High Performance Homes in the Southwest: Savings Potential, Cost Effectiveness and Policy Options

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ABSTRACT

The Southwestern United States (specifically Arizona, Colorado, Nevada, New Mexico, Utah and Wyoming) is a fast-growing region that is experiencing rapid growth in population and new housing construction. Nearly 2 million homes are projected to be built in the Southwest between 2008 and 2020, equivalent to about 150,000 new homes per year. Increasing the energy efficiency of new homes offers a cost-effective way to help homeowners save money and lower their energy use, while reducing the energy and environmental impacts of new homes. A growing number of utilities, states and local governments in the Southwest are implementing programs and policies to accelerate adoption of highly efficient homes in the marketplace.

The Southwest Energy Efficiency Project (SWEEP) recently completed a study analyzing the energy, economic and environmental benefits of improving the efficiency of new homes in the Southwest region. The study found that new homes in the Southwest region can be built cost-effectively while achieving energy savings of 50% or more through energy efficiency measures, and up to 65% savings by incorporating on-site renewable energy systems. These homes save homeowners an average of $1,600 annually on their energy bills, with positive monthly cash flow immediately. Peak electricity demand is also significantly reduced, particularly when energy efficiency and renewable energy measures are combined.

This paper summarizes the results of the study findings, identifies barriers to high performance homes, and recommends programs and policies that utilities, states and local governments can implement to support increased market adoption of highly efficient homes.

Introduction

The six-state Southwest region of the United States (Arizona, Colorado, Nevada, New Mexico, Utah and Wyoming) is a fast-growing region that is experiencing a boom in population and new housing construction. Nearly 2 million homes are projected to be built in the Southwest between 2008 and 2020, equivalent to about 150,000 new homes per year (SWEEP 2007). Growth rates are as much as triple the national average in parts of Arizona and Nevada, and electricity demand is growing at rates as high as 4% per year. Total peak electricity demand in just three of the Southwest States (AZ, NM, and NV) is expected to grow by 1,000 MW per year for the next 15 years (Arizona Department of Commerce, 2007). Two-thirds or more of the electricity generated in the Southwest region comes from coal-fired power plants, which release emissions of air pollutants that harm public health and contribute to global warming.[1]

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[1] U.S. Energy Information Administration, Electric Power Monthly, Net Generation By State By Sector, 2006-2007 (Tables 1.6.B and 1.7.B. http://www.eia.doe.gov/cneaf/electricity/page/at_a_glance/gen_tabs.html

Purpose and Scope of the Study

The purpose of this study was to analyze the energy savings, cost and cost-effectiveness of high performance homes for five Southwest states (AZ, CO, NV, NM and UT). Utilities, states, local governments and home builders can use the information from the study to develop new programs, policies and strategies for increasing the energy efficiency of new homes.

The Southwest Energy Efficiency Project (SWEEP) analyzed the energy savings and net economic benefits of significantly increasing the energy efficiency of new homes, versus typical homes built to minimum requirements of currently adopted state or local energy codes. SWEEP's final report makes recommendations for utility, state and local government programs and incentives to accelerate the adoption of high performance building practices in the new homes industry, including a 3-tiered incentive structure for ENERGY STAR®, Best Practice and Net Zero-Energy Homes. Best Practice homes are defined as homes that achieve 30-50% energy savings through energy efficiency measures. Net Zero-Energy Homes incorporate energy efficiency and renewable energy features to achieve a 50-70% reduction in energy use, and are capable of producing as much energy as they consume on an annual basis.

The study includes several case studies and examples of high performance homes and communities in the Southwest – ranging from ENERGY STAR qualified homes to Net-Zero Energy Homes – that document the energy and cost savings achieved from increasing the efficiency of new homes. It also addresses the technical, financial and institutional barriers to constructing high performance homes, and presents strategies and best practices for overcoming each barrier, based on lessons learned and successful programs that have been adopted by utilities, states and local governments.

Features and Benefits of High Performance Homes

Increasing the energy efficiency of new homes offers a cost-effective way to help homeowners save money and lower their energy use, while reducing the energy and environmental impacts of new homes. High performance homes – defined as homes that maximize energy efficiency, comfort, and durability – can be built cost-effectively while achieving energy savings of up to 50% through energy efficiency measures, and between 50-70% energy savings by incorporating on-site renewable energy systems, such as solar PV and solar thermal systems. High performance homes are also designed to reduce the risk of indoor air quality problems through programs such as the ENERGY STAR Indoor Air Package.

The energy, economic and environmental benefits of improving the efficiency of new homes in the Southwest region are significant. Achieving the high performance home scenario analyzed in this report would result in the following energy and cost savings between 2008 and 2020:

- Over 2.7 million GWh of grid electricity savings – enough electricity to meet the annual electricity consumption of approximately 250,000 typical households.
- Residential natural gas consumption would be reduced by 228 million therms (up to 50% reduction in natural gas use per household).
- Summertime peak electricity demand would be reduced by nearly 200 MW annually by 2020, and average hourly summertime peak loads per home would be reduced between 50% and 67%.
- Southwest households would reap $500 million in reduced electricity and natural gas bills, with savings of $30 million in the first three years alone.

- Electricity from customer-sited solar PV systems would generate more than 500 GWhs of electricity, worth $52 million to homeowners.
- Emissions of greenhouse gases from power plants would be reduced by 2.4 million tons of CO_2.

Cost and Cost-Effectiveness of High Performance Homes

Energy Efficiency

There are many cost-effective opportunities to improve the energy efficiency of new homes through a combination of improvements to residential building design, construction practices, higher efficiency levels of installed equipment, and homeowner education.

Typical energy efficiency measures used in high performance homes in the Southwest include:

- Optimized orientation of the home to maximize solar heat gain in the winter but with proper window shading to reduce heat gain in the summer.
- A tight envelope (e.g., meets ENERGY STAR thermal bypass checklist)
- Increased insulation levels (e.g., walls, attics, basements or slabs)
- High performance windows with low solar heat gain coefficients
- High efficiency heating and cooling systems that are properly sized and installed
- Sealed ductwork that is placed inside conditioned space and tested for air leakage
- Efficient lighting systems, including 50% or greater CFLs, ENERGY STAR fixtures and utilization of controls on interior and exterior fixtures
- Energy efficient water heating (e.g., solar thermal hot water systems or natural gas water heaters with an energy factor of 0.80 or greater))
- ENERGY STAR appliances (dishwasher, refrigerator, clothes washer and ceiling fans)

The incremental cost of energy efficiency measures analyzed ranges from $2,500 to $6,500, equivalent to 1% of construction costs for an ENERGY STAR home, and 2-3% for the Best Practice home), before any tax credits or incentives. Incremental costs were calculated using construction and equipment cost estimates developed by NREL for the Building Energy Optimization Model (BEopt) (Anderson et al, 2004). The additional cost of using energy-efficient building designs and systems can be partially offset by reductions in the size of cooling and heating equipment (particularly if proper equipment sizing procedures are followed and adhered to during construction and equipment installation) and other building design changes (e.g., reducing framing materials used by going to 2” x 6” wall construction with studs spaced 24” apart). When done properly, this can represent a significant cost savings to the builder and homeowner, as the smaller systems and reduced material requirements achieve construction and operating cost savings.

Renewable Energy Systems and Design Features

Renewable energy systems and design features – such as incorporating passive solar thermal design strategies, solar PV electric systems and solar thermal hot water – can reduce the heating and cooling load of the home and generate a portion of a home’s electricity and water heating needs. Passive solar thermal design strategies can often be implemented at little or no incremental cost through proper building orientation, daylighting, and use of thermal mass.

Typical residential solar PV systems are between 2 kW and 4 kW in size, and are capable of offsetting approximately 25-30% of total household electricity consumption (DOE 2006). Although renewable energy systems have a high initial cost (approximately $15,000 for a 2 kW solar PV system), state and utility incentives are now available in some states that make them more affordable to the builder and homebuyer (Vang and Hammon, 2007). The initial cost of constructing a highly efficient home that includes renewable energy systems (PV and solar thermal hot water) is 6 to 8% more than a typical home (before incentives), but the net cost of ownership is lower because of reduced utility bills.

Most utilities now offer net metering for residential PV systems, at retail rates, which allows the homeowner to receive a credit for electricity generated by their PV system. A few offer renewable energy certificate (REC) payments to owners of grid-tied renewable energy systems. This payment may be made in the form of a lump sum payment or an additional premium per kilowatt hour generated by the PV system. For example, Xcel Energy in Colorado provides an additional $2.50 per watt for residential PV systems (up to 10 kW in size), for a total of payment of $4.50 per watt. In New Mexico, Public Service Company of New Mexico (PNM) pays owners of grid-connected PV systems $0.13 per kWh, which is about 50% greater than the retail electricity rate (PNM 2008).

Analytical Methodology

The analyses in this report were prepared using the BEopt building optimization software and its related components, which were developed by the National Renewable Energy Laboratory (NREL). BEopt analyzes a range of home energy designs, operating conditions and technologies to identify optimal combinations of energy efficiency and renewable energy measures that achieve maximum savings at the lowest cost, using readily available technologies and construction practices (Christensen 2005). BEopt has been used to design and analyze many zero-energy homes, such as Habitat for Humanity's affordable zero energy home in Denver, Colorado.[2]

Using BEopt, SWEEP analyzed four levels of home performance for five Southwest states (AZ, CO, NV, NM and UT):

- A reference case home built to current state or local building energy code requirements (i.e., IECC 2003 or 2006), using standard home building industry construction practices and equipment.
- An ENERGY STAR qualified new home (15-30% energy savings).
- An energy-efficient 'Best Practice' home (30-50% energy savings).
- A 'Zero Energy Home' incorporating renewable energy measures as well as being highly energy efficient (50% or greater energy savings).

As part of this study, SWEEP conducted research on homes built by production builders at each of these performance levels. Across the Southwest, homebuilders are currently constructing homes that achieve each of these performance levels, including net-zero energy homes that are being built on a production basis by several large builders in California and a few smaller production or custom builders in the Southwest.[3] These homes use energy efficiency

[2] For more information, see: http://www.eere.energy.gov/buildings/building_america/affordable_housing.html.

[3] Profiles of individual projects are available on the SWEEP web site at www.swenergy.org/buildingefficiency/

measures and renewable energy systems that are readily available in the marketplace, and have been most successful where state and utility incentive structures are favorable (Vang and Hammon, 2007).

Separate market penetration scenarios were developed and analyzed for each state, based upon the current building code in effect, levels of ENERGY STAR market penetration, and housing styles and preferences (e.g., 1 versus 2 story, basement, slab on grade, etc.). The analysis was designed to achieve savings in a typical production built single-family home in each location. The per home savings estimates for each city (or average of cities in cases where more than one city per state was analyzed) were scaled up to the state level using historical estimates of total and single-family housing units by state, and population projections from the U.S. Census Bureau for the 2008-2020 time period.

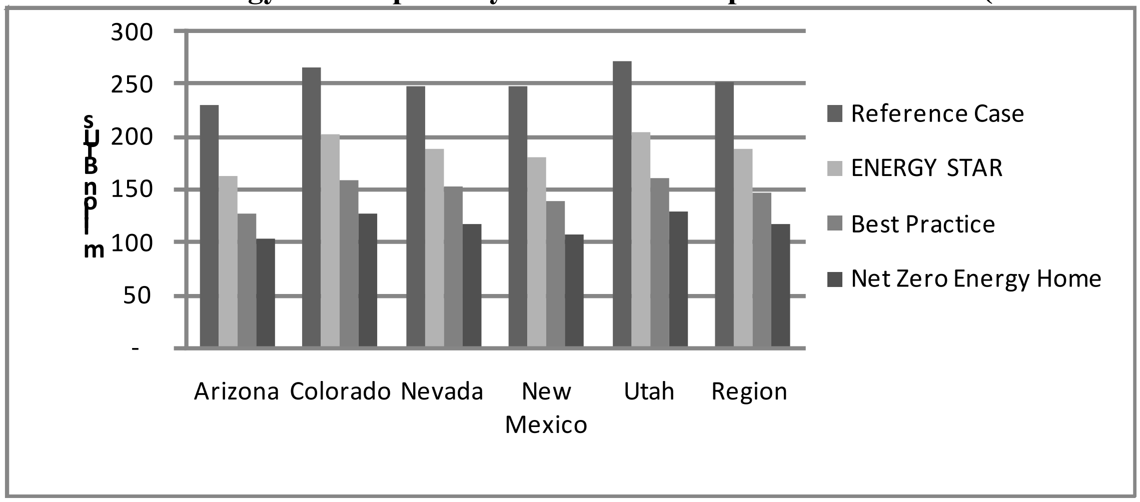
The Best Practice and Zero Energy Home levels set aggressive yet achievable near, mid and long-term goals for raising the overall performance of residential new home construction, using readily available efficiency measures and construction techniques (e.g., SEER 15 air conditioner, 92% AFUE gas furnace, 2" x 6" framing, CFLs, tight envelopes, etc.). Higher performance levels may be achievable as more advanced building practices, materials and technologies are introduced into the production home building industry. The average annual market penetration rates for Best Practice and Zero Energy Homes increases in each state by 2% per year, allowing time to train builders and contractors and support higher performance levels through the growth of utility DSM programs and state and local building energy code requirements. In each state, the scenarios achieve a minimum of 50% market penetration for ENERGY STAR Homes by 2020, 20% market share each for Best Practice Homes and Net-Zero Energy Homes, with the remainder of homes built to current codes. We assumed some of the homes would not be built in compliance with state or local codes, and that market penetration will happen more quickly in some areas, and more slowly in others. For example, in some regions of the Southwest, the market penetration rate of ENERGY STAR homes is already very high (e.g., 36% in Arizona and over 70% in Las Vegas, NV). A few localities in the Southwest have already established energy efficiency standards for new homes at the Best Practice level (e.g. Boulder, CO and Albuquerque, NM); others are initiating programs that will require all new homes to be built to net-zero energy performance levels by 2020 (e.g., State of California and Austin, TX).

Results

Home energy savings by performance level.

The analysis of energy savings was conducted for each home performance level and main city in each state. Figure 1 shows the annual energy savings for each home performance level analyzed, by state. The average source energy savings across the region are 25% for the ENERGY STAR home, 42% for the Best Practice home, and 54% for the Zero Energy Home. These savings estimates are consistent with findings from other Building America studies of field-monitored high performance homes in the Southwest, and data provided to SWEEP by individual homebuilders (Christensen et al., 2005; DOE 2006; Vang and Hammon, 2007; Barna 2008; CARB 2008; Farhar 2008).

Figure 1. Source energy consumption by state and home performance level (million BTUs)



Source: Analysis by SWEEP using the NREL BEopt model.

Cost savings per household

High performance homes are cost-effective for homeowners, with net savings versus a typical new home (built to the 2003 or 2006 IECC) when compared on the basis of the total cost of mortgage and utilities payments.[4] The incremental costs and net savings (calculated as the difference in mortgage and utility payments versus a standard home) of each performance level are shown in Table 1. Combining energy efficiency and customer-sited renewable energy systems reduces net energy consumption by 60% or more, with net annual cost savings of up to $960 per household.

Table 1. Incremental costs and net savings per home

	Incremental cost			Net savings, annual(3)		
State / City	ENERGY STAR(1)	Best Practice	Zero Energy Home(2)	ENERGY STAR	Best Practice	Net-Zero Energy Home
Arizona (Phoenix)	$3,218	$3,474	$15,210	$552	$946	$767
Colorado (Denver)	$2,917	$6,588	$19,895	$432	$616	$271
Nevada (Las Vegas)	$3,236	$5,547	$16,231	$550	$961	$960
Nevada (Reno)	$3,653	$5,640	$18,491	$139	$262	$97
New Mexico (Albuquerque)	$2,464	$5,539	$16,629	$763	$884	$834
Utah (Salt Lake City)	$2,946	$6,588	$19,331	$434	$636	$247
Regional Average	$3,072	$5,563	$17,631	$478	$718	$529

Source: Analysis by SWEEP.

[4] The homeowner cashflow analysis assumes a 30-year fixed rate mortgage with a 7% annual interest rate.

Notes for Table 1:
(1) Includes ENERGY STAR Appliance Package (dishwasher, refrigerator, clothes washer).
(2) Includes adjustment for federal tax credits for energy efficiency ($2,000) and renewable energy systems ($2,000 for solar hot water and $2,000 for solar PV).
(3) Net savings represents the savings to the homeowner in the annual cost of the mortgage plus utility bills versus a typical home. The net savings is after federal tax credits to the homebuilder and homeowner for EE and RE measures, and excludes utility rebates and state tax credits.

Avoided Peak Electricity Demand

Peak electricity demand in high growth states such as Arizona has doubled in the past 15 years, and is expected to double again in the next two decades (Schlegel 2007). Much of the growth in peak electricity demand is driven by increased air conditioning loads from new homes, and retrofits to existing homes that either had evaporative cooling or no cooling at all.

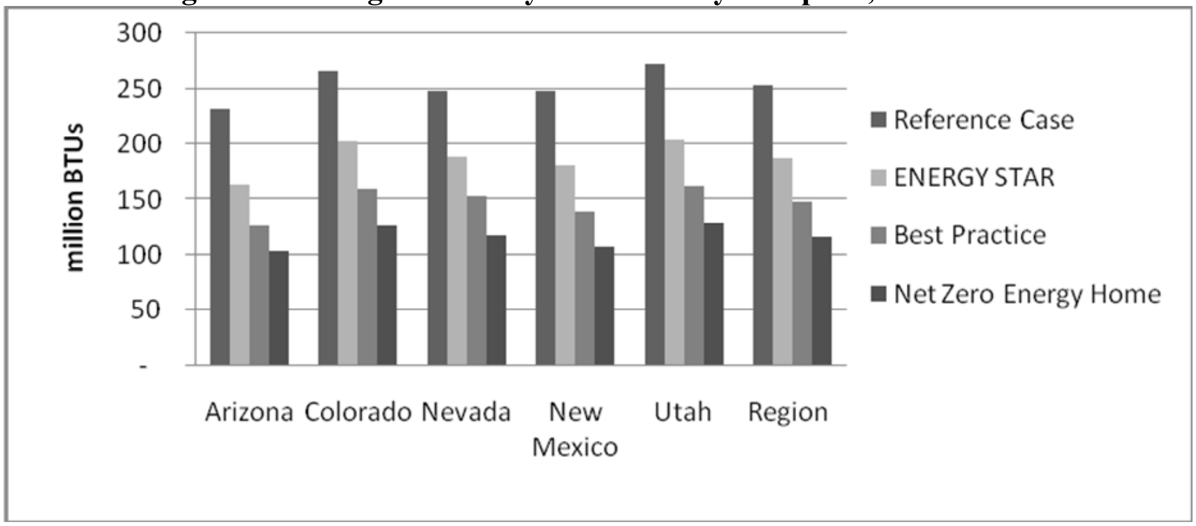
Energy efficiency design features that achieve peak savings include, but are not limited to:

- Proper orientation of the parcel and the home, with shading to reduce cooling loads;
- Improving the efficiency of AC systems through higher SEER levels, or use of evaporative cooling;
- Tightening the thermal envelope, and placing ducts inside conditioned space with proper sealing and diagnostic testing; and
- Reducing indoor loads from lighting, appliances and consumer electronics.

The expected summertime peak savings by home performance level and state are shown in Figure 2. On average, improving the energy efficiency of new homes can reduce the daily peak electricity demand per home in the region by more than 50%. As a fraction of electricity demand in the region, the reductions in peak electricity demand achieved by high performances homes are much more significant than the total electricity savings.

The combination of a highly-efficient home with a moderately-sized solar PV system (2 kW) can achieve even greater peak reductions, eliminating 70-85% of the peak load throughout the afternoon and early evening hours on hot summer days. Maximum peak demand levels in zero energy homes are reduced by as much as 4 kW per home in hot climates, such as Las Vegas, Nevada and Phoenix, Arizona. In some cases, the net power draw from the utility grid drops to less than 1 kW at system peak (typically 4pm) on a hot summer day (SWEEP 2007).

Figure 2. Average electricity demand at system peak, 5 Southwest States



Source: Analysis by SWEEP using hourly electricity load profile data from the BEopt model.

Statewide and regional savings potential, costs and cost effectiveness

The projected cumulative electricity and natural gas savings by 2020 from the high performance scenario for all new single-family homes expected to be built in each state and the Southwest region (1.8 million homes total) are shown in Table 2. The annual electricity savings in the region by 2020 are 427 GWh, and the annual reduction in peak electricity demand is 208 MW. The total annual electricity generation from PV systems installed on new homes is 81 GWh per year in 2020.[5]

The high performance scenario achieves significant cost savings for Southwest households, with net economic benefits of $4.4 billion from efficiency measures between 2008 and 2020, and an additional $430 million in net benefits from renewable energy measures, shown in Table 3.

Each home performance level has a positive benefit-cost ratio in every state and region of the Southwest, shown in Table 3. The highest savings ratios are in Arizona and Nevada, which are also the fastest-growing states in the region. Approximately 95% of the net economic benefits come from energy efficiency measures; the remainder comes from a combination of rooftop solar PV and solar thermal hot water systems. While on-site renewables are marginally cost-effective on a lifecycle basis (excluding utility and state incentives), many types of readily available energy efficiency measures are highly cost-effective. Moreover, renewable energy measures are capable of delivering significant reductions in peak electricity demand (up to 100% at system peak loads), and are expected to become more cost-effective in the future as the cost of PV systems continues to decline and additional federal, state and utility incentives for solar systems become available (Vang and Hammon 2007; SMUD 2006).

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[5] Peak electricity demand savings were analyzed by SWEEP using hourly load duration curves generated by the BEopt software model and summertime peak electricity load information obtained by SWEEP for individual electric utilities serving Southwest states. The estimates of electricity generation from PV systems were developed by SWEEP using city-specific data from BEopt on annual electricity generation from roof-mounted solar PV systems.

Table 2. Summary of Analysis Results: Annual Savings in 2020 and Cumulative Energy Savings, 2008-2020

State	Annual Savings, 2020		Cumulative electricity savings (GWh)	Annual Avoided Peak Demand (MW), 2020	Cumulative Natural gas savings (million therms)	Cumulative Primary Energy Savings (trillion Btus)
	Electric (GWh)	Natural Gas (million therms)				
Arizona	183	5.4	1,159	93	34	21
Colorado	94	16.4	606	40	106	18
Nevada	69	2.1	425	43	13	8
New Mexico	25	3.0	166	10	20	4
Utah	56	8.7	354	21	55	10
Region	**427**	**35.5**	**2,710**	**208**	**228**	**62**

Table 3. Summary of Incremental Costs and Savings: 2008-2020[6]

State	Total investment, energy efficiency (millions 2008 $)	Net economic benefit, energy efficiency (millions 2008 $)	Benefit-cost ratio: energy efficiency measures	Total Investment, energy efficiency & renewables (millions 2008 $)	Net economic benefit, energy efficiency & renewables (millions 2008 $)	Benefit-cost ratio: energy efficiency & renewables
Arizona	$401	$1,296	3.2	$1,034	$1,455	1.4
Colorado	$443	$1,409	3.2	$974	$1,493	1.5
Nevada	$279	$583	3.1	$905	$699	1.2
New Mexico	$94	$338	3.6	$191	$366	1.9
Utah	$229	$757	3.3	$538	$802	1.5
Region	**$1,446**	**$4,383**	**3.3**	**$3,642**	**$4,815**	**1.5**

Source: Analysis by SWEEP.

[6] Notes: EE measures include the incremental cost of all energy efficiency measures, excluding renewable energy system costs. Net present value assumptions: 20 year lifetime for energy efficiency and renewable energy measures and 5% real discount rate (capital recovery factor = 12.5). The benefit-cost ratios are based upon annual incremental costs and savings; RE incentives include federal tax credits only and exclude state and utility incentives.

Findings and Recommendations

Key findings from the study are summarized below, with recommendations for programs and policies that utilities, states and local governments can implement to advance high performance homes.

Energy savings and cost-effectiveness

High performance homes are capable of achieving whole-house, source energy savings of up to 50% in both cooling-dominated and heating-dominated climate zones in the Southwest. Maximum savings are achieved by combining energy efficiency and renewable energy features, starting with efficiency improvements. High performance homes significantly reduce peak electricity demand – eliminating 80% or more of afternoon peak electric loads.

High performance homes are cost-effective in all Southwest climate zones, with higher first-costs recovered through lower combined mortgage and utility bills. Incentives for renewable energy systems, including buydowns, net metering with time of use rates, and REC payments significantly improve the economics of customer-sited renewable energy systems for both the homebuilder and the buyer. Although initial costs are higher than typical homes, the homes sell faster than standard homes, and have lower net operating costs for homeowners.

Implementation barriers

The main barriers to implementation of large-scale high performance home projects are their higher up-front cost and a lack of awareness of the features, costs and benefits of highly efficient homes. A coordinated package of state, utility and local incentives can help overcome the barriers posed by higher initial costs, particularly when combined with efforts to train and educate the homebuilding industry and homebuyers about the features and benefits of high performance homes.

Savings of 50-70% are achievable using advanced yet readily available construction design approaches, equipment and materials. Achieving a truly net-zero energy home, however, will require the introduction of new approaches to residential design and construction that include not only the building envelope and mechanical systems, but also interior loads from lighting, appliances and other plug loads.

Low-energy cooling and heating strategies for hot, dry climates that incorporate a combination of passive and active design approaches need to be researched and demonstrated. Cooling loads and associated peak electricity demand could be significantly reduced through a combination of passive and active cooling strategies, including shading and proper orientation, evaporative cooling, whole-house fans and night ventilation. Off-peak thermal storage systems could offer additional peak electricity savings. In cold climates, heating strategies could include a combination of passive and active solar systems coupled with thermal energy storage, or ground-source heat pump systems. Neighborhood-scale thermal energy storage systems are also being developed that may prove to be more cost-effective than installing individual residential systems.

Recommendations for Utilities

SWEEP recommends that utilities with low levels of market penetration for ENERGY STAR new homes (<10%) offer a 3-tiered incentive package to builders, beginning at ENERGY

STAR ($350 - $500) and ramping up to a Net-Zero Energy Home level of performance ($750 - $1,000 for energy efficiency measures and $4,000 - $8,000 for renewable energy measures). Several Southwest utilities (e.g. Rocky Mountain Power and Questar Gas in Utah, and Arizona Public Service in Arizona) have been offering incentives at the ENERGY STAR level that are achieving cost-effective savings. A few utilities, including Questar Gas and Nevada Power, have initiated new incentive programs for homes that exceed ENERGY STAR requirements.

For utilities that already have high levels of market penetration for ENERGY STAR new homes (>35%), utility programs and incentives should focus on achieving the higher performance levels of Best Practice and Net-Zero Energy Homes, or include incentives for optional ENERGY STAR measures, such as the Advanced Lighting Package. Utilities should also consider offering additional incentives for measures that reduce miscellaneous electrical loads in the home.

Other recommendations include improving coordination between energy efficiency and renewable energy incentive programs, so that all new homes that receive renewable energy incentives also be required to meet high performance efficiency criteria (i.e., 30-50% improvement in efficiency); offering time of use rate structures with month-to-month carryover of net-metered electricity; and supporting programs that help homeowners more effectively manage their home energy use, such as home energy displays and plug load controls.

Utilities are also encouraged to conduct additional evaluations, measurement and verification of new home performance to assess the actual performance of new homes and the impacts of utility incentives and technical assistance programs. If feasible, the assessments should also include evaluations of traditional, code-built homes to provide a more accurate baseline for evaluating home performance.

Recommendations for States

States can play an important role in advancing high performance homes by adopting a comprehensive and coordinated portfolio of policies designed to promote investment in energy-efficient building and renewable energy systems.

States can implement a coordinated package of incentives, programs and policies to support high performance homes, including more stringent building codes; performance-based tax incentives for energy efficiency measures and renewable energy systems; and training, education and outreach activities to architects, builders, building contractors, real estate professionals and local building code officials on the features and benefits of high performance homes. States can also partner with utilities and the home building industry to conduct homeowner education and outreach campaigns on the benefits of energy efficient homes.

Recommendations for Municipalities

Local governments play an important role in high performance home projects through the siting, permitting and building inspection and approval process. Recommended actions that local governments can take to promote high performance homes include green building programs, incentives to builders (e.g., fast-track permitting, permit fee deferrals or reductions, and builder recognition through events, participating builder lists, or listings in outreach materials), conducting educational programs, training and outreach to the building industry, and maintaining a directory or network of participating architects, builders, suppliers, realtors and lenders that offer high performance home products or services.

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