Advancing a Market for Zero-Energy Homes

A comparative study reveals that with supportive policies, **high-performance homes can be cost-competitive with other houses.** Are zero-carbon homes ahead?

By Barbara C. Farhar, Ph.D.

As U.S. policymakers, businesses and citizens get serious about addressing the global climate crisis through carbon-mitigation efforts, one obvious target is the buildings sector. According to the U.S. Department of Energy, buildings account for 71 percent of electricity used in the United States. The annual carbon dioxide (CO_2) emissions associated with buildings' electricity demand, 658 million metric tons, is equal to the combined emissions in Japan, France and the United Kingdom. Residential buildings represent a prime opportunity, with more than 2 million constructed each year — representing nearly 2 percent of the nation's 114 million single-family, multifamily and mobile homes.

According to the Intergovernmental Panel on Climate Change (IPCC) 2007 report, "Mitigation of Climate Change," energy efficiency for new and existing buildings can considerably reduce CO_2 emissions with net economic benefit, and improve indoor and outdoor air quality, improve social welfare, increase employment and enhance energy security. The IPCC identifies codes and certification as effective ways to decrease greenhouse gas emissions from new buildings. By 2030, the IPCC estimates, new buildings will include technologies such as intelligent meters that provide feedback and control and building-integrated solar electric systems.

Several states are adopting policies to encourage builders to construct highly energy-efficient homes with renewable energy systems. (See Hammon, "Building a Market for Solar Homes," September/October issue.) Builders, meanwhile, are using new technologies and practices to construct houses that increasingly rely on on-site energy systems tied to the utility grid to supply all of their energy in the net over the course of year.

According to the conventional wisdom, these net-zero-energy homes appeal only to early adopters. This thinking assumes that zero-energy homes cost more to build and buy than conventional homes (excluding conventional electricity and fuel costs). In this view, mainstream homebuyers are put off by the appearance of solar photovoltaic panels, which thereby negatively affect resale value. Conventional wisdom assumes that mainstream homebuyers, in opting for zero-energy features, are motivated by economic payback on an incremental financial investment. Homebuyers' satisfaction, then, is considered contingent on their perceived payback of energy features.

As this article discusses, however, study findings offer an alternative paradigm that stands the conventional wisdom on its head. These findings suggest that markets for new high-performance homes are essentially equivalent to those for conventional new houses, assuming a supportive policy framework. Rather than new homebuyers, the early adopters are the builders, utility companies and policymakers who make high-performance homes the standard best practice for many willing homebuyers.

Raising the Bar for Energy-Efficient Housing

In April 2001, the Scripps Highlands development of new homes in San Diego became the first in the United States to offer "high-performance homes" (HPHs) — energy-efficient homes with solar water heating and photovoltaic, or PV, systems. To examine buyer and builder experiences and responses, colleagues and I conducted a multiyear comparative case study of the Scripps Highlands HPHs and adjacent homes. In collaboration with and support from the National Renewable Energy Laboratory, we collected data from 2001 through 2006 on the market response to HPHs, builder experiences, increases in home values over time, and the consumption and cost of electricity and natural gas in the HPH and adjacent comparison homes. (Download the complete, two-volume report, "A New Market Paradigm for Zero-Energy Homes: The Comparative San Diego Case Study," by B. Farhar and T. Coburn, December 2006, at www.nrel.gov.)

SHEA HOMES-SAN DIEGO VIA U.S. DEPARTMENT OF ENERGY

Shea Homes located its two high-performance developments in the Scripps Highlands area of San Diego County.

Shea Homes located its two HPH developments in the Scripps Highlands area of San Diego County. The 110-home San Angelo development and the 196-home Tiempo development, with houses similar in architectural style, ranged from 2,600 to 3,376 square feet. The builder claimed the homes would reduce energy use 30 to 50 percent over "conventionally built homes" (referencing homes built to California's Title 24 building code then in effect). Prices ranged from $480,000 to $840,000, with an average of $601,984. Each of the 306 Scripps Highlands homes featured ConSol's "ComfortWise" energy-efficiency package, incorporating features such as tightly sealed ducts, solar radiant barriers, spectrally selective glass and special HVAC systems (www.consol.ws). Of them, 293 of the homes had solar water-heating systems and 120 had PV systems.

We selected a comparison community consisting of 103 homes of a similar vintage, size, and price located near the Scripps Highlands developments. Built to California's 2001 Title 24 building code, these homes were fairly energy efficient but came with no special energy-efficiency or solar features.

The Scripps Highlands development was the first step in making energy-efficient homes with on-site heat and electricity generation the routine best building practice in the United States. The figure on page 28, "The New-Housing Energy Continuum," portrays energy improvements in new grid-tied production housing. Such homes, produced in quantity, save significant percentages of utility-supplied electricity and natural gas, thus reducing costs

SAN ANGELO BY SHEA HOMES, SAN DIEGO DIVISION

With Scripps Highlands, Shea Homes moved along the new-housing energy continuum toward net-zero-energy homes.

Table 1.

Prices for High-Performance Homes (HPHs) vs. Comparison Homes

Home Type	Home Price per Square Foot
HPHs with photovoltaic systems	$198.45
HPHs without photovoltaic systems	$194.36
Comparison homes	$215.89

Table 2.

Gains in Property Values and Length of Ownership for HPHs and Comparison Homes (as of 2/7/05)

Variable	High-Performance Homes (n=15)	Comparison Homes (n=12)
Original price (mean)	$556,344	$598,028
Length of ownership (mean)	22.5 mos.	28.1 mos.
Resale price (mean)	$862,853	$862,590
Mean $ gain in property value	$306,510	$262,968
Mean percent gain in property value	55.4%	44.7%
Mean $ gain per month owned	$14,492	$9,301

and CO_2 emissions. Beyond HPHs, near-zero-energy homes (near-ZEHs) save 60 to 90 percent of their energy costs in the net, and zero-energy homes (ZEHs) approach 100 percent of cost savings annually. Shea Homes moved along the continuum from producing HPHs built to building energy codes toward developments in which homes save 30 to 50 percent on home energy costs.

The continuum is a route from fossil fuel-dependent homes that generate large quantities of greenhouse gases to carbon-neutral ZEHs or even *zero-carbon* homes (ZCHs), which not only are energy self-sufficient but also export energy to the electric grid. If sufficiently large arrays of PV are included, these homes might also power plug-in hybrids or electric vehicles. Being built today as custom homes, ZCHs, through efficiency and renewable technologies and, to some extent, owner behavior, export net electricity, thus offsetting the greenhouse gas emissions embodied in the homes' materials.

California's net metering legislation made it possible for owners of Shea Homes with PV systems to interconnect with the utility grid and, in effect, use the grid to store their electricity. Net metering allows owners of small renewable energy systems to receive credit on their utility bills for bills for the self-generated electricity they use and at least a portion of the excess electricity their systems provide to the grid. Forty states and the District of Columbia have net metering legislation.

Examining Comparative Pricing, Profitability

The Scripps Highlands homes were competitively priced. On average, they sold for 9.2 percent less per square foot than the comparison homes. Table 1 above shows the mean price per square foot of HPHs with PV systems, HPHs without PV systems, and comparison homes.

On balance, the costs to the builder for the solar features did not seem as high as might have been expected. Shea Homes took advantage of three incentives from the California Energy Commission: (1) $750 (about 44 percent of the $1,700 cost) for each solar water-heating system; (2) a 50 percent subsidy for each PV system; and (3) a 15 percent tax credit on the full PV system cost. The installed costs of the solar features were as follows: Sun Systems Inc. solar water-heating system, $1,700; 1.2-kilowatt (kW) AstroPower Inc. PV system, $7,900; and 2.4-kW AstroPower Inc. PV system, $14,200. (Note: The cost estimates detailed in this article do not apply to the current market situation.)

Calculating the builder costs for the solar features and subtracting the offsets provided by rebates and customer charges, we estimate that the total net costs to Shea Homes for the solar features alone on the 293 homes that had them was approximately $600,000. (This net cost estimate does not include other factors that affected the builder's net costs and profits, such as the 15 percent tax credit and the costs of energy-efficiency measures.) The homes' energy-efficiency features may have cost more in the net, although the offsets provided by equipment downsizing and rebates would have reduced costs. Shea Homes management stated that they "did not lose money on the project" even though they sold the homes for less per square foot than competitor homes cost.

NATIONAL RENEWABLE ENERGY LABORATORY, GOLDEN, COLO.

Shea Homes-San Diego had advertised that its homes, incorporating "the latest in solar electric home power generation, solar water-heating and energy-efficiency technology," would reduce utility bills by 30 to 50 percent over conventionally built homes — a claim validated by utilities analysis.

Table 3.

Average Electricity and Gas Consumption for One Year by Home Category

Home Category	Average Monthly Electricity Consumption (Kilowatt-hours)	Average Monthly Gas Consumption (Therms)	Average Combined Monthly Utility Bills
Comparison homes	793	42	$174
High-performance homes (HPHs) without photovoltaic systems	694	35	$150
HPHs with 1.2-kilowatt photovoltaic systems	573	31	$123
HPHs with 2.4- kilowatt photovoltaic systems	318	30	$80

The builder's pricing strategy was designed to achieve "velocity" in the market. The lesson is that, given a bulk-purchase scenario, subsidies and a roll-in of costs to home prices, the builder could offer HPHs at prices that, compared to comparable homes, were not only competitive but also profitable when sales were brisk.

Originally, the HPHs sold for $556,344 on average and the comparison homes for $598,028. During our study period from 2001 through February 2005, the values increased dramatically, as detailed in Table 2 (see page 26).

In this group of homes, PV systems had no negative effect on resale value. Five percent of HPHs and 15 percent of the comparison homes were resold by February 2005, suggesting that HPH owners were more satisfied with their homes. By February 2005, the HPHs had increased in value 55.4 percent on average and the comparison homes by 44.7 percent. During this period, the high end of the range for HPHs increased from $701,184 to $1.1 million, and for comparison homes, from $711,887 to $995,900.

Assessing the Buyers and Their Decision Factors

How were buyers of HPHs different from buyers of comparison homes? The research found that HPH and comparison homebuyers were very much the same, comprising a homogenous population of first-time buyers looking for upscale houses. The similarities between these groups in terms of demographics, environmental attitudes and early-adopter characteristics far outweighed any differences.

Surprisingly, energy features were *not* important decision factors for most of the buyers. The data showed that energy features were far less important in home purchase decisions than location, the safety and security of the area, the quality of the neighborhood and financial considerations.

Owners of PV homes more frequently reported being satisfied with their homes than did comparison homeowners. Although most buyers tend to be satisfied with their new homes, those who bought HPHs (especially those with PV) were more satisfied than comparison buyers. Several pieces of evidence in the study support this conclusion. These owners appear to become increasingly satisfied as they receive feedback from their systems, modify

Building Technologies On the Horizon

Technological advances in building design and technologies are rapidly superseding the high-performance building technologies used by Shea Homes in 2001. The 2007 Solar Decathlon, held in October, showcased some of these cutting-edge technologies. Key design themes included affordability, attractiveness, adaptability, comfort, efficiency, inside/outside links with natural space and the community, natural lighting, recycling of water and materials, self-sufficiency and sustainability.

Electricity/Transport
- Large photovoltaic systems (7 kilowatts)
- Transport vehicle powering
- PV systems integrated with structure, replacing roofing

Electronics
- Digital energy feedback monitors
- Sustainability meters to measure carbon footprints (and ultimately to use carbon savings in the sale of carbon credits)
- Smart house automatic control systems
- Artificial intelligence for temperature control and energy use, shading, lighting and ventilation
- Energy simulation for design
- Touchscreen programmable thermostats

Environmental/Water Features
- Reflecting pool with wetlands
- Rainwater collection and recovery
- Gray water recycling
- Cooling greenscapes
- Weather forecast systems
- Contained roof ponds to maximize daylight through reflection and as heat source for geothermal heat pump

Heating/Cooling/Passive Features
- Solar thermal units with absorption chillers
- Solar hearths
- Vertical evacuated-tube collectors
- Raised flooring
- Solar thermal systems combined with passive and efficiency features
- Radiant heating and cooling
- Solar chimneys

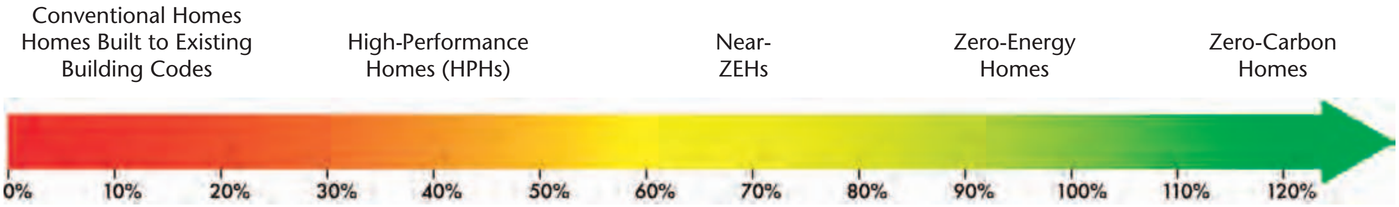
Lighting/Fenestration
- Hybrid lighting (CFLs and LEDs)
- Electrochromic windows
- Translucent siding for daylighting
- Light-emitting capacitors
- Translucent skylights filled with Nanogel
- Translucent walls filled with "solid smoke" aerogels
- Light canopies

Wall Systems
- Integrated siding and louvers
- Manufactured wall units and fabricated cores combined with local materials and containing HVAC systems, electrical systems and laundry and kitchen systems
- Shuttered building skin
- Structural insulated panels

Source: Solar Decathlon, www.solardecathlon.org

New-Housing Energy Continuum

Net Percentage of Energy Saved and Supplied by New Homes Annually



Conventional homes: Built to comply with existing building energy codes; 100 percent reliant on utility-supplied electricity and natural gas.

High-performance homes (HPHs): Save 30 percent to 50 percent of utility costs over conventional homes using efficiency and solar technologies.

Near-zero-energy homes (near-ZEHs): Save 60 percent to 90 percent of utility costs over conventional homes.

Zero-energy homes (ZEHs): Homes that, in the net, supply virtually all of their own electricity and space and water conditioning.

Zero-carbon homes: ZEHs that export electricity equivalent to 20 percent more than the energy used in the home for at least 25 years, thereby offsetting the energy embedded in building the home.

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their behavior and observe (and brag about) their utility bills.

PV System Feedback. The amount of electricity the PV systems produced was important to homeowners. HPH owners with PV systems had digital displays of electricity production and consumption in real time, and 70 percent rated the displays as important; 58 percent said they looked at their display at least once a week. They used the displays to schedule electricity-consuming chores and otherwise became more sensitive to their household electricity consumption.

Utility Bill Savings. Shea Homes had advertised that its homes, incorporating “the latest in solar electric home power generation, solar water-heating and energy-efficiency technology,” would enable homeowners to reduce their utility bills by 30 to 50 percent over the conventionally built homes — a claim validated by our utility analysis. Among the homes we studied, HPHs consumed less electricity and gas, on average, than adjacent comparison homes. They incurred lower utility costs, on average, than comparison households.

As detailed in Table 3, page 27, the HPHs experienced electricity cost savings of 38 to 62 percent, depending on the size of the PV system. Electricity consumption was much higher in comparison homes than in all types of HPHs, and it was considerably lower in homes with PV systems. In addition to the energy-efficiency and solar features of these homes, the presence of feedback and changes in occupant behavior may have played a role in energy savings.

Uncovering a New Market Paradigm

Our study findings suggest a novel paradigm for building and marketing new-production zero-energy homes. These findings, although originating from the San Diego case study, may be useful more generally, even though market and environmental circumstances have changed. This paradigm addresses sales prices, uptake, homebuyers, aesthetics, home purchase decisions and satisfaction.

Sales Prices. Although conventional wisdom holds that HPHs cost more to build and purchase than other homes, our study found that quality upscale homes with market appeal can be built and sold profitably in a supportive policy environment.

Uptake. The commonly held view is that builders should offer HPHs optionally and only a few will be sold. We believe that builders should offer HPHs standard; the pace of sales will probably be accelerated over that of conventional homes.

Homebuyers. Conventional wisdom holds that only innovators and early adopters will buy ZEHs. Our results show that HPH buyers were mainstream buyers in their price ranges.

Aesthetics. Contrary to the conventional view that solar panel aesthetics negatively affect the resale value of HPHs, we found that solar homes had higher resale value than comparison homes. Increasing concerns about climate change may make panels a political statement in the way hybrid vehicles have been.

Home Purchase Decisions. It is usually thought that, other than early adopters or “environmentalists,” buyers of HPHs would be motivated by economic payback for a chosen incremental financial investment. Our study found that HPH buyers may be *unaware* of any potential additional financial investment if the costs of energy systems are built into the homes’ sales prices and mortgages. However, buyers are aware of their substantial benefits from reduced utility bills. In this paradigm, financial incentives (e.g., rebates) go to the builder, although buyers could receive income tax credits or renewable energy credits.

Satisfaction. Conventional wisdom holds that homebuyers’ satisfaction is contingent on perceived payback of energy features. We found that owners of HPHs with PV systems actually perceived three kinds of benefits: (1) altruistic (helps address climate change and improve air quality and benefits the local economy and future generations); (2) financial (reduces electricity bills, provides free electricity once system is paid for, enables owner to sell excess electricity back to utility and increases home’s resale value); and (3) those related to personal satisfaction (increases self sufficiency, is technologically innovative and feels good to have it).

BARBARA C. FARHAR, PH.D.

The next step in low-energy housing, zero-carbon homes are emerging as one-off custom homes. One such house is the Next West Home in Boulder, Colo. Bruce Oreck is leading the project with architect Jim Logan and builder Bob Hughes of Hughes Construction.

Progressing Along the New-Housing Continuum

In the three years since Shea Homes completed its project, the new-construction market has slowed, while climate change concerns have accelerated. Several major production builders have adopted HPH technology as standard offerings. The next near-ZEH development after Scripps Highlands was Premier Gardens in Sacramento, Calif., where studies have shown electric utility bill savings of more than 60 percent compared with nearby conventional homes. Other California builders have followed suit, including Grupe Homes (Carsten Crossings), Clarum Homes (Pajaro Vista in Watsonville), Centex Homes (San Ramon) and Lennar Homes (Hunters Point). These developments are reporting electricity savings of about 60 percent with 2.4-kW PV systems.

At a conference last July, Grupe Homes reported on its success in selling the near-ZEHs at Carsten Crossings. Eight competitors with comparable offerings provided a baseline for sales. As of April, the competitors had sold 225 homes in total, at an average rate of 1.9 homes per month per builder. For Grupe, the additional cost of Grupe Green features in 144 homes was $2.642 million; its monthly carrying cost was $311,000. To break even, Grupe calculated that it would have to sell 2.1 homes per month. However, the builder sold an average of 4.6 homes a month — 144 homes in 31 months. The 45 months saved (compared to baseline) equaled $14 million saved. Grupe Homes concluded that if just 18.8 percent of the accelerated pace of sales was due to the Grupe Green features, the program paid for itself ($2.642 million/$14 million).

New near-ZEH developments are being built in California, New Mexico, Colorado and other states. By 2020, experts at the U.S. Department of Energy expect near-ZEHs to be commonly available nationwide.

Zero-energy homes are already on the path to becoming best building practice. On Oct. 18, the California Public Utilities Commission issued decision 7-10-032 affirming cost-effective energy efficiency measures as the state's highest energy priority. The decision directs California's utilities to prepare a comprehensive long-term energy-efficiency plan, including initiatives for all new residential construction and all new commercial construction in California to be net-zero energy by 2020 and 2030, respectively. Stakeholders will be involved in developing and implementing California's planning decision for net-zero-energy buildings.

This decision follows on the United Kingdom's Dec. 13, 2006, announcement that all new homes in the UK must be net-zero-energy by 2016. (Access the policy statement, "Building a Green Future," at www.communities.gov.uk/planningandbuilding/theenvironment. Although the statement references "zero carbon homes" as the goal, it describes homes that use efficiency and renewable energy for energy self-sufficiency.) The UK plans to achieve this goal by tightening energy-efficiency regulations in three stages.

More recently, innovators have looked beyond energy self-reliance in houses to efforts that would actually offset the embodied energy used in their construction. The Next West Home, due for completion in February, is billed as "a true net-zero-carbon and LEED Platinum residence." Although traditional in appearance, the 3,500-square-foot house in the historic district of Boulder, Colo., showcases a multitude of advanced technologies, including 10 kilowatts of PV capacity, geothermal heating, energy-efficient appliances and advanced insulation. Boulder businessman Bruce Oreck is building the house as a project of The Zero Carbon Initiative, a grassroots coalition that promotes energy-saving construction based on off-the-shelf-technology. According to Oreck, the Next West Home will be used to demonstrate what can be achieved with commercially available technology and construction techniques replicable in any house. (Find videos and details at www.zcinitiative.com/.)

If the experiences of the high-performance and zero-energy housing movements are a good indication, we can expect to see more zero-carbon homes built as one-off custom homes, just as HPHs first emerged. The lessons we're learning today will serve builders, utilities and policymakers well as we progress along the new-housing energy continuum — and offer real promise for slashing greenhouse gas emissions. ●

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