Marketing Zero Energy Homes to Production Builders

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ABSTRACT

The Department of Energy is sponsoring an initiative to encourage homebuilders to produce "zero energy" homes (ZEH's), or homes that approach net zero consumption of electricity by combining energy efficient construction and appliances with solar electric and solar thermal systems. This paper describes the experiences of two of the four national zero energy teams in marketing zero energy home concepts to production builders in California, and presents four case studies. One case study describes methods used to achieve net zero electrical use in a demonstration home, as well as analytical methods for optimizing ZEH designs. Three other case studies relate experiences with the implementation of ZEH designs with additional builders. These studies demonstrate the potential for reducing utility costs by up to 80% while offering buyers a positive cash flow, and growing acceptance by builders.

The ZEH program is of interest to developers and implementers of any new technology because it tests marketing techniques needed to overcome resistance from builders and buyers, and explores builder/buyer motivations. Production builders are motivated by profit and the need to obtain entitlements for new developments, and must differentiate themselves in the market. They are also strongly risk-averse and require a high degree of standardization of their products, yet must capture the imagination of their buyers. Buyers try to balance value and affordability against convenience, luxury, and status. Interwoven with the case studies are approaches that are used effectively to produce zero energy homes in this environment.

Introduction

Zero Energy Buildings Program Origins and Purpose

Recognizing the enormous impact of the construction of new residential buildings on electrical energy consumption and peak electrical demand, the Department of Energy's (DOE's) Office of Building Technology established a goal of reducing energy use in new buildings by 50% as part of the "Buildings for the 21st Century" strategic plan (NREL 2001). In addition, the mission of DOE's Office of Power Technologies is to develop clean, competitive energy technologies for the 21st century. In light of these shared missions, the DOE Solar Buildings Program adopted the long-term goal of creating cost-effective buildings that have a zero-net need for off-site energy on an annual basis. This *Zero Energy Buildings* (ZEB) strategy entails transforming the design and construction of new buildings so that they use solar energy and energy-efficient technologies at levels consistent with building functionality, market needs, and societal concerns. The ZEB concept is intended to catalyze a process that begins with the integration of energy efficiency and solar technology, and that evolves into the construction of buildings that generate as much energy as they consume on a net annual basis.

The Players

The National Renewable Energy Laboratory (NREL) issued a request for proposals in 2001, and four teams were selected to implement the ZEB program with residential production homebuilders. The four team leads include Davis Energy Group (DEG), ConSol, Steven Winter Associates, and the National Association of Homebuilders Research Center (NAHBRC). Teams are made up of the lead firms and partners who include builders, manufacturers, research organizations, marketing groups, and other entities that may be selected to facilitate meeting the program objectives. DEG partners include Centex Homes of Northern California, the Florida Solar Energy Center (FSEC), and The Stone Group, a public relations firm. ConSol partners include Morrison Homes, Clarum Homes, and Pardee Homes.

The Rules of the Game

While the program name suggests an objective of attaining zero net energy use, this is an unrealistic goal in today's production home building environment. The immediate objective is to come as close as possible to achieving net zero energy use (electric and gas) within extant economic and market constraints, while incorporating a strategically cost-effective mix of energy efficiency measures, photovoltaics, and solar thermal water heating. All components and systems have to meet applicable codes and standards, and solar thermal systems that are listed by the Solar Rating and Certification Corporation (SRCC) are strongly preferred.

The strategy suggested by DOE and NREL is to design, install, test, evaluate, and re-design in an iterative loop to generate systems and approaches that come closer and closer to the zero net energy goal. Another agenda of the program is to reach a level of market penetration that encourages the more conservative, larger builders to participate.

This paper describes the experience of the DEG and ConSol teams in designing and marketing zero energy home (ZEH) concepts to production builders in California between 2001 and 2004. This paper describes their two different approaches and presents case studies for each.

The Current Market for Sustainable and Zero Energy Homes

The Backdrop

There is no single way to characterize the potential market for homes that are "sustainable", or that include energy efficiency, renewable energy, or "green" components in their designs. In some locations buyers are camping out in order to earn the right to purchase new homes, and in others there is significant sales competition between adjacent developments and homes move more slowly. Builders in very strong markets can add energy efficiency or renewables upgrades without losing market share, but usually choose other ways to differentiate themselves. In these markets the houses will sell almost regardless of cost. Builders in weaker markets need to differentiate themselves to remain competitive, but may not see energy efficiency and renewables as the best way to accomplish this. These builders are more sensitive to cost issues.

Perception by building industry professionals of the value or market importance of sustainable design also varies. On one hand, the National Association of Homebuilders' Green

Building Conference attracts many homebuilders, and the U.S. Green Building Council is proceeding to develop a residential LEED program that will have a strong energy component. Some builders have adopted green design and construction practices as a means of image building, viewing this as a way to earn entitlements, or simply as the responsible way to build. On the other hand, some builders view the obligation to meet green building requirements in order to earn entitlements as verging on criminal (PCBC 2004).

The California market for photovoltaic (solar electric) systems is influenced by two financial incentives. First, the California Energy Commission offers a "buy-down" for grid-connected photovoltaic systems. Initially worth up to $4.00 per Watt, this rebate was decreased to $3.80 in 2003, is now $3.20, and declines about every six months. The second major incentive is that buyers may subscribe to time-of-use rates that provide credits of $0.31 per kWh or more for power generated on-peak (between noon and 6 PM), and charge as little as $0.08 for electricity consumed off-peak[1]. Builders directly benefit from the buy-downs since they can be paid to the builder, but the rate incentives must be advertised through builder marketing programs to have an impact on home sales.

Market Research – What Do Buyers Say?

In the process of convincing builders that they should build energy efficient homes it helps if they can be convinced that the homes will sell, that they will be profitable, and that they will not increase builder risk. To address the first two issues it is valuable to determine whether buyers are willing to pay more for zero energy homes in anticipation of energy savings.

To date, three market surveys have been completed under the Zero Energy program. The first, a qualitative study based on homeowner interviews, was completed on a 306-unit development in San Diego called Scripps Highlands (Farhar et al. 2002). Photovoltaic (PV) systems were "pre-plotted", or installed as standard equipment, on 88 of the 293 homes. Some of the buyers selected zero energy homes (ZEH's) over similar up-scale homes nearby reportedly because of the zero energy features. This study determined that "ZEHs designed as desirable, up-scale homes will be accepted—or even pursued—by homeowners in today's market, and will not be treated as weird aberrations from normal housing patterns." The study also reported that there is strong evidence that pre-plotting PV systems rather than simply offering them as an option can result in greater homeowner satisfaction, and that most people like, or at least tolerate, their PV systems and learn to appreciate them more as they live with them. Quantitative results were difficult to ascertain from this study because the market was so active that the added cost for homes with PV systems was probably a minor factor in the decision to buy.

A second study conducted in Florida (Winter et al. 2002) found that 27% of respondents expressed willingness to add $10/month to their mortgage payments to pay for a solar hot water system that would offset two-thirds of their electric hot water load, but only 5% would be willing to pay $100/month for a system that provides one-half of their electrical energy. Given a list of eight different items (including solar hot water and solar electric systems) and a theoretical $30,000 to spend on options, twenty-four percent selected the solar hot water system and 19% selected the solar electric system. Nine percent selected both systems within the $30,000 limit. Another interesting finding from this survey was that that willingness to buy solar energy systems varied only slightly with income level.

[1] Based on the Pacific Gas & Electric E-7 rate schedule.

One of Davis Energy Group's initial ZEH program efforts was to commission a survey to determine, among other things, how much more potential homebuyers would spend for a house that reduced their energy bills. Completed by the firm *American Lives* in the spring of 2002, this survey represents a sample of 317 people living in the San Francisco bay area (Warrick & Kuzcel 2002). Figures 1 and 2 summarize responses to the most critical questions asked in this survey.

Figure 1. "What Is the Likelihood That You Would Have Considered Buying a House That Costs $8,000 More But that Generates 40% of its Own Energy?"

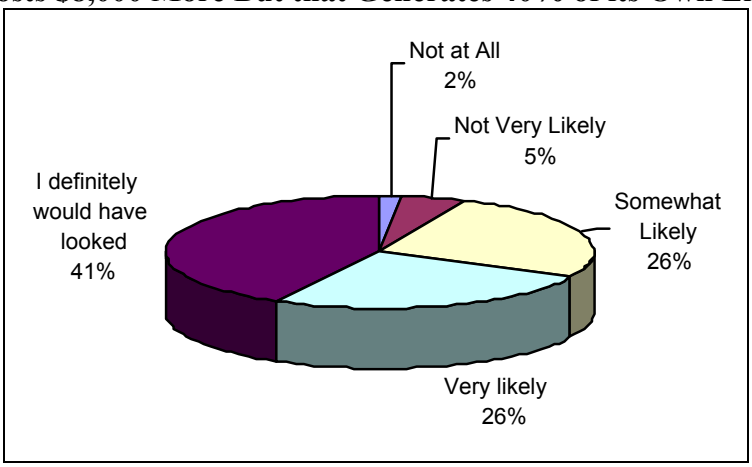


Figure 2. "If Such a Home Came with a Mortgage That Would Allow You to Borrow More Money Since It Would Be Taking Your Energy Savings into Consideration, How Much More, per Month, Would You Be Willing to Pay to Get It?"

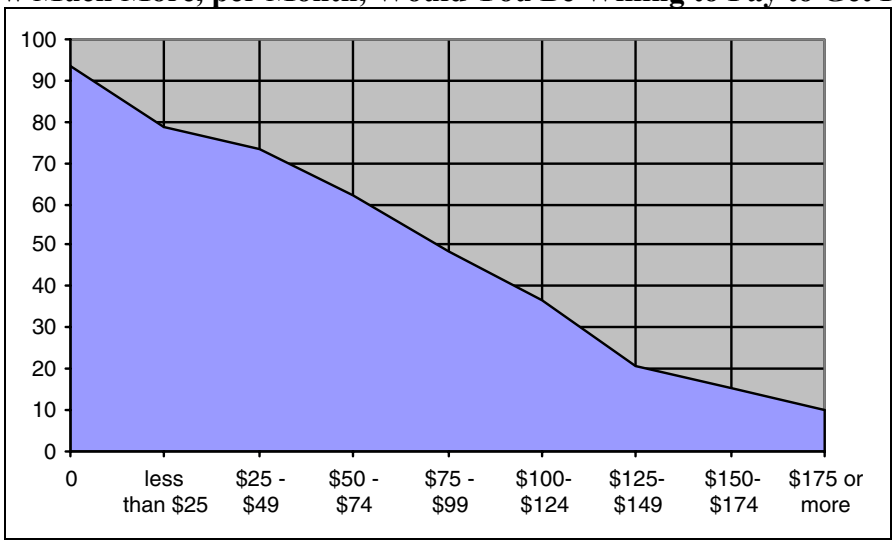


Figure 2 shows that 50% of the respondents say they would be willing to pay $75 to $99 more in monthly mortgage payments for an indeterminate amount of energy savings. At 6% interest rates on a 30-year loan this translates to about $12,500 to $16,500 in energy saving upgrades, enough to fund efficiency measures and small solar electric systems (with rebates).

Other results showed that quality of construction is the most highly valued factor, by a wide margin, in buying a new home, suggesting builders should be marketing energy efficiency and renewables as part of a quality home package. The survey questions were structured to segregate respondents by their orientation to energy savings versus concern about the environment. Interestingly, 69% ranked the importance of both as "medium", but only 7.1% indicated a "high" concern for both energy and the environment. This finding suggests a marketing approach that also appeals to environmental concerns as well as energy savings would be more effective than appealing only to one or the other.

When shown these results, a project manager with Centex Homes reacted with the comment "buyers are liars". While an avid advocate for energy efficient construction, his experience has taught him that buyers cannot be trusted to vote their good intentions with their pocketbooks. This skeptical view of the value of market surveys shifts the focus toward exploring how buyers actually respond when given the choice.

DEG Team Case Studies

Approach

The DEG team applied a strong research approach in identifying the economical limits of zero energy design and construction under the current market environment. Building on experience gained from prior projects such as the Pacific Gas & Electric Company sponsored Advanced Customer Technology Test (Elberling & Bourne 1994), the DEG team applied refined sequential analysis methods using simulation tools to develop designs and predict performance, and employed detailed monitoring to evaluate the performance of these designs. In addition to performance factors, the team considered results from market surveys and experience from other projects such as the New Smyrna Beach Zero Energy Home (FSEC 2004) in the development of new designs for the California market.

The Centex 21st Century Performance House Pilot Project

As an initial undertaking, Centex Homes, with design assistance from DEG and FSEC, built a zero energy house called the *21st Century Performance House*, in a development located in Livermore, California. The objective of this pilot project was to acquaint purchasing agents, superintendents, subcontractors, and other key players with the process of building a ZEH, and to uncover potential problems and identify solutions. Since the project was launched after the development was well underway, the zero energy option was not offered to buyers of other homes. Construction was completed in July 2002.

House description and energy measures. This 3080 square foot one story home was also a demonstration for a research project called *Alternatives to Compressor Cooling* funded by the California Energy Commission (Springer 2004). The focus of the Energy Commission project was to reduce peak cooling load and to explore the possibility of eliminating or substantially reducing the need for conventional air conditioning. Measures that were added to the house to improve summer performance included:

- High performance windows[2]
- Radiant barrier roof sheathing
- R-10 slab perimeter insulation
- 50% of slab floor covered by hard surface flooring (for thermal mass)
- ⅝" instead of ½" drywall (for thermal mass)
- Trellis shading of south and east windows (west windows were shaded by an overhang)
- Nighttime ventilation cooling integrated with variable speed air handlers
- Tankless water heater (for combined domestic hot water and space heating)

Each of the two air handlers is coupled to two-ton split system condensing units for supplemental cooling. Zero energy measures included a 3.6 kW PV array and an active solar water heater. The PV array, which consisted of standard, rack-mounted modules, was integrated with the tile roof so as to minimize the visual impact from the street. Concern about roof penetrations and subcontractor responsibility for module installation were both significant issues. Similar issues were encountered with the solar water heater, which also involved multiple trades.

Marketing experience. The home was open for visitors for about one month, and then placed on the market. Literature describing the house and its features was prepared, and a grand opening was held that attracted many visitors, the two local network TV stations, and a great deal of publicity in the press (e.g. Frischberg 2003). Efforts to train sales staff were frustrated by lack of interest, probably stemming from a poor understanding of the house, and high staff turnover rate.

After being on the market for an additional month the house sold to a couple with no children. The sales staff was convinced at the time that the buyers had no interest whatsoever in the energy features. When initially interviewed the buyers expressed that they were motivated to buy the home because they felt it was a good value[3]. Subsequent interviews showed the buyers to be very committed to the principles of energy efficiency, both personally and politically (Springer 2004).

The importance of communicating to the owner how the house is performing became apparent, as indicated by the following anecdote. The PV system includes a wall-mounted meter that displays how much energy the house uses compared to how much it is generating. The owners' initial reaction to the meter was to ask whether they could hang a picture over it. After living in the house a few weeks they became very interested in watching the meter, and began making efforts to keep consumption down by managing electrical load. Their excitement about the house has grown, fed by the fact that they have yet to pay for electricity since moving in.

Although the pilot project was not very instructive about the current marketability of zero energy homes, it showed that owners can become strong advocates for these homes through their experience of them. This kind of positive experience is likely to influence consumer demand in the long term.

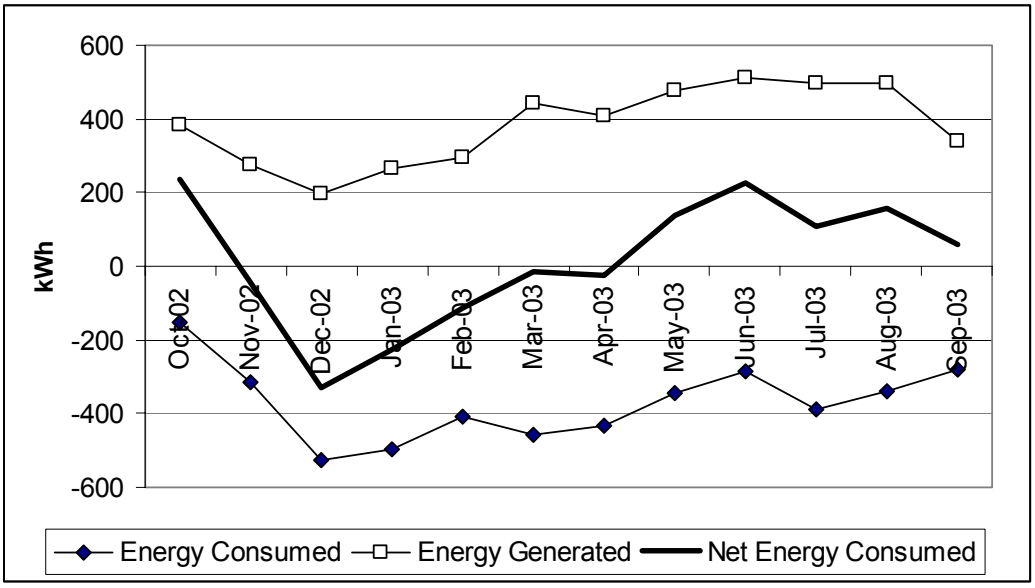
[2] These were included in all homes in the development as a means of complying with California Title 24 energy standards.

[3] Centex offered the house at a price that was comparable to other models that did not include many of the upgrades that were included in the house beyond the zero energy and efficiency measures, such as granite counter tops and premium floor coverings.

Pilot project energy performance. The home has proven to be a technical success in that it has used very little energy for air conditioning and has generated more electrical energy than it has used on a net annual basis. Monitoring data for a typical summer day showed the 21st Century House using no air conditioning, and consuming only 19% of the cooling energy compared to another house with the same floor plan located in the same development. The combination of envelope design improvements and ventilation cooling made a strong contribution to energy savings, enabling the PV system to achieve the net zero electrical energy goal. Figure 3 graphs annual electrical usage, PV generation, and net energy use for October 2002 through September 2003. For this one-year period the PV system generated 104% of the energy needed by the house.

For homes that rely on natural gas for winter space heating and water heating it is impractical to achieve net zero gas energy use, since, unlike electrical energy, thermal energy cannot be generated on site and fed back to the grid. Solar thermal systems that provide 100% of space heating energy are far from being economically feasible. However, the solar water heater that was installed on this home did contribute 45% of the annual domestic hot water energy.

Figure 3. 21st Century Performance House Net Electric Use



Development and Marketing of a Second-Generation Design

Design development. Using information learned from the pilot project and other zero energy experiments, DEG and FSEC tackled the problem of developing a marketable, cost-effective, second-generation ZEH design by applying a scientific approach. A large list of potential energy efficiency measures was compiled, and this list was reviewed with Centex to develop a plausible group of measures to be evaluated. Cost and performance data were accumulated for each of these measures, and measures were evaluated by simulating them with DOE-2[4] using a typical 3167 ft² two-story Centex plan. Benefit-cost ratios were calculated from energy savings, utility

[4] The Energy Gauge USA program was used as a "front end" to develop the DOE-2 input files and compile results.

rates[5], and measure costs.[6] The measures were then ranked by cost-effectiveness and added sequentially to the baseline house model. Following the addition of each measure to the model, all other measures were individually reevaluated using the new baseline model and re-ranked. This approach accounts for all interactions between measures.

Since the objective was to include both photovoltaics[7] and solar water heating in the final design, all measures with benefit-cost ratios greater than those of the solar measures were included. Lacking the incentives offered for PV systems, solar water heating had the lowest benefit-cost ratio. Table 1 lists the results of this analysis.

Table 1. Sequential Analysis Results

Measure	Measure Cost	Overall Costs	Measure Savings	Overall Savings	Present Worth	BCR	Overall BCR	Percent Savings	Measure Payback	Overall Payback
Light colored exterior walls	$1	$1	$114	$114	$1,555	1555	1554.6	5%	0.0	0.01
Zero defect wall insulation	$400	$401	$148	$262	$3,229	8.1	11.9	11%	2.7	1.5
Tight construction	$500	$901	$163	$425	$2,844	5.7	8.5	17%	3.1	2.1
Insulated headers	$68	$969	$17	$442	$379	5.6	8.3	18%	3.9	2.2
Fluorescent lighting	$712	$1,681	$297	$740	$3,324	4.7	6.7	30%	2.4	2.3
Efficient refrigerator	$200	$1,881	$68	$807	$758	3.8	6.4	33%	2.9	2.3
R-14 Ducts Buried	$350	$2,231	$40	$847	$870	2.5	5.8	35%	8.8	2.6
Radiant Barrier	$317	$2,548	$33	$880	$578	1.8	5.3	36%	9.6	2.9
R-49 attic insulation	$257	$2,805	$21	$901	$459	1.8	5.0	37%	12.2	3.1
Horiz. axis clothes washer	$250	$3,055	$26	$927	$354	1.4	4.7	38%	9.7	3.3
NightBreeze system	$3,000	$6,055	$271	$1,199	$3,713	1.2	3.0	49%	11.1	5.1
⅝" drywall	$400	$6,455	$17	$1,215	$366	0.9	2.9	50%	23.8	5.3
High efficiency dishwasher	$50.00	$6,505	$4	$1,219	$44	0.9	2.8	50%	12.7	5.3
2.5 kW PV array*	$8,672	$15,177	$492	$1,711	$7,751	0.9	1.7	70%	17.6	8.9
50% tiled floor slab	$2,500	$17,677	$74	$1,785	$1,605	0.6	1.6	73%	33.9	9.9
Solar water heater	$2,750	$20,427	$71	$1,856	$970	0.4	1.4	76%	38.8	11.0

*The PV system cost includes a $3.80/Watt rebate. Savings include adjustments for elimination of interior ducts & R5 sheathing, and corrections to PV analysis.

Projected performance. Results of final computer simulations show that the optimized zero energy design will save 5961 kWh per year, or 60% of electrical energy use, and 404 therms, or 47% of gas energy use. Converted to dollars, annual savings for electricity and gas are projected to be $1627 (100%) and $380 (46%), respectively, with total savings estimated at $2007 (82%). The difference between electrical energy and dollar savings percentages is a result of the application of the time-of-use rate, which values the electricity generated by the PV system and fed into the grid at a significantly higher price than electricity that is consumed off peak.

Buyer economics. Table 1 shows that the total cost of the zero energy package is $20,577 and the annual energy savings are $2006. If the cost is amortized at 6% for 30 years, the incremental

[5] Baseline electric energy costs were calculated using PG&E standard (E-1) rates, and ZEH energy costs were calculated using time-of-use (E-7) rates.

[6] The cost of the PV system takes into account California rebates and tax credits.

[7] A 2.4 kW PV array was selected as being most feasible given the roof area available in the four orientations of the baseline model.

annual mortgage cost is $1480. Since the energy savings exceed the mortgage cost, the buyer should experience a positive cash flow when buying a home that incorporates the second-generation design. Centex views the positive cash flow as an essential ingredient in successfully marketing zero energy homes, and also has expressed concern that buyers be convinced that they can recover their investment at resale. This view is not necessarily shared by all builders.

Second generation ZEH design implementation. Construction of two zero energy model homes that implement the features described in Table 1 was initiated in January 2004. The models are located in adjacent subdivisions in a San Ramon, California development. Although subcontractors and suppliers were consulted to develop the costs shown in Table 1, actual costs are exceeding the original estimates. One explanation for this outcome is that design changes offer subcontractors an opportunity to make up for profits that they tend to minimize when submitting competitive bids for entire developments. Also, since the technology is unfamiliar, subcontractors add margin to adjust for the perceived increase in risk. This problem could be overcome by pre-plotting zero energy homes on a certain percentage of lots so that subcontractor competitive bids include these homes.

The second-generation design utilized a new building-integrated PV product manufactured by AstroPower[8]. This product integrates with flat concrete roof tiles, eliminating the need for roof penetrations required by mounting racks, saves roofing materials, speeds the installation, and results in an improved appearance that is likely to be acceptable to most buyers. Precise cost savings resulting from use of this product have not been determined.

Marketing approach. Builders have the option of either offering zero energy packages as buyer options along with floor coverings and other options, or "pre-plotting" homes that are equipped with zero energy features. Both approaches are instructive in that they reveal buyer attitudes towards efficiency and renewables. In a strong market the pre-plotting approach may not be as revealing because buyers are inclined to buy what is available, regardless of what options come with the home. Centex Homes chose to market the second-generation design as a buyer option to test the waters before committing to pre-plotted homes. A "PowerSave" brand was developed that offers two levels, one that includes the eleven best energy measures plus tankless water heating, and the other (PowerSave Plus) that includes the full zero energy package listed in Table 1.[9]

Most production builders allow buyers to select options such as colors and floor coverings after the house has been sold. Centex buyers have three meetings with sales staff at a "design studio" facility that includes displays, literature, and samples to help buyers make decisions. A PowerSave display was developed for Centex's design studio, and brochures providing information on the options were printed. In addition, a touch-screen computer display is provided in the design studio that will allow buyers to visualize actual daily and monthly energy use and savings for standard versus PowerSave models.

Design studios are generally self-supporting, that is the income from sale of upgrades supports the sales staff and the facility. This structure provides an incentive to sales staff to sell expensive upgrades. In theory, if an upgrade effectively has a positive or neutral impact on the

[8] AstroPower was acquired by GE Energy in March 2004.
[9] Thick drywall is only used on the second floor ceiling, and tiled floors and efficient appliances are recommended buyer options.

buyer's cash flow, then the sales staff should be both motivated and successful at selling it. This theory is being tested and exit surveys will be conducted to determine why buyers did or did not select the PowerSave option. The two model zero energy homes are under construction at the time of this writing, and to date no PowerSave options have been sold.

ConSol Team Case Studies

Approach

ConSol chose a different path that had a lower emphasis on producing cost-effective designs and bypassed the demonstration phase that was employed by Davis Energy Group. ConSol emphasized zero energy as a market concept rather than an economic expedient, and successfully carried this message to a several builders. ConSol's goal was to develop designs that would encourage builders to construct multiple ZEH homes in a single subdivision by offering ZEH homes both as standard products as well as buyer options. ConSol's prior experience suggested that builders could be stretched to build homes that combine energy-efficiency and solar technologies to reduce energy bills by at least 60% and achieve net-zero annual electricity use.

Builder-Partners and Projects

During the first few months of the project ConSol developed prototype plans for its builder partners and additional builders who expressed interest in building homes under the Zero Energy Home program. Three builders proceeded with these plans: Pardee Homes, Morrison Homes, and Clarum Homes. Pardee built a ZEH model home in their Santa Barbara community and has offered the ZEH features as an option, Morrison built a ZEH model in their Lakeside community in Elk Grove (near Sacramento) and offers the ZEH features as a standard feature on 10% of the lots, all of which are pre-plotted (12 of the 120 lots). They also offer the ZEH features as an option on many of the remaining lots. Clarum identified two projects for the ZEH program: Shorebreeze, 20 homes in East Palo Alto, and Vista Montana, 257 homes in Watsonville (near Monterey). Clarum built all 20 of the Shorebreeze homes as ZEH-program homes, and all sold very quickly. They are currently building the entire 257 lot Vista Montana community as a ZEH-program community. Vista Montana consists of affordable, attached townhouses, entry-level detached single-family homes, and move-up homes[10]. All 257 have the energy-efficiency and solar features specified in the ZEH program designs. Over 60% of the homes had been pre-sold before the Grand Opening in August.

The best indication of the success of the ZEH program for the participating builders is that they are all willing to participate further. Pardee has added the ZEH program option to their Living Smart program. Living Smart is an amalgam of resource-conscious construction, including features for improved indoor air quality, use of renewable construction materials, and super energy-efficient features. They have seen ZEH as an extension of this program and currently offer the ZEH program option in three recently-opened communities, one in south Orange County, and two in Las Vegas. Clarum has been so successful with their ZEH program

[10] Homes sold to current homeowners who are interested in larger homes with more features.

efforts that they have changed their business plan to include ZEH and Green Building in all of their future projects.

Zero Energy Measures and Costs

For each of the three subdivisions the builders started with Energy Star™ and ComfortWise[11] designs (to ensure 3rd party inspections and marketing support), then added energy-efficiency features and solar to achieve a target of 60% reduction in the energy bill. Each of the builders were encouraged to use solar water heating and in every case this was rejected. The builders did not like having water on their roofs and they argued that tankless gas water heaters would provide similar energy-efficiency at a substantially reduced cost. They were unconvinced by arguments presented comparing solar electric to solar water heating, and they felt that some homebuyers would be attracted to the solar electric (photovoltaic) systems but not necessarily to the solar water heating.

Energy-efficiency features included in ZEH program homes for all three builders were similar and are represented in Table 2, which lists the specific measures for the Morrison Lakeside project. There were some differences; for instance radiant barrier roof sheathing was rejected by Morrison because of construction timing issues. Third-party inspections and tests were included on all homes.

The incremental costs for the ZEH program homes varied by builder for a number of reasons. The highest cost was for the Morrison Homes project, which was in the harshest climate, therefore requiring the most expensive features. In addition, Morrison chose higher-efficiency furnace and air conditioners rather than the more cost-effective radiant barrier, for reasons already discussed. Morrison's incremental costs were approximately $14,000, including the PV system with the California buy-down. Clarum incremental costs, which were the lowest, were approximately $8,000, also including the PV system with the California buy-down. Another reason for the large difference in cost between Clarum and Morrison is that the ZEH features allowed Clarum to completely eliminate air conditioning, saving them the cost of the condensing unit and evaporator coil.

Energy consumption and savings for space conditioning and water heating were predicted using Micropas, an hourly simulation that is BESTEST[12] certified. The baseline houses were assumed to just meet California Title 24 energy standards. Other energy uses were estimated from PG&E data (PG&E 1997). Some uses were modified based on improved appliances and in all cases use of fluorescent lighting was maximized. The energy impact analysis for the Morrison Plan 2 zero energy model home is provided in Table 3.

[11] ComfortWise is a program similar to Energy Star that is offered by ConSol and supported by California's public goods program.

[12] BESTEST is a method for testing and diagnosing the simulation capabilities of the exterior envelope portions of building energy simulation programs. See http://www.eere.energy.gov/buildings/tools directory/

Table 2. Zero Energy Measures, Morrison Homes "Lakeside"

ENVELOPE INSULATION R-VALUES	
Roof/attic R-value	38
Wall R-value (Exterior Front)	13
Wall R-value (garage and all other exterior)	R-13 + R-4.2
Floor R-value (above garage/cantilever)	30
Building Tightness (Specific Leakage Area, ft²)	3.1
GLAZING:	
Window U-factor	0.35
French Door U-factor	0.55
Window SHGC	0.35
French Door U-factor	0.65
HVAC SYSTEM:	
Furnace AFUE	0.92
Air Conditioner SEER (with TXV)	14
Duct Insulation R-value / Location	4.2 - 6.0 (attic)
Ducts Buried in Ceiling Insulation	Yes
Ducts Sealed & Tested (<6% leakage)	Yes
ACCA Manual D (Short Runs)	Yes
WATER HEATING:	
Energy Factor	0.82
Water Heater Type	Tankless
Insulated Hot Water Piping	
LIGHTING:	Fluorescent
PV SYSTEM:	2 kW

Table 3. Measure Energy Costs and Savings, Morrison Plan 2

	Baseline House			ComfortWise / Energy Star			Zero Energy		
	Energy Use		Cost,	Energy Use		Cost,	Energy Use		Cost,
	Therms	kWh	Dollars	Therms	kWh	Dollars	Therms	kWh	Dollars
Space Heating	387		$290	336		$252	270		$203
Space Cooling		1914	$159		1258	$105		914	$76
Water Heating	234		$175	220		$165	158		$119
Cooking	44		$33	44		$33	44		$33
Microwave		209	$17		209	$17		209	$17
Dishwasher		361	$30		361	$30		361	$30
Clothes dryer		700	$58		700	$58	35		$26
Refrigerator		1100	$92		1100	$92		1100	$92
Miscellaneous		1800	$150		1800	$150		1088	$91
Photovoltaics			n/a			n/a		-3,060	-$406
Totals	665	6084	$1,005	601	5428	$902	507	612	$280
Savings				64	656	$103	93	4816	$724
Percent Savings				9.6%	10.8%	10.2%	14.0%	79.2%	72.1%

]All three builders are using AstroPower PV systems. Pardee and Morrison are using 2.4 kW solar systems, and Clarum systems average 1.6 kW. Some of the Clarum homes have 1.2 kW systems because of roof area limitations, and some are as large as 3.6 kW. The Clarum and Pardee projects are using standard, rack-mounted PV modules. Clarum's are mounted on the roofs, and Pardee's are mounted on trellises. Morrison is using a building-integrated (BIPV) system that installs with flat concrete tile.

Market Assessment

In the process of bringing near zero energy homes to buyers, ConSol has encountered three entirely different marketing approaches used by the three different builders. Clarum Homes, a smaller Northern California builder, is equipping all homes with ZEH features. Morrison, a national builder, opted to pre-plot one ZEH in each phase. Pardee, a large regional builder, is offering ZEH as an option only. The first two builders marketed their communities as ZEH neighborhoods. Pardee markets their homes as having "ZEH possibilities."

Clarum Homes has completed the largest California ZEH community to date, Vista Montana, in a suburb of Santa Cruz. Every home includes a 1.2-to 3.6 kW photovoltaic system, a tankless water heater, radiant barrier roof sheathing, Energy Star appliances and recycled building products. Numerous news articles stemming from Clarum's media events have generated substantial traffic and led to sales rates in excess of expectations and project completion nearly a year ahead of schedule. One of the model homes at Vista Montana includes an "Enviro Studio" that houses displays of the green and ZEH features.

Despite the added costs, Clarum has kept prices competitive with three neighboring subdivisions. Although buyers reported that the Zero Energy label did not bring them to the project, they were enthusiastic about the energy features, and two of the sales agents took advantage of the energy features in their selling tactics. Buyer concerns about maintenance were generally allayed by warranty information. Buyer education was discovered to be a very important part of the process.

Clarum has two upcoming California projects, one in Menlo Park, and another in Borego Springs, which Vice President John Suppes indicated will also be built under the ZEH program. Suppes receives frequent invitations to speak and to participate in conferences, and receives calls from either other builders and private parties interested in energy efficiency. He considers ZEH very good for business; he recently wrote "We have shifted our entire company mission and business plan to building nothing other than Zero Energy Homes from this point forward."

Morrison Homes is a national builder, whose Sacramento division chose to build 10% of their Lakeside community to near ZEH standards[13]. Their initial reason for doing so was to help generate traffic for this in-fill project in a well-established master-planned community. Interest in the homes proved to be substantial irrespective of the ZEH label, and Morrison initially had concerns that the higher costs would discourage buyers. However, because of higher than expected buyer income levels, the higher prices had a minor impact on sales.

[13] Homes built to "ZEH standards" typically include both photovoltaics and solar water heating. Solar water heating was not an acceptable option to Clarum, Morrison, or Pardee.

Morrison did not expect that buyers would recover the incremental ZEH cost in energy savings. Particularly because of the low electric rates charged by the Sacramento Municipal Utility District (SMUD), it is estimated that the cash flow will be slightly negative. Despite this, the sales of the pre-plotted ZEH homes are about 10% better than expected, perhaps because of buyer environmental sensitivities. Morrison is also selling a small percentage of ZEH's as options. This success has led Morrison to consider building as many ZEH homes in the community as orientation allows and demand dictates.

Pardee Homes is a regional builder in California and Nevada who has made a commitment to energy-efficiency and green building. They were the first large production builder to build 100% of their homes to Energy Star standards, and have recently developed their own green-building program that they call *Living Smart*. The *Living Smart* program, which includes energy efficiency, indoor-air quality, renewable construction products, and ecological landscaping elements was first introduced at their "Santa Barbara" community in San Diego. This was also the first community at which they demonstrated their ZEH option package.

"Evergreen", Pardee's most recent community to participate in the ZEH program, markets homes with "ZEH possibilities." Evergreen is located in the Village of Terramor, a "green" community in Ladera Ranch in South Orange County, California. A few of the Evergreen homes were pre-plotted with ZEH features, but ZEH is primarily offered as an option. The ZEH homes also include sustainable building materials as well as the energy measures listed in Table 2 to improve the appeal to environmentally conscious buyers. During the sales process the home-buying prospect first meets with an agent, then goes through a "green room" which presents the sustainable and renewable features, before proceeding to the models.

Sales of PV systems have trailed behind other energy options, and Pardee feels this is due to the high cost of their trellis system, on which they have been mounting PV modules to avoid potential roof penetration problems. They now offer AstroPower's "Gecko" module that integrates with flat concrete roof tile. Joyce Mason, VP of Marketing for Pardee, thinks the integrated modules will make PV systems much more acceptable to their buyers. It is interesting to note that, at 5% of the house price, the $18,000 Morrison ZEH package was much better received by buyers than the $26,000 trellis-mounted PV option offered at Pardee's Santa Barbara development, where the package was only 3% of the $800,000 selling price.

Pardee is not quick to credit increased sales to ZEH features. As an indication of the market conditions when the Evergreen models opened in December 2003, the sales agents were confronted with 300 buyers for seven homes. According to Mason it is difficult to factor out the exact reasons for sales, saying "We sell everything we put up right now." What has been most gratifying for them, however, is how well the idea of environmental building is reflected in their brand, and public perception of them as quality builder in part because of their environmental efforts.

Conclusions and Lessons Learned

The California Centex Homes projects demonstrated that it is possible to build marketable homes that generate all of the electricity they use on a net annual basis, and that homes can be designed with smaller, more affordable, PV systems that achieve a zero annual electric bill at no net cost to the buyer. Design optimization can lead to energy savings of about

45% for gas and 60% for electricity, and combined utility cost savings of 80%.[14] Further study is needed to identify market opportunities in other climates and in states that do not offer rebates. The persistence of the California market will be important to watch as rebates decline.

Integration of energy efficiency measures that reduce or eliminate the need for air conditioning can result in cost breakthroughs and reduce the required size of PV systems, thereby resulting in a synergistic cost reduction. These opportunities are facilitated by careful measure analysis such as is described in this paper.

The larger, more conservative builders are inclined to make ZEH packages optional. This an approach, which requires a well organized sales staff and good marketing materials, and has yet to be demonstrated as an effective means of marketing ZEH's. As shown by the Clarum and Morrison projects, pre-plotting zero energy homes clearly results in greater market success, and may be necessary to reduce construction costs.

While buyers are certainly motivated by price, there seem to be ample buyers who will spend more for ZEH's even when there is no clear prospect for cost recovery. Given decreasing incentives, this point is a critically important to the continued viability of ZEH programs. Builders who are considering building ZEH's to boost their image, gain publicity, earn entitlements, or to "do the right thing" should market the solar and efficiency features as part of a total quality package. Training of sales staff and making zero energy homes a part of the builder's standard repertoire are key factors in successful ZEH marketing programs.

New building-integrated PV products are more acceptable to builders and buyers, are easier to install, and can involve fewer subcontractors and less coordination by project superintendents. More builder experience is needed to standardize PV installation processes. Solar water heating is problematic with many builders, possibly because of bad experiences with systems installed during the 1970's and 80's under the California tax credit. Lower cost, reliable building-integrated solar water heating systems are needed to overcome this barrier.

Education of sales staff and, through them, buyers should be a part of every ZEH builder's program. Education is also needed for subcontractors installing energy features and building officials inspecting them. The ZEH logo is not recognized as is Energy Star, but appears to be compelling and complements builder branding, but needs explanation.

Upon completion, the four subdivisions described in this report will serve as a source of information on the effectiveness of zero energy features sold as options vs. those sold "pre-plotted". Experience from these developments will also aid in identifying whether marketing approaches that provide detailed economic information or those that sell ZEH features based on emotional appeal are more effective.

Finally, we have learned that a home designed to maximize annual energy production does not necessarily maximize summer peak reduction. This factor merits research; maximizing peak reduction may have as much or more value to the utility and the community as does zero net energy use, at least in the near term. There may be as much or more utility and societal value to maximizing peak reduction than from achieving zero energy use, at least in the near term. Future research should explore the benefits to utilities of ZEH program communities that also achieve zero peak demand. If the benefits to utilities outweigh the disadvantages, utilities could be strong allies in the promulgation of Zero Energy Home program communities.

[14] When time-of-use rates are employed.

References

Elberling, L., D. Bourne. "ACT^2 Project: Maximizing Residential New Construction Energy Efficiency". In *Proceedings of the 1994 ACEEE Summer Study on Energy Efficiency in Buildings*. Washington, D.C.: American Council for an Energy-Efficient Economy.

Farhar, B.C., T.C. Coburn, N. Collins. 2002. "Market Response to New Zero Energy Homes in San Diego, California". In *Proceedings of the 2004 ACEEE Summer Study on Energy Efficiency in Buildings*. Washington, D.C.: American Council for an Energy-Efficient Economy.

Frischberg, M. "Unplugged". *Discover*. Vol. 24, No. 4. April 2003.

[FSEC]. Florida Solar Energy Center. 2004. "Florida Zero Energy Home 2: New Smyrna". Available online: http://www.fsec.ucf.edu/bldg/active/zeh/n_smyrna/index.htm.

[NREL] National Renewable Energy Laboratory. 2001., "Zero Energy Home Concepts and Project Development". Request for Proposals Number RAA-1-31429 National Renewable Energy Laboratory. Appendix A: Statement of Work. Golden, Colorado.

[PCBC] Pacific Coast Builders Conference. 2004. *Green Collar Crime: Dealing with a more radical environmental movement*. Presentation description in the announcement for the 2004 Pacific Coast Builders Conference, p. 20.

[PG&E] Pacific Gas & Electric Company. 1997. *Residential Energy Survey Report*. San Francisco, California.

Springer, D. *Phase V Final Report, Alternatives to Compressor Cooling Project*. California Energy Commission Public Interest Energy Research Program Contract #500-98-024. 2004. Sacramento, California.

Warrick, B., G. Kuzcel. "Energy in the Home Study". Report submitted to Davis Energy Group under NREL Contract #KNAA-2-31492-01. American Lives. 2002. Oakland, California.

Winter, S.W. 2002. "Zero Energy Homes Survey with Mercedes Homes in Melbourne, FL". Zero Energy Buildings program report. Steven Winter Associates, Norwalk, CT.