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Blueprint for Advancing High-Performance Homes

Even in today's harsh housing environment, high-performance homes make sense—for residents, the nation, and the environment. Here is a plan for promoting them.

Given the economic devastation caused by the housing industry collapse in the United States and the years remaining until full recovery, it may seem out of touch to be talking about meeting 21st-century needs through high-performance homes that can deliver comfort and well-being to the average homeowner at levels rarely reached before. Yet the housing problems that the nation faces are systemic and do not lend themselves to short-term fixes. Carbon emissions from the housing sector are at several times sustainability levels. Homes use excessive amounts of water. Average indoor air quality needs to be improved. There are safety and security problems. When homes do not meet the needs of elderly and handicapped people, medical costs increase. Homes are unaffordable to a growing segment of the population.

Furthermore, most homes, unlike electronics or cars, will be here decades from now, because they evolve more often than they are replaced. Thinking about homes holistically over their life cycles is the only way to reach their potential.

Basic knowledge of how to do this is not the problem. Since the 1970s, federally funded and private-sector research programs, along with overseas advancements, have improved understanding of most aspects of building performance. The basic science behind high-performance buildings is well understood, and a few top firms in architecture, engineering, and construction have created high-performance buildings, including homes that come close to economic, environmental, and social sustainability. The problem is moving this knowledge from larger and higher-priced buildings and the building elite to the broader market of moderately priced new home construction and retrofits, where costs are paramount and knowledge of high-performance principles is less prevalent.

Still, tough times are also innovative times, and when past ways of doing business were not working well, the nation and its people have traditionally looked for change. Today's economic pause is an ideal time to think about how to optimize the housing sector, by reducing costs through eliminating wasteful practices, by adopting best practices from manufacturing, and by unleashing the power of information technology. This is not an easy task, because the housing industry and the housing stock are quite diverse. But it is not an impossible task, and there are some clear reforms that can move the U.S. housing sector much of the way to achieving its potential.

What is high performance?

High performance is what people should expect from buildings, where we spend about 90% of our lives. The Whole Building Design Guide, a project of the federally chartered National Institute of Building Sciences, defines a high-performance building as being cost-effective over its entire life cycle, environmentally sustainable, safe, secure, functional, accessible, aesthetic, and productive (see www.wbdg.org).

For homes, achieving safety and security means withstanding foreseeable disasters. Functionality requires meeting residents' expectations and needs. Accessibility means meeting the needs of the elderly and disabled through universal design. Aesthetics relate to a home's desirability and ease of resale. Productivity depends on appropriate day lighting and a healthy indoor environment.

Cost-effectiveness is measured on a life-cycle basis, taking into account the initial purchase price, operational costs, improvements, and long-term maintenance and repairs. In high-performance construction or renovation, the initial design is done with future enhancement in mind. Building science dictates the most appropriate design, materials, technologies, and site orientation. Precise, cost-effective execution follows through engineering, construction, and operations. Once high performance is achieved, a home becomes as cost-effective to own as it is to purchase, energy costs are minimized if not eliminated, building performance is maximized, and the quality of life for building occupants is enhanced.

FANDRA CHANG, *End of Horizons (Derived from "Eyewire Images: Main Street America E008417")*, Fuji Crystal Archive on Plexiglas, 13 x 59 inches, 2000.

For environmental sustainability, maximizing energy efficiency is a key. Because some homes will never achieve peak performance in energy efficiency, reaching overall environmental sustainability across the residential sector will require that other homes reach net zero energy (NZE) or become net energy producers. NZE residences use site-generated renewable energy to offset all fossil fuel use. The Home Energy Rating System Index, which measures energy use on site, scores NZE homes at 0. By comparison, the average existing single-family residence scores 120. Among other more energy-efficient home types, a home that meets the 2004 International Energy Conservation Code scores 100, a home that attains an Energy rating scores 85 or lower, and a home that meets the current level of the U.S. Department of Energy's (DOE's) Builder's Challenge scores 70.

Relearning lessons

The United States experienced a concerted effort to improve energy efficiency in buildings, including homes, in the years after the 1973 OPEC oil embargo. But in the early 1980s, fossil fuel prices declined, domestic energy research plummeted, and only the visionaries of high performance pushed forward. It took the U.S. Green Building Council's LEED rating system and certification program in the late 1990s to reengage the public. LEED is a comprehensive rating of a building's potential environmental impact, but is only a first step toward high performance. It currently treats deep energy efficiency and most nonenvironmental high-performance goals as optional and does not emphasize building performance. Still, LEED is a remarkable success story that has established a U.S. market for better buildings, including homes, and a formula for addressing environmental sustainability and potentially high performance that nearly everyone can understand and undertake.

The Sustainable Buildings Industry Council and various councils established under the National Institute of Building Sciences have been leaders in integrating high-performance residential building attributes and in showing that simul-

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taneously considering all aspects of a building's performance leads to synergies and savings in new construction and renovation. Some LEED award winners have used advanced manufacturing techniques and quality assurance to move beyond environmental sustainability toward high performance. For instance, one award winner in Maine now offers new NZE homes with other high-performance attributes at only a slight premium over conventional construction. However, homes this high in quality are still the exception, and understanding of how to do a high-performance retrofit trails progress in high performance in new homes worldwide.

In several parts of Europe, new high-performance homes are now moving from niche market to mainstream. There is movement in Japan as well. Europe's most energy-efficient new homes are near NZE, while taking seriously indoor air quality, water use, and other high-performance values. As Europe learned energy-efficient building design from the United States in the early 1970s, the United States can now learn about how to transition to high-performance–related standards, financing, business practices, and building components from Europe.

Consider the Swiss experience. About 15 years ago, what eventually came to be called the Minergie Association introduced the MINERGIE standard as a trademarked marketing label for low-energy–consumption buildings. Over time, additional voluntary MINERGIE standards were developed for passive solar buildings, along with a green option and an NZE option.

As the Swiss gained experience, they brought design and construction costs for new MINERGIE buildings, including residences, close to the costs of conventional construction. Currently, 25% of new construction across Switzerland meets the standards, and they are now influencing the mandatory building codes in some Swiss cantons. Banks are offering slightly lower rates to homeowners for MINERGIE buildings, consumer demand is increasing, and resale values of such homes now exceed those of conventional buildings of similar size and quality. In the retrofit market, however, MINERGIE has only a 1% share.

Making it happen

High-performance homes are available in the United States when money is not an object. The question is how high-performance can be adapted so that it is available in the rest of the housing market, where price is of utmost importance and buyers cannot afford everything they want. High performance will come when consumers feel they must have it and can afford it. Getting to that point requires streamlined new ways of doing business for the construction industry, for related real estate professionals, for those who service homes, and for residents. These changes must be structured to make high performance in homes easier to achieve and more affordable. Once that happens, those homes should be recognizable as superior and gain prominence in the market.

With this goal in mind, there is a set of eight actions that can accelerate movement toward high performance. They are:

Develop precise methods and analytic tools for estimating present value and life-cycle costs and for achieving high performance over time. A home is a very long-term asset that changes over time. Home purchases are based on quality and price, and existing homes are improved when it makes financial sense to do so. High-performance homes should be inherently more valuable to consumers than conventional homes, because they are designed to improve over time, focused on user needs, and cheaper to operate than conventional buildings. But current methods of appraising and pricing rarely recognize this value.

Therefore, for homes with high-performance features to reach their market potential, there need to be an objective, common methodology and related tools to calculate as precisely as possible a home's true present value, the effect on that value of specific features and improvements, and the likely costs to own and operate the home. Mortgagers could then more accurately estimate the effect of lower operating costs on a mortgagee's ability to handle a larger mortgage payment, builders could accurately estimate which energy efficiency and renewable energy upgrades make economic sense, and purchasers would have a better understanding of how specific upgrades increase their home's value. The first generation of software designed to make this analysis is emerging in the banking industry and will soon begin testing for both new construction and retrofits. If successful in the banking industry, this valuation method could be extended to appraisers, architects, engineers, and insurers.

Mortgagers' risk is also reduced when actual performance approaches design performance. Some people in the mortgage industry are considering requiring that mortgagees provide them access to real-time energy and water use and other performance data that will be generated by smart home technology, and then conditioning the lowest interest rates on specific performance levels. The same data streams could give real estate professionals, appraisers, and potential buyers a more precise picture of a home's actual performance and condition to use in pricing and purchase decisions.

Current construction practices create waste and increase the cost of future upgrades when they do not anticipate how a home will be modified over time. In contrast, a "high-performance–ready" strategy can be adopted as the first step toward high performance and would be modified in stages as technology improves and becomes more affordable. The foundation and other parts of the building envelope that cannot be upgraded would be designed initially at a high-performance level, including incorporating passive solar techniques and high R values where appropriate. If active solar is initially too expensive at a specific location, but prices will fall, the building should be properly oriented for solar and wired to permit easy future installation. For components whose replacement is predictable, such as windows, lighting, and certain appliances, the anticipated life of the initial component should be factored into construction budget allocations. If a home addition or an occupant aging in place is foreseeable, preparing for easy expansion or modification in the initial design could reduce waste and make the eventual attainment of high performance easier. A high-performance–ready strategy could lead to repeat customers for production builders if they periodically offer retrofit packages to entire subdivisions at a wholesale price. High-performance–ready principles should also be applied to major retrofits.

Leverage savings from energy efficiency and improved operations to pay for home improvements. Because most of today's current housing stock will exist for the foreseeable future, financing the incremental improvement of existing homes is essential, and redeploying currently wasted funds is the key to this happening. The Energy Information Administration projected that electricity and fossil fuel costs in the residential sector in 2011 would be more than $250 billion. Most of these costs would not be incurred by high-performance homes. Other wasted money can be found in the water bills and unnecessarily high home maintenance costs. Collectively, wasted funds make up the largest pool of money now available to incentivize high-performance–ready homes, and they are largely in the hands of homeowners. A McKinsey & Company study in 2009 concluded that if the barriers to using energy savings for reducing building-related carbon emissions could be overcome, energy savings would pay for all cost-effective conversions through 2020. The barriers to actually tapping these funds, however, are formidable and differ depending on whether a home is tenant- or owner-occupied and whether the owner has good credit.

Home improvement loans informed by better analytic tools are the most direct financing method for harvesting the waste, but only if the increased value and reduced operating costs from improvements are allowed to be considered in lending decisions. Bipartisan legislation was recently introduced in the U.S. Senate to permit these changes. Loans work only if homeowners are creditworthy. During the recession, banks and credit unions have cut back on lending for construction, reduced loan-to-value ratio requirements, and approved only two out of five home improvement loan applications, but it can be hoped that these trends will reverse as the economy improves.

Energy savings performance contracts are designed for building owners who want to use a middleman. They enable owners to contract with private-sector energy service companies (ESCOs) that pay capital costs related to energy efficiency improvements in exchange for the contractual right to most of the resultant energy savings for up to 25 years. ESCOs use licensed, certified, and bonded professionals and defined retrofit packages. As of March 2010, energy savings performance contracts were saving the federal government an estimated $11 billion annually, of which the government retained $1.4 billion. ESCOs also work with state and local government, universities, schools, and hospitals. Only occasionally have energy savings performance contracts been in communities for homes and small commercial markets. ESCO requirements that all tax credits, depreciation, and any assets provided under the contract belong to the equipment owner reduce the desirability of these contracts to homeowners.

Property assessed clean energy (PACE) programs can reach homeowners who are less creditworthy. Municipalities float bond issues that fund 15- to 20-year energy improvement loans that are repaid through additions to property tax bills. Secured through a lien, the obligation to repay automatically transfers to the buyer when the home is sold. The increased monthly payments generally are offset by reduced energy bills. However, because PACE agreements put the taxing authority ahead of mortgagers for repayment, Fannie Mae and Freddie Mac oppose such programs. This has greatly slowed residential PACE programs. Also, homeowners tend to favor home improvement loans over PACE agreements, because PACE interest rates are higher and closing costs are generally at least 5%. Homes with tax or contractor liens are not eligible for PACE.

Some utilities run on-bill financing programs that can be geared to moderate-income homeowners who are unlikely to get bank financing for retrofits. The programs enable energy efficiency purchases on terms similar to energy purchases. Borrowing is done by a state or local government; utilities bill for pre-retrofit levels of service, and the loan balance is reduced by the amount of payment for energy not used. States sometimes subsidize these programs by absorbing any losses from unpaid debts or interest charges they incur. These programs probably would be more prevalent if utilities were permitted to count energy efficiency loans toward renewable portfolio standards that require utilities to satisfy a portion of energy demand with nonfossil energy.

In short, there is huge amount of money available for financing retrofits from energy savings, but the mechanisms for releasing that potential are not yet widely available. Programs that enable homeowner participation without their becoming energy or finance experts, and that will show homeowners why moving toward high performance is in their financial interest, are especially important. Although some progressive communities are expanding financing programs to cover major energy efficiency upgrades, combining these programs with high-performance–ready concepts has not yet occurred.

Bring modern design tools and manufacturing techniques to home construction. Typical home builders cannot be expected to have a research scientist's knowledge of how to achieve high performance. They need a basic understanding of the principles of high performance, easy-to-use design tools that adapt a standard high-performance or high-performance–ready design to site-specific characteristics and the likely preferences of buyers, and the skills to execute the designs. Retrofit will be more complicated, but developing standardized retrofit packages that produce obvious benefits and can be carried out by workers and even homeowners with modest skills will be key to achieving success. The National Institute of Standards and Technology (NIST), the National Institute of Building Sciences, universities, and DOE's national laboratories are all potential innovators here.

Current use of manufacturing techniques in housing is far different from the days of cheap housing built under permissive codes established by the Department of Housing and Urban Development. Increasingly, large segments of building are coming preassembled to building sites, and high-end builders are experimenting with computer-aided design and computer-aided manufacturing–based housing. As the residential building industry's use of digital design and information technology becomes more sophisticated, the potential for a more totally integrated process involving design, construction, and commissioning will be increased. This will mean workforce changes. Because the transportation and installation of factory-built homes and subsystems affect quality, environmental performance, and energy performance, they are factors in achieving optimal design. The skill levels of equipment operators, installers, assemblers, and finishers need to be considered in the planning and design processes.

Computer-aided design and construction is already showing its potential to deliver a cheaper, yet more precisely built product. It improves communication among the client, builder, fabricators, and operators, thereby decreasing mistakes and waste while making it possible to deliver a higher-quality and more profitable product much faster than conventional site construction. Although automated fabrication design and the fabrication of building components currently are concentrated at the high end, "mass customization" of affordable, high-performance homes and performance-based upgrades should eventually lead to higher qual-

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ity throughout the sector and ease the transition of ideas and technology from lab to marketplace. Many more machine-fabricated homes have been built in Europe than in the United States, but the practice is spreading domestically, especially in custom design of wooden buildings.

The renewal in 2010 of the America COMPETES Act authorized NIST's Manufacturing Engineering Partnership program to bring its manufacturing expertise to the construction sector. This concept is now being piloted in Philadelphia. NIST should make it a priority to use its network of 50 state partnerships to accelerate the adoption of modern manufacturing techniques throughout the building industry. DOE should also work with home improvement stores, which supply and support small contractors, to make sure that the stores' product selections and the guidance they give contractors are consistent with high-performance–ready concepts.

Encourage experimentation and demonstration in government programs. Local clusters of high-performance and high-performance–ready homes are needed to stimulate the development of regulatory procedures, supply chains for advanced components, improved design tools and codes, markets for creative financing, and businesses that support the operation and maintenance of high performance. Encouraging early high-performance adopters will create models for others and accelerate the time when widespread public demand for high-performance homes will occur. In Europe, change toward highly efficient homes happened first in specific locales and then spread when consumers saw the advantages of advanced housing.

Technologically savvy communities, including university towns, are good candidates for early adoption. Community organizations and nongovernment organizations, such as Habitat for Humanity, can also spread knowledge of best high-performance practices to affordable and low-income housing. At the national level, home builders, bankers, and real estate agents often represent the status quo, but in local communities they can be a force for change. The Department of Housing and Urban Development, Fannie Mae, and Freddy Mac should be reviewed for opportunities to demonstrate and promote high-performance and high-performance–ready building. The Department of Defense, which has hundreds of thousands of residential units, a need to cut costs, and an expressed commitment to energy efficiency, is also a prime candidate for leading cutting-edge demonstrations.

Focus building research on high performance. Robust applied research programs in the public and private sectors are needed to fill current high-performance knowledge gaps, including in such areas as building materials that perform reliably over time, measurements and standards that will back up performance, and tools that more accurately predict and verify building performance initially and over time. DOE, with its multidisciplinary national laboratories and relationships with leading universities, has deep knowledge of energy efficiency and renewable energy systems, materials, and sensors. An important part of the DOE effort is the Builders' Challenge, in which participating builders aim to be able to cost-effectively produce new NZE homes anywhere in the nation by 2030. Some home builders are already ahead of where they expected to be at this time. NIST has a long history in building and fire research and metrology, advanced manufacturing, and computer software standards, and shares smart grid responsibilities with DOE. NIST also is the main technical backup for building standards and code developers. These and other agencies have important roles to play in advancing the state of the art; staying current on overseas research; advocating for up-to-date building codes and standards; and making high-performance buildings, including homes, easier to construct and operate. Information dissemination through nationwide networks, including NIST's Manufacturing Engineering Partnership program, the Department of Agriculture's Cooperative Extension Service, and various private-sector organizations, is also necessary.

Keep residential building codes and related standards technologically current and use "reach codes" to articulate a long-term vision. Building codes ensure a minimum level

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of public health and safety in residential and commercial buildings. The International Code Council (ICC), formed in a 1994 merger of regional model code-writing organizations, draws its membership from a cross-section of industry and government officials related to the building industry. It has issued and regularly updates a compatible set of codes covering various aspects of residential building design and construction, including the International Energy Construction Code and the International Green Construction Code.

The country's legally binding residential codes are primarily enactments by state and local governments of ICC codes, modified to local needs. More than 20 states have enacted the most recent code; most other states have earlier versions in place. A handful of states encourage voluntary compliance with ICC codes or have no statewide codes in place. Most areas with no code in place are rural, because cities generally adopt codes even if their states do not. Occasionally, Congress has conditioned aid on having up-to-date codes in place. The most recent code revisions' requirement of a 30% increase in energy efficiency in new residential construction is proving to be a driver for increased energy efficiency. Some jurisdictions' building codes go beyond minimum ICC requirements. Some have enacted voluntary reach codes to provide guidance to those aiming for high performance or NZE.

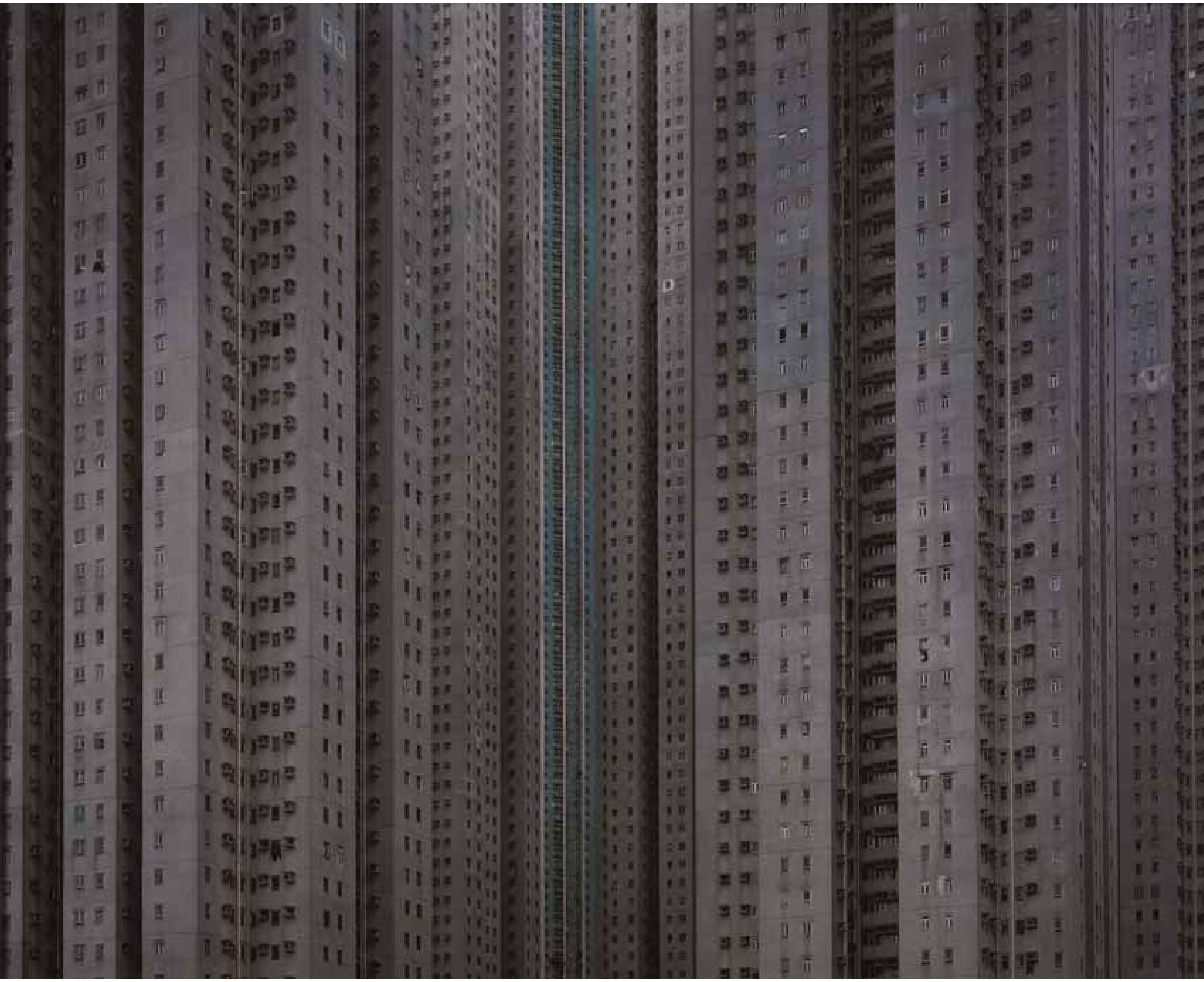
High-performance–ready concepts would be taken more seriously if ICC codes were revised to reflect the best affordable technology and the most current versions were routinely adopted and updated in all jurisdictions. Both building codes and reach codes should cover home performance, including monitoring, inspection, maintenance, and ease of repair, alteration, and upgrade. They also should consider the impact of home construction and modification on neighboring buildings' attainment of high performance, including solar and renewable access. Reach codes are needed to articulate high-performance end goals and to provide guidance for the first movers toward high performance. Codes and voluntary standards will probably need to be regularly revised as more smart grids and smart homes are introduced.

Codes are developed by consensus, and some regular participants instinctively favor the status quo. The federal government and other advocates for change have increased their participation in recent code revision cycles. This trend toward representation of all interested parties must accelerate for codes to achieve their potential.

Coordinate and measure overall progress toward high performance. Preparing for widespread deployment of high-performance residential buildings is a complicated process that involves many actors. Expertise in the various parameters of high performance is scattered among several agencies. Expansion of President Obama's October 2009 Executive Order 13514 on federal environmental sustainability to establish a central focus for high-performance policy in the White House would help in making sure that key steps are taken in a timely and coordinated fashion.

The order now requires each federal agency to appoint a designee to carry out the order, to produce a Strategic Sustainability Performance Plan, and to report annually to the Council on Environmental Quality on progress toward high-performance sustainable buildings and NZE buildings. Expanding the order's definition of sustainable buildings to cover all high-performance attributes and broadening the scope of reporting to cover all federal activities related to high-performance buildings would put in place most of the pieces needed for the federal government to keep track of overall progress toward high-performance new construction and retrofits.

Make achieving high performance in home operations easier. The best-designed building cannot achieve high performance without proper building operation. Because energy use routinely varies by 25% or more in identical homes, occupant education and behavioral change are important. Students from an early age should be taught about natural resources and how their behavior affects those resources' use. Adults also need aids, such as energy labeling of appliances and homes, to understand the probable operational costs of



MICHAEL WOLF, *Architecture of Density #44*, C-print, 40 x 50 inches, 2005/2010.

their purchases, along with smart meters to show the actual contribution of appliances and home features to monthly energy bills. Striving for goals such as reducing energy use by 20% by 2020 can also help spread knowledge of potential and actual energy use.

However, no amount of education will completely overcome human tendencies to avoid hassles and take shortcuts. Automation, annual inspection, third-party vendors, and accountability are needed to guarantee high performance. The buildingSMART Alliance, a council of the National Institute of Building Sciences, envisions Building Information Modeling (BIM) standards becoming a common platform throughout the life cycle of commercial facilities, including multifamily housing (see www.buildingsmartalliance.org). Buildings would be planned, designed, constructed, commissioned, and renovated using open BIM standards that allow data gathered in those phases to be accessed during operation, monitoring, maintenance, or repair. A scaled-down version of BIM would be desirable in the rest of the residential sector as well. In Germany, the Passivhaus Planning Program already is enabling more "average" home designers to achieve high-performance energy efficiency. Data-driven modifications may extend beyond the individual building and its operation as the existing home site, neighborhood, and community all digitize.

Sophisticated third-party monitoring systems that continuously watch the performance of an entire residence and its individual components for energy use, environmental quality, safety, security, and user preferences are natural technological extensions of the variety of security and maintenance services many homeowners now purchase. Given recent trends, it is expected that home energy applications analogous to phone apps will become an integral part of future homes. Such apps will give alerts, originated by new generations of sensors and remote monitoring systems, when human intervention is necessary for maintenance or repairs, to reduce peak or overall energy use, and to improve quality of life in ways unforeseeable today. It is an important part of the high-performance–ready concept to think about how control and sensor systems will be upgraded as technological advances occur and how predictable upgrades to future home energy uses, such as electric vehicle charging, can be made easily.

At the same time, the natural systems that support the built environment should not be overlooked. Site orientation and design strategies that use or block the Sun for passive heating and cooling and prevailing winds for natural ventilation are among the oldest methods for designing higher-performing homes, and they also can be designed not to be dependent on human behavior.

Meeting the challenge

The challenge, then, is to think high performance and high performance–ready for new home construction and for retrofits, focusing on what is available and marketable in improvement packages today while laying the groundwork for future complete conversion to high performance when it makes financial sense with or without government subsidies. In this interim period, efforts should center on continuing the research, doing the demonstrations, upgrading the financial and design tools, regularly revising the building codes, thinking strategically, and modernizing construction practices. There also needs to be a sustained effort to understand how performance advances in larger and more costly buildings can be simplified for use in the residential market. Significant pieces of the puzzle are falling into place, but more in high-end and new construction than in the retrofit of the average existing home.

Achieving sustainability will require millions of small steps, so the federal government needs to measure progress and provide continuity. With all parties acting together to lay the proper groundwork, it should be possible that by the end of the Better Building Challenge in 2030, monitoring systems, renewable energy technologies, energy storage systems, and other components will all have come down in price, the smart grid will be operational, and smart appliances and home energy-saving applications will be commonplace. The nation would then be well on the way to sustainability in new housing. Completing the conversion to high-performance homes would then be a deployment exercise that will largely be carried out in the private sector and retrofit market. It will involve customizing knowledge of high performance to the wide variety of existing homes, many at the low end where the economics are more challenging and subsidies are likely to be necessary.

The challenges are great, but so are the benefits, and the consequences of doing nothing are so great that there is no choice but to try.

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