Shaping the Next...

Future of Residential Construction

ASHRAE Journal is highlighting the 2013–14 Presidential theme "Shaping the Next—Our World, Ourselves, Our Work" (http://tinyurl.com/bahnfleththeme) by publishing groups of forward-looking essays about the future of areas of high importance to ASHRAE, our industry, and society. This third group of "Shaping the Next" essays considers the future of residential construction, a topic that many might think does not belong in ASHRAE Journal. The eight short essays in this collection show why that is clearly not the case.

Chris Mathis sets the stage with a discussion of why ASHRAE needs to be involved in developing the next generation of sustainable homes. Evan Mills points to the growing need to add resiliency in the face of extreme climate events to other considerations of sustainability. Ben Newell, whose Equinox House project I have had the pleasure of visiting, tells us that a future of net zero energy housing may be closer than we think. Max Sherman's comments focus on air quality, in particular, moving beyond ventilation to performance-based design that addresses specific exposures.

Ty Newell, one of the occupants of Equinox House, takes on the developing water crisis and explores the potential of technological improvements and behavior modification to reduce the impact of homes on water supplies. John Gibbons discusses the potential of "connected homes" that use supervisory controls in ways now limited primarily to non-residential buildings to conserve resources and improve comfort while John Mix considers the consequences of widespread adoption of inverter compressor technology in residential systems, again, a trend that has already matured in the non-residential market.

Finally, David Yashar analyzes the shortcomings of the equipment ratings currently in use and imagines how they could be improved to provide homeowners with more and better information for managing their home's performance. As these essays show us, there are opportunities to make our homes better performing, more safe, healthy, and comfortable places to live if the technological community puts its resources to work to create the next generation of high performance homes that will rival what is achieved in their commercial and institutional counterparts.

– BY WILLIAM P. BAHNFLETH, 2013–14 ASHRAE PRESIDENT

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Bringing ASHRAE Home

BY CHRIS MATHIS

ASHRAE generally is characterized as focusing on commercial buildings. However, many ASHRAE members are engaged daily in critical issues involving the performance of homes. From energy efficiency to indoor air quality (IAQ) to the performance of new and innovative building materials, ASHRAE members play a key role in shaping the next generation of housing. Let's consider some of the key trends in housing that are demanding ever more attention by ASHRAE members.

We've all seen the data showing that buildings represent more than 40% of total U.S. energy use. Globally, the number may vary. But we find that housing is responsible for more than 22% of that energy appetite, using more energy than our commercial buildings. Just like commercial buildings, air conditioning has changed not only where we build but how we build our homes. Couple this demand for home cooling comfort with increasing plug loads (TVs, computers, cell phone chargers, and more electrical gadgets) and we quickly begin to see the energy and power implications—for our utilities, as well as for our nation as a whole.

Couple this growing demand with basic statistics on how our homes have changed. Prior to the oil embargo days of 1973 less than 49% of our homes had air conditioning. Today, almost 90% of the homes we build in the U.S. have air conditioning.(*Figure 1*). As we look closer at these data, we find some additional challenges. In 1973 the average new home size was 1,660 ft^2. Today's average is more than 2,400 ft^2—a 44.5% increase in size! (*Figure 2*) As we focus on metrics for building energy performance, we know that envelope surface area and floor area matter. We regularly try to come up

Reinventing Resiliency

BY EVAN MILLS

Natural disasters are on the rise, both in terms of frequency and severity, and the consequences are compounded by humanity's increasing tendency to settle in harm's way. Events of concern are not limited to headline-catching catastrophes; they also include more diffuse and gradual threats such as sea-level rise, soil subsidence, increases in airborne allergens, and reductions in water availability.

The built environment, residential and commercial, is particularly vulnerable. The resiliency is far lower than it could be. Impacts of concern extend well beyond physical damages to buildings—they also include human health and safety and costly "business interruptions," both of which can stem from disruption of essential utilities and the building services they support: lighting, comfort, communications, water.

Power outages today represent three-quarters of reported disruptions on the wholesale grid nationally, a number that has been rising steadily for at least two decades.

This suggests the need and opportunity for an expanded notion of building performance, and gives new meaning to the old idea of sheltering in place. An integrated strategy of improved land-use planning and physical resilience, together with design and operational strategies that can keep buildings at least minimally functioning and habitable can reduce the need for evacuations and post-disaster reconstruction.

Of particular interest are the resiliency co-benefits of many emerging technologies in the building energy performance domain. Among the many examples, research has shown a significant improvement in the integrity of roofing systems under wind pressure when insulated and "cemented" with spray-foam insulation. Multi-pane glazing systems slow the progress of fires. Efficient building envelopes reduce risks during heat storms in summer and ice dams in winter. Vehicle- or building-based energy production can support critical loads during power outages. Passive space-conditioning strategies function even when the grid doesn't. The list goes on.

The nexus of climate change and extreme weather events calls for a broadened definition of "sustainability." To be truly sustainable, buildings must be "climate-friendly" and disaster resilient. Building designers, consulting engineers, and operators are at the hub of an exciting new set of opportunities for simultaneously improving buildings in terms of energy-environmental performance and disaster-resilience.

The public and private sector alike should cultivate new approaches. Research and trade organizations can play an essential role in assessing the options and quantifying the benefits. There is huge scope for "out-of-the box partnerships," e.g., between insurers and utilities who share interests in sustainability, resilience, and risk management.

The challenge now is to elevate resiliency from buzzword to standard practice.

Evan Mills is a staff scientist at Lawrence Berkeley National Laboratory.

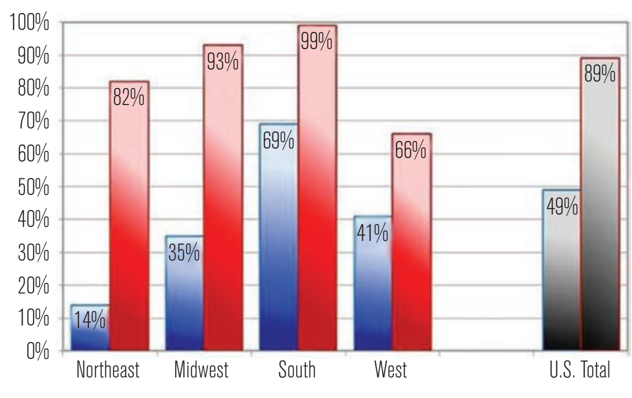

FIGURE 1: Homes with AC—1973 vs. 2012.

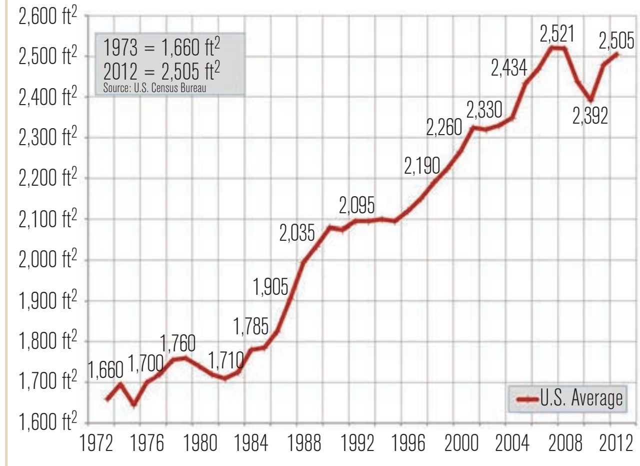

FIGURE 2: Average U.S. home size—1973 vs. 2012.

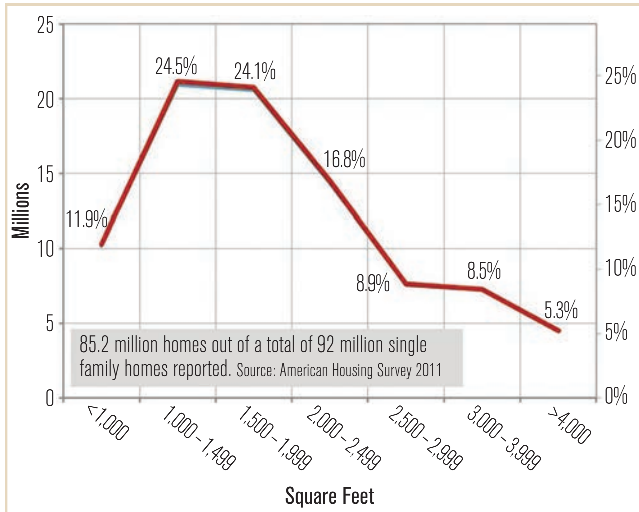

FIGURE 3: Distribution of U.S. home sizes—2011 totals.

with meaningful metrics of building energy performance —from site energy to EUI to tons of carbon—knowing all too well that size matters. But let's look even closer.

Average size does not reflect the true energy demand trends of the residential marketplace. *Figure 3* shows the typical distribution of single family home size. What are the heating and cooling demand implications of those homes larger than the average size? Do our current energy performance metrics fully capture the implications of smaller homes?

Of course, the elephant in the room must be acknowledged. It is relatively easy to focus our attention on the energy use and size trends for new homes. New homes are easy. But we only build about 1 million new homes in the U.S. in a good year, and these include a mix of single and multi-family types. So what do we do about the energy needs and demands of the more than 115 million existing homes? One percent new. Ninety nine percent existing. And just like our commercial buildings, more than two-thirds of these homes were built before 1989.

Is ASHRAE doing all it can to address the challenge of improving *all* our homes? Are we making sure that all our members worldwide have access to our latest understanding of residential building performance? The need is definitely not limited to home energy use. These same trends have implications for water use, indoor air quality and other topics embodied in the expertise of ASHRAE members. But home energy use is certainly an excellent place to start. We need to bring renewed focus to the many challenges of residential building performance—for new homes and old; from water use to indoor air quality; from new green building practices to priorities for home renovation; and from residential research needs to grass roots policy priorities.

As we focus on ever-improving our understanding, knowledge base and services to the commercial building industry, let's renew our commitment to bringing those same skills, knowledge and abilities home.

Chris Mathis is president of M C Squared in Asheville, N.C.

Residential Air

BY MAX SHERMAN, FELLOW ASHRAE

The home most of us grew up in was leaky. Many were drafty. Many had leaky ducts pumping large volumes of conditioned air when we wanted them too. One-third to one-half of that conditioned air went toward those leaks. This was not a very energy efficient thing to do, but it supplied lots of air to dilute indoor-generated contaminants.

To save energy in homes we made them tighter. Sometimes that caused indoor air quality (IAQ) problems because there was insufficient air to dilute indoor

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Connected Home

BY JOHN GIBBONS

Historically, efficiency improvements in residential HVAC systems have focused on individual components such as the gas furnace or outdoor cooling unit. Recent efforts to increase efficiency have taken a total system design approach. This is because engineers are running into theoretical limits of existing technology to cost effectively improve HVAC system efficiency. Current trends suggest that altering the design approach to look at the house as a whole system, rather than just a stand-alone HVAC system, can result in further improvements in comfort and efficiency.

When examining these emerging trends, manufacturers must take into consideration a number of factors to develop solutions addressing whole-home management, and introduce products that help homeowners manage their home environment from one interface, while also having the ability to be accessed remotely. In a world of increasing remote connectivity, homeowners are more connected than ever before and they have begun to demand the ability to monitor and control the home system from anywhere in the world. Plus, a wall control's ability to translate diagnostics to the homeowner and contractor in real-time will help raise awareness of system issues, as well as strengthen the contractor-customer relationship through regular interaction.

Interoperability will be necessary as whole-home management evolves. A wall control will not only need to be able to manage the home's HVAC system, it will need to integrate itself into other systems in the home as well, whether it is the security network, lifestyle and entertainment components or other household appliances. The central control hub will need to communicate with all technology in the home and OEMs need to recognize this need as they further develop products.

Energy management will also be an important factor for homeowners. As they become more informed, the desire to monitor and adjust the home's energy consumption will grow. OEMs must take this trend into account moving forward as energy management continues to be a significant point of interest.

As homeowners become more engaged in their home management, the players in the HVAC industry will need to stay ahead of these trends in order to stay top-of-mind as consumers look for total home-management solutions.

John Gibbons, is director, Product & Platform Strategy, Carrier.

contaminants. Air tightening was a highly cost-effective efficiency measure, but IAQ concerns threatened to halt such performance improvements. In 2003, ASHRAE came out with the first national consensus standard on residential ventilation so that energy efficiency and acceptable IAQ could be jointly provided.

The high performance new (or retrofit) home of today probably has a mechanical ventilation system in it to provide the air required by ASHRAE Standard 62.2. That home is probably tight. That ventilation may still require one-third of the (now much lower) space conditioning energy.

There are various heat recovery approaches to reduce the energy impact of ventilation air, but if we are to Shape the Next for residential air quality, we will need to go beyond specifying ventilation rates, when what we really care about are the impacts of contaminants in the indoor air. Recent work has allowed us to understand the health impacts of many contaminants of concern typically found in homes.

A near-zero energy home will have a mixture of low-emitting materials, source control and air cleaning, which will allow much lower ventilation rates to be used much of the time: Formaldehyde emitted from materials, once the dominant health-related pollutant, continues on its downward trend. Particles, now the most important indoor contaminant, can be filtered relatively easily. Cooking, probably the single largest indoor source, can be treated by improving range hoods and their use. What is left over can undoubtedly be handled by lower ventilation rates than might be needed today.

The path forward takes innovation in our technology, standards and design. ASHRAE has a key role to play in Shaping the Next in Residential Air.

Max Sherman is a senior scientist at Lawrence Berkeley National Laboratory.

When the Well Runs Dry

BY TY NEWELL, PH.D., P.E., MEMBER ASHRAE

Growing up during a multi-year drought in the 1960s in rural, southwestern Missouri, I know what happens when the well runs dry. You get very good at conserving water, and spend a lot of time hauling water. The flow of water is critical to our survival, and it can stop in an instant as it did in a West Virginia community earlier this year when contaminated water disrupted the lives of 300,000 people.

Residential water use parallels residential energy in many ways. It is mostly "conserved" as is energy. We can degrade its quality. Our health and well-being depend on it. Similar to energy, water is precious, yet not expensive. Water is used in many ways in our homes ranging from our basic human consumption needs to flushing wastes. And, like energy, it is a confusing puzzle that requires a systematic design approach to achieve sustainable, economic use.

Home water consumption is small (11%)[1] in comparison to power generation and agriculture water use. Reduction of residential water consumption and local "harvesting" strengthen a community in a similar manner as solar energy collection.

Significant strides have been made in home water conservation with improvements in faucets, showerheads, laundry, dishwashers and toilets. Toilets followed a similar improvement path as today's energy efficient refrigerators with water efficient toilets using as little as 1.2 gallons (4.5 L) per flush for an 80% reduction from yesteryear's toilets. More than half of the homes in the U.S. are estimated to have older, high flush volume toilets. EPA[2] estimates that as much as 14% of indoor home water use is leakage. Minimizing leakage and conversion of all toilets to low flush volume would decrease home water use by 25%.

Our behavior is a significant factor in home water consumption. Using the dishwasher when full, turning the faucet off while brushing teeth, and other small details add up to important savings. Use of "gray" water from showers, sinks and clothes washing provides another avenue to reduce overall consumption. Gray water can supply a significant fraction of water for toilet flushing and vegetation. Gray water filtration, storage and pumping provide opportunities for entrepreneurs and for local residential service providers. Condensate water collected from heat pumps and air conditioners provides another source. In our Equinox House project,[3] we collect an average of 185 gallons (700 L) per summer and 160 gallons (600 L) per winter for vegetation watering.

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Finally, precipitation harvesting should be encouraged across the country. Atlanta enacted guidelines for rainwater harvesting after a series of dry years. Texas has been a leader in the development of practical rainwater harvesting systems.

Our home, Equinox House, was the first home in Illinois to receive permission from the State Department of Public Health to use rainwater in the home for toilets. Since its commissioning in the fall of 2010, the system has reliably supplied nearly 30,000 gallons (113 562 L) of water through some of the driest summers and coldest winters in our history. During a dry 2011 August, we collected 160 gallons (600 L) of dew through night-sky cooling on our roof. If 2% of our residences included a similar system, one to two months of critical emergency water supply would be available for our community's residents. Manufacturing and installation of rainwater harvesting systems employs people at a water supply cost that is competitive with our public water supplier.

The time is now to envision and enact a future based on sustainable resources. We can do this while maintaining a high quality of life in an economically sustainable manner.

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Ty A. Newell, PhD, P.E., Professor Emeritus Mechanical Engineering and Education,University of Illinois at Urbana-Champaign.

Inverter Technology

BY JOHN MIX

Variable speed compressor technology consists of a static inverter and compressor. The static inverter converts the incoming alternating current (ac) to direct current (dc) and then uses pulse-width modulation to produce ac of a desired frequency. This variable frequency ac is then used to drive the compressor motor.

Since the speed of the motor is proportional to the frequency of the ac, the compressor can now run at different speeds and thus vary the amount of heating or cooling

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depending on a number of different inputs including, but not limited to, outdoor air temperature and/or humidity, indoor temperature and/or humidity, the occupant's set point, and how far away the indoor conditions are from the setpoint(s).

Some outdoor units are even able to communicate with the other parts of the system such as the wall control and/or the indoor unit to provide considerably high levels of efficiency and occupant benefits. When included as part of the system's design, the inverter can monitor system variables such as refrigerant pressure and temperature, thereby providing diagnostics and safety controls that other systems cannot as easily achieve.

Benefits of inverter technology can include:

• Increased system efficiency: up to 20 SEER, 13 HSPF and 16 EER. When comparing efficiency levels, it is always recommended to compare the ratio of the unit cost divided by the efficiency value. This will tell you how many dollars you are paying for each point of SEER, HSPF or EER and help to compare one system versus another.

• Enhanced comfort. Multistage and variable speed systems more closely match the home's heating and cooling needs and vary the output accordingly. This means longer run cycles at lower speeds, which can result in fewer temperature fluctuations and improved humidity control.

• More heat at colder ambient conditions. Because a variable speed system, if designed correctly, can increase the speed of the compressor to pull more heat out of the outdoor air as the ambient temperature gets lower, variable speed systems can deliver more heat at lower ambient conditions, even enough to rival the performance of traditional gas furnaces.

• More efficient heating with HSPF ratings as high as 13 HSPF, variable speed heat pumps offer efficient heating performance; up to 30% more than single-speed units.

• Quieter operation: traditional single-speed compression heat pumps are limited in how quietly they can operate, since anytime the compressor is operating, it is always at the same speed (or RPM). Variable speed compressor heat pumps can vary the compressor and/or fan speed and thus, vary the operating sound of the device.

• Adaptability: if the variable speed system is designed to monitor both temperature and humidity, and change its mode of operation accordingly, then the system can be much more adaptable to achieve improved occupant comfort when compared to a single-speed system.

John Mix is platform manager Split Systems & SPP, Carrier.

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Net Zero Homes

BY BEN NEWELL

It is approaching four years since we completed construction on the net zero energy Equinox House, which we detailed in a 12-part ASHRAE Journal series titled “Solar NZEB Project.” While the name Equinox House is in reference to the time of year when the clerestory window overhang shifts between allowing in or shading direct sunlight, we also see this as the Equinox of the home building industry. Shifting to a time when energy standards, labor training, construction materials, systems, and verification are all readily available and economically feasible to make energy efficient home construction the standard. Add to this the exciting fact that solar PV is now at grid parity and you have an easy pathway to solar powered net zero homes.

The obvious impact of net zero homes is reducing energy consumption and moving towards 100% renewable energy, however, arguably more important is a healthier indoor environment. Zero energy construction also creates good paying jobs and leaves more money in our communities making them stronger and more sustainable.

So how do we get to a time when net zero homes are the norm rather than the exception? No longer is it an excuse that we don’t have the tools. It’s a circular problem of today’s consumer market drivers coupled with inadequate home appraisals and a lack of innovation and education in lending.

As consumers start demanding super insulation, A+ efficient appliances, and solar panels like they currently do granite countertops, three car garages, and stainless steel appliances appraisers will begin giving value to these features. Despite their role in the sub-prime lending bubble, banks are hesitant to make construction loans for features that receive anything but a footnote from the appraiser. This, despite the fact that this would be to their advantage to lend for net zero energy construction. A larger loan for extra insulation, more efficient appliances, and solar power eliminates a utility bill, meaning more cash flow for mortgage repayment.

We are close to a tipping point where this shift in market demand will mean more net zero homes. A positive of the decline in housing construction has meant less bad homes are being built. Hopefully this gives more time for the new innovations in housing construction to make it to the general market. As always the continual increase in energy prices will always make net zero an attractive option.

Ben Newell is president of Newell Instruments in Urbana, Ill.

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Beyond Standard Efficiency Ratings

BY DAVID YASHAR, PH.D.

One of the greatest challenges to cost-effectively reducing the energy consumption of an occupied building lies in the accuracy of the energy use predictions of the installed equipment/appliances. In residential buildings, the challenge is further complicated because the equipment's installed efficiency and total energy consumption are highly dependent on (1) the type and level of interaction it has with the occupants and (2) its installed environment.

While current rating methods provide a benchmark for equipment performance, they only provide enough information to predict how that equipment will work under a standard set of operating conditions. Furthermore, as manufacturers are required (through federal minimum standards) and encouraged (through utility rebate, state and federal tax credit programs, and other market forces) to increase equipment efficiencies at the rating condition(s), the question arises as to how well those increases translate to the installed performance in a given home.

One of the major reasons for having efficiency ratings is to assist consumers in making purchasing decisions. As we progress through the 21st century, people have increasingly more decision-assisting power at their disposal but they need access to useful information; otherwise the power is futile. Historically, detailed information on the operational modes of equipment was far too complicated for most homeowners to understand. Today, however, decision-assisting information exists in abundance and it doesn't require the homeowner to understand the complex mechanics of consumer products. A homeowner can obtain a realistic estimate of the monthly operating expense for each product under consideration simply by using a smartphone and some basic information. Unfortunately, all of the data needed to enable that type of decision making is not available with the current ratings; therefore, the consumer cannot realize the benefit.

Consider residential air conditioners, which often dominate the utility bill in a home. Their efficiencies are rated on the basis of a nation-wide Seasonal Energy Efficiency Ratio (SEER), which characterizes the efficiency over the course of the year but does not

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consider many of the factors that influence the performance in the field. Manufacturers are required to run several tests and use them to calculate a small handful of parameters, but the information from these tests is generally not provided to the homeowner. Instead the consumers are only told that it is a "SEER 14" or "SEER 16," which means little more than a tax credit to most individuals. At a minimum, the combination of the efficiency ratings and the uncertified data from which those ratings are derived, as well as other "catalog" data available from the manufacturer, could provide enough information to tell homeowners in New Orleans and Las Vegas that they would be better off buying products with different sensible heat ratios even though they have the same SEER value.

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Thinking bigger, information embedded in a bar code could be used with local weather data, occupant preference on thermal set points, and building information (type, size, etc.) to predict a detailed schedule of energy use over the course of a year. All or part of that same schedule could also be used as a set of performance metrics for commissioning purposes, to provide information on how the unit would respond to changing utility rates, as a tool for fault detection during the unit's lifetime, or even as a mechanism for utilities to forecast demand.

In fact, the field performance of nearly every rated product would be improved in some way if consumers could leverage more detailed information into their purchasing decisions than just published efficiency ratings. Homeowners are often unaware of how their daily routines impact a product's energy use and additional data could help them pick the best products for their lifestyle. If we really wish to reduce overall energy consumption, increasing the level of information provided beyond efficiency ratings is not only a good idea, it is essential.

David Yashar, Ph.D., is deputy chief, Energy and Environment Division, National Institute of Standards and Technology. ■

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