders (NAHB) recognized the 43rd anniversary of Earth Day, on April 22, 2013, by citing the extensive progress toward sustainability and efficiency in American homes.

“Many building practices that were considered green just 20 years ago are now standard for a lot of home builders,” said Matt Belcher, co-chair of NAHB’s Energy & Green Building Subcommittee, in an NAHB press release. “As consumers and the green movement have evolved through the years, it has been important for the home building industry to evolve as well.” (To view the press release, go to *http://www.nahb.org/news_details.aspx?sectionID=122&newsID=16255*.)

Energy codes prescribing specific insulation requirements, whole building tightness testing, lighting, duct testing and low-flow fixtures were heralded as achievements in the residential arena, as well as the growth of renewable energy.

According to the NAHB release, a 2011 survey of NAHB members forecasts green homes to makeup as much as 38% of the home market by 2016, rising from just 2% in 2005. It was this type of market-scale change that prompted NAHB to champion the development of the ICC 700 National Green Building Standard (NGBS), the only residential green building approved by the American National Standards Institute (ANSI) and the foremost green rating system for single-family, multifamily and remodeled homes in the United States.

Given the growing acceptance of green homes, NAHB released the 2012 ICC 700 National Green Building Standard (NGBS), which was published earlier this year to reflect changes in updated building codes, building practices, and home technologies. Among revisions to the Standard were changes to the energy component, land development, material resource, indoor environment, and owner education and maintenance sections. Additionally, NAHB revised the remodeling component so that the Standard would be easier to apply for small and large remodeling projects.

Correction: In the May 2013, "What's in Rating? (Part 2)" article by Srikanth Puttagunta,

"The temperature of the drawn water is 1,355 °F and the ambient temperature is 67.5 °F." appeared on Page 16. The 1,355 °F should read instead 135.5 °F

IN PRACTICE

NEXUS' North Pointe Community

North Pointe, a 59-home GeoSolar Community development in Frederick, Maryland is the realization of 3 years of intensive research and development between NEXUS EnergyHomes, Inc., and the Home Innovation Research Labs™, formerly the National Association of Homebuilders Research Center (NAHBRC) (see Figure 13). Not only did North Pointe homes achieve the National Association of Homebuilders (NAHB) "Emerald Certification," they demonstrate the reality of delivering high performance homes on a budget of $300,000 or less. Stevensville, Maryland-based NEXUS is the winner of the EnergyValue Housing Award® 2012 Builder of the Year, as well as the EVHA New Homes Gold Award for Production in Moderate Climate.

All NEXUS homes are 100% certified to the National Green Building Standard (ICC 700-2008), and NEXUS currently boasts the most Emerald Certified Homes in the US. The average NEXUS home scores 25 on the Home Energy Rating Scorecard (HERS) index. Each home is designed to be a near net-zero energy home (nZEH); each home is also designed for photovoltaic (PV) production to account for all builder installed electric end uses. NEXUS homes are also selling for more than comparable homes in the region, and of the 21 home contracts in the North Pointe Townhomes in Frederick, Maryland North Pointe homes were on the market 31 days, compared to 56 other home contracts in the area, which were on the market 78 days. NEXUS was recognized by the Home Innovation Research Labs for their "enormous potential to affect both the local and national home building industry."

Energy Design Update spoke with Mike Murphy, Construction Division President at NEXUS, to explore the company's integration of energy performance, value, and cost. We also wanted to check in and see how the North Pointe homes are performing.

Tell us about your vision for the North Pointe development.

We knew we wanted North Pointe Emerald Certified in the National Green Building Certification Program, as well as all designed for NEXUS net-zero. There are lots of definitions of net-zero. Our definition was that, in a net-zero home, the homeowner would never pay for the energy needed for heating, cooling, lighting, and appliances. Accessory loads we considered separately. This way, when we delivered the home, the home was net-zero. Once people moved in and plugged in, they will have some accessory load, but on average homeowners have $15 or $20 electric bills.

Our homes are also designed to help homeowners monitor and be mindful of how much energy they use, through NexusVision™. NexusVision is an integrated hardware and software system that monitors energy production, via the home's Solar system, as well as consumption of all energy in the home (see Figure 14). A smart-grid compliant electrical distribution centralizes the power feed to the home and monitors energy consumption throughout every room on every floor. Homeowners interact through the web-based NexusVision™ Smart System to access information about their home's performance, including real-time energy production, current energy usage and its impact in both economic and environmental terms, and historic and trend data. NexusVision™ also allows a homeowner to communicate with their home's security, lighting, thermostat systems. This unparalleled capability comes standard in every residence Nexus EnergyHomes builds. When you're talking about analyzing energy usage at the breaker level, it enables the homeowner to precisely isolate what each plugged in component is doing to the home's performance.

What features of the homes support this vision?

The concept of a NEXUS Energy Home started with the idea of Passive House. The Passive House concept originated in Germany, and really focused on making the envelope of the home as efficient as possible, by making the envelope extremely tight and then moving air throughout the house in such a way to promote efficiency. We took these founding concepts from Passive

Figure 13. North Pointe Community in Frederick, Maryland. Photo courtesy NEXUS EnergyHomes, Inc.

House and asked, "How can we make this better? How can we get to net-zero?" So we deconstructed the home: we broke it down to parts and pieces, and evaluated how we could improve on each one of the parts and pieces, to make it more efficient, and make the parts work together more efficiently. We looked at the whole house holistically and tried to change the view of how a home should perform.

The very first part of the house we had to pay attention to was its envelope. We spent about 3 ½ years of research and development to create the recipe for our high performance homes. We had to make sure we could make it work and make it affordable, in comparison with other homes being sold. How can we insulate and make the envelope tight? We looked at 2'x6' framing with cellulose insulation, with fiberglass insulation, and with a combination of part spray foam and part cellulose. Ultimately, we found ourselves focused on structural insulated panel (SIP) construction (see Figure 15). We made the determination that SIPs were best for what we set out to achieve. We started using 6 9/16" panels with an insulating value between R-24 or 25, and that recipe is reflected in most of our homes to date. Recently, we have been looking at polyurethane SIPs that are more comparable to a traditional 2'x6' framing space, with insulation values up to R-33. SIPs were our formula for getting the envelope right and tight.

We also don't use traditional attics as part of our ultra-tight envelopes. We apply spray foam to the underside of the roof sheathing itself, putting 9" to 9 ½" of exposed polystyrene open cell foam right up against the sheathing itself (see Figure 16). This does two things for us: it makes what was an attic space usable, and also gives us the ability to put ducts and even equipment up there, all within a conditioned space. That makes a huge difference on the load on the HVAC system.

Then we needed to look at heating and cooling design. For us, this was kind of a no-brainer; we used geothermal. We knew we were going with this system, but just as important as picking the type of heating and cooling system, we also had to change the concept of how the duct system is run in a home. Up to this point, duct systems have been traditionally positioned to combat areas of infiltration, for example, located by windows and along walls. Of course we used high efficiency windows and doors, so we weren't faced with the infiltration issue. However, because our home is tight, we have to deal with moisture. Mold and mildew is a huge issue. How do we combat that? The best way to combat mold and mildew is through dehumidification or humidification, depending on season and situation. You can do that with your heating, ventilation, and air-conditioning (HVAC) system if you're getting air blowing properly through each room and returning through the system, and pushing back through the home. We had to have an HVAC contractor design the duct system for exact cubic feet per minute (CFM) flow in rooms. In a typical home, there is really no rhyme or reason to measuring CFM, you simply hoped it the system didn't leak too much. In the average constructed home, the duct system leaks 25-28% of its air,

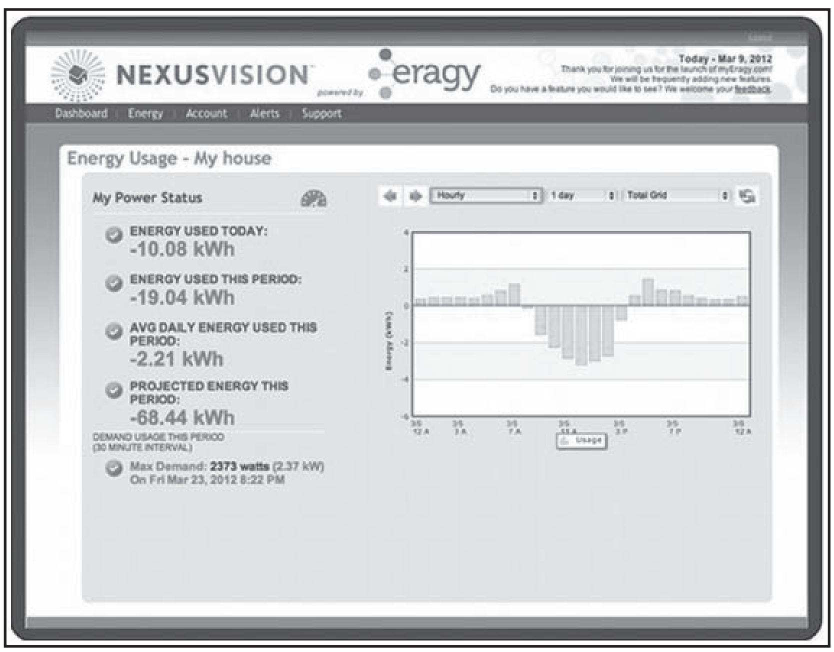

Figure 14. NexusVision™ allows the homeowner to interface and understand energy generation and consumption at their home. Figure courtesy NEXUS EnergyHomes, Inc.

Figure 15. Construction phase at North Pointe, showing Murus® Structural Insulated Panels. Photo courtesy NEXUS EnergyHomes, Inc.

which is a complete waste of energy and pressure. Our ducts are designed specifically for each home to create proper flow in rooms. We can achieve a precise CFM goal because our ducts are tested and have 6% leakage loss or less. If we go over 6%, we go find the leak. We have actually had homes with 0% leakage recently because we have helped the HVAC guys understand the attention to detail that is necessary. For North Pointe, we are using all metal ducting, all HVAC ducts are within the conditioned space, and all connections are done with mastic rather than UL181 tape. Mastic is a bonding material very similar to a cement tape where it actually will seal those seams really well, and when done with the necessary level of detail, it can achieve excellent results. We also built the ducts so there is a clean transition through the register and through to the drywall. Many home builders just route areas out for ducts, with no seal or boot to make sure that the air is coming into the room and not back under the drywall. To certify that we've done things correctly, we have a third party verifier come into each room, and put a balometer (air flow hood) on the register to make sure we have the exact CFM flow necessary for the volume of the room. If it's not precisely right, the system has manual dampers that allow us to damper certain areas, meaning each room can achieve an exact flow.

Part of the successful recipe behind a tight home is air exchange. In each home we use an energy recovery ventilator (ERV) to bring in fresh air, exhaust old air, and strip energy from the outgoing air to precondition the incoming air. When air comes in, it comes in through the ERV with a high-efficiency particulate air (HEPA) filter, to ensure clean ventilation air. To further clean the air, we offer the NEXUS CleanAir® system (see Figure 17). The air from the ERV is then put into the home through the HVAC system and as it returns, the air goes through another filter with a titanium dioxide screen energized with UVA light. As particles hit the titanium dioxide charged by the light, the filter incinerates down to .001 microns, so we have a system that can actually filter and eliminate viruses and bacteria. That is clean room air!

All exhaust fans in the home are ducted to the outside.

What initial monitor and performance results have you seen?

While actual performance is extremely dependent on the homeowner and their patterns of use, the top performing nZEH home is producing 109% of consumption, making it a true net zero home! In addition, each month the North Pointe homeowners get together for a utility bill party. This helps encourage even more the sustainability of the entire community. We will continue to partner with our homeowners to detail the performance of the community as a whole.

Our homes have an average HERS Index of 25, duct leakage of less than 6%, and blower door tests of less than 3ACH50 at 50pa.

So far, our homeowners have been very pleased with their low utility bills and the high indoor air quality. One homeowner even reported no more allergies!

What is the biggest challenge NEXUS has faced on the road to making affordable, efficient homes a reality?

The most challenging thing we have faced to date is actually having contractors understand the level of detail that is necessary, and teaching them how to understand what we are trying to achieve. They've never had to do it. They've always done it their way. When you are trying for a set level of performance, you have to go into it with a focus, not willy-nilly. You have to have a focused plan.

What is the biggest surprise you've had?

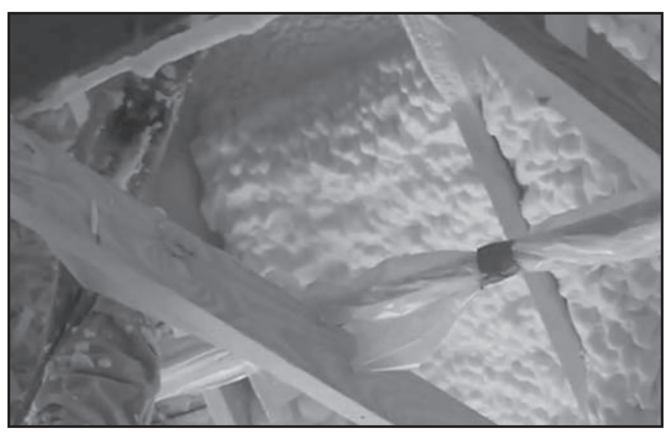

Figure 16. Applied spray foam at the underside of the roof sheathing. Demilec (USA) LLC® spray foam. Photo courtesy NEXUS EnergyHomes, Inc.

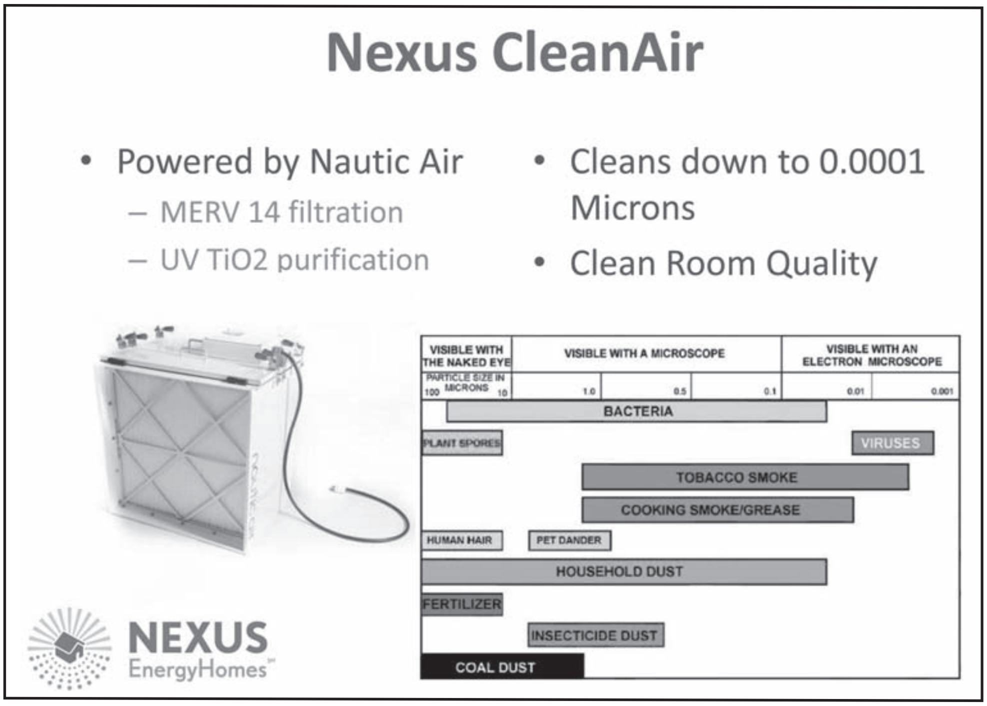

Figure 17. NEXUS CleanAir® system. NEXUS utilizes continuous ventilation to provide even temperatures, fresh air, and enhanced indoor air quality. Homes incorporate an energy recovery ventilation (ERV). Figure courtesy NEXUS EnergyHomes, Inc.

The most surprising thing that I have experienced to date would be the variety of the buyer profiles for the homes that we have sold and built.

When we started this company and concept, we had thought that the people that would be most interested in this product would be environmentalists and technology-driven people. What we found is that our product is desired by every known geographical buyer profile: first time home buyers, young families, down sizers, professionals, active adults, and of course the expected environmentally friendly and technology-driven buyers.

It is obvious to us that the idea of having a home that is built to a much higher performance standard, with extremely clean indoor air, and not paying for the electric to run said home, is what homebuyers have been looking for (see Figure 18).

Energy Design Update extends our thanks to Mike Murphy and NEXUS for this interview. Murphy is a central figure in the research and development that has led NEXUS in creating the home of the future, the "Energy Independent" Nexus EnergyHome. With the demand for traditional homes drastically curtailed in the housing recession, Murphy decided that the housing industry needed to be more proactive than simply "waiting out" the housing recession and began looking into newer and more innovative housing products geared to the next generation of homebuyer. Murphy's role as the company's construction leader is to maintain the superior level of technology, performance and quality that Nexus EnergyHomes has been recognized for with their Builder of the Year award. As the nation's leader in energy-efficient and performance home building, Murphy is dedicated to the mission of innovation. To reach beyond the highest existing standards, he is committed to seeking out the leading edge products, implementation strategies, and emerging technologies that are tantamount to building a singularly superior product. Murphy has worked for multiple companies in the construction and remodeling fields as well as software and technology firms. He created a partnership and operated his own home remodeling company, where he worked with sales and installation personnel to ensure that the products used were marketed correctly and that the quality of installation was at its best.

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Figure 18. Photovoltaics at North Pointe GeoSolar Community. Photo courtesy NEXUS EnergyHomes, Inc.