ZERO ENERGY HOMES FOR NEW CONSTRUCTION MARKET ACTIVITIES

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ABSTRACT

Zero Energy Homes is a term used to describe advanced efficiency measures, typically combined with solar technologies for new residential construction. The United States Department of Energy (DOE) has awarded two research and development solicitations on advancements in Zero Energy Homes (ZEH). California's Public Interest Energy Research (PIER) program has recently completed a $10 Million solicitation for Zero Energy New Homes (ZENH) in California. This paper explores the process of involving builders, utilities, communities, efficiency, and solar technologies in advancing ZEH concepts. Efficiency packages are used in conjunction with incentives and high electric rates to justify the solar equipment.

Market analysis is investigated for these types of buildings, including resale values. State and federal programs are compared and contrasted. Recommendations are made for policy decisions on why, where, and how ZEH can be most effective in new community growth.

1. INTRODUCTION

In this paper we will review ZEH programs at the Department of Energy (DOE), Oak Ridge National Labs (ORNL), the National Renewable Energy Laboratory (NREL), the Million Solar Roofs initiative (MSR with 89 partners) and the California Energy Commission (CEC). The paper attempts to quantify the builders, buildings, and locations that are advancing ZEH concepts.

In 1980 the Massachusetts Institute of Technology commissioned Solar Design Associates (SDA) to design and engineer a 3,200 sq. ft. energy-efficient, passive solar residence powered by photovoltaics (PV). The 'Carlisle House', as it became known, features passive solar heating and cooling, super-insulation, internal thermal mass, earth-sheltering, daylighting, a roof-integrated solar thermal system and a 7.5 kilowatt (kW) PV array. This was the first residence ever to be powered by a utility-interactive PV system. It needs no fossil fuel and exports surplus power to the utility on an annualized basis (1).

More recently, DOE awarded ZEH contracts to the National Association of Home Builders (NAHB), Davis Energy Group (DEG), Consol, and Steven Winters and Associates (SWA).

Figure 1 shows one of the first ZEH homes in Livermore California from the Florida Solar Energy Center (FSEC) and DEG research activity. Figure 2 is a home on Long Island researched by SWA. Of particular interest is the lengthwise shade structure above the first story, providing summer shading for the wall and glazing below, while still allowing the lower winter sun to passively heat the interior spaces. These two examples reflect the coast-to-coast opportunities to combine energy efficiency and solar technologies in new home construction.

Fig. 1: Livermore California Zero Energy Home FSEC / DEG Project

Fig 2.: ZEH home on Long Island, courtesy of Solar Strategies Development Corp.

The DOE Building Technologies Program's goal is to create technologies for low-cost net-zero energy residences by 2020. Both ZEH and Building America fall under the Building Technologies Program. "It's just a matter of time before such homes are truly affordable for the masses", according to Lew Pratsch, Zero Energy Homes project manager for the U.S. Department of Energy (DOE). Pratsch says that within the next decade, zero-energy homes could cost no more than comparable conventional homes. By 2020, he predicts, they could become the building-industry standard (2).

Quite often in ZEH discussions, the disingenuous title Zero Energy Homes is mentioned. Recent programs and policies are not attempting to zero out the energy usage, but attempt a major reduction in energy consumption, combined with onsite generation. Program participants' replies tend to revolve around the marketing magnitude of the name, not the overall goals of the program or building energy performance. As Rob Hammon of Consol has indicated, buyers need a "no-brainer" term when considering new home features (3).

2. EXAMPLE OF WORKING WITH BUILDERS

In 2001, NREL contracted with DEG to investigate and document the process of involving a medium sized builder with ZEH.

The first task for involving builders in ZEH is determining which builders to approach; which builders are already efficiency minded, Energy Star, or have branded energy efficiency on marketing brochures from builders is a good beginning. Researching attendance records of building efficiency meetings to see if builder representatives have attended meetings in the past is an opportunity to find receptive builders. A medium sized builder was chosen for its ability to make quick decisions on new building components. Large companies need Board of Directors approval, whereas a medium sized company might only need approval from a Vice President who champions energy advancements. DEG assembled a ZEH team of energy experts including a PV manufacturer with a roof integrated PV system, and a solar thermal manufacturer.

Phone calls introduced our champion to the scenario:

1. Look at existing and near term projects, consider a list of rank ordered efficiency measures that have proven paybacks in the builders climate zones.
2. Consider solar thermal and solar electric opportunities including current and projected incentives.
3. Consider the type of roof and the kinds of aesthetically pleasing building integrated products that would be acceptable to the builder and their customers.
4. Consider the utility ramifications; are they solar friendly, is natural gas available onsite making solar thermal less economically attractive?
5. Obtain an existing building design from the builder that can be analyzed for energy efficiency, effective orientation, and solar technologies.
6. Perform energy calculations on chosen efficiency measures and solar technologies for optimally oriented building. Iteratively present results, work with builder and repeat evaluations.
7. Develop a plan for the builder to include the most appropriate energy advancements in a standard package, with optional super advanced packages if necessary.
8. Work with builder and marketing firm to brand the advancements.
9. Work with builder to assist in on site modifications in new homes built with advancements.

Using this approach with a real builder, after four successful meetings the builder had advanced energy concepts integrated into their standard designs. The builder was sold on the ZEH concept and was determined to include ZEH in 10% of all new homes for new projects. The process reveled 10-year system warranties are a must for builder interest.

3. MARKET SECTORS

3.1 Low Income Housing

ORNL has been working with Habitat for Humanity low-income housing. Small, efficient houses can be constructed in Tennessee for an estimated $100,000, which includes the

cost for 2 kW of PV, structural insulated panels, windows with 0.34 U- Factor, 0.33 SHGC, and sill seal pans. Various strategies were tested for utilizing warmer crawlspace and basement temperatures for optimizing heat pumps, occasionally utilizing geothermal heat pumps. These heat pumps were also used for the domestic hot water capitalizing on moderate temperatures in the vented crawlspace, insulated crawlspace, or insulated basements. Air-to-Air heat exchanger in bathroom exhaust, and HVAC ducts in conditioned space were also considered advantageous. Various metal roofs with cool roof strategies are included in these designs by ORNL (4).

At a recent briefing on new technologies, Jeff Christian briefed the President of the United States on ORNL ZEH topics. "Awesome" was reportedly the Presidents reply to the presentation (5).

3.2 Multi Family Housing

Housing is tending towards higher density and ZEH programs are evolving with the trend. A majority of the proposals for the CEC Zero Energy New Homes (ZENH) solicitation included Multi Family Housing opportunities as discussed in Section 4.

3.3 Market Rate Single Family Homes

Figure 1 shows the Centex home, located in Livermore California, completed July 2002. ZEH features include cellulose wall insulation, radiant barrier roof sheathing, high performance windows with exterior shading, slab edge insulation, and enhanced thermal mass. Mechanical systems include a variable speed hot water air handler, integrated night ventilation cooling, tankless water heater with a solar water heater, and a 3.6 kW PV system. The first year actual performance was a net negative electrical use of 158 kilowatt-hours (kWh) and a positive 546 therms of natural gas.

A second-generation design resulted from the following interactive process:

- Review of first generation results
- Select energy efficiency measures for analysis
- Measure specifications and screening
- Measure ranking
- Sequential analysis
- Reevaluate costs & refine package
- Complete design
- Testing

The second-generation design includes improved wall and attic insulation, insulated headers, high performance windows, buried ducts, tankless water heater, fluorescent lamps and a high efficiency furnace. The PV Option includes Energy Star appliances, integrated night ventilation cooling, and a 2.4 kW PV system. The projected performance of the complete package with PV Option is 77% less electrical, 45% less natural gas, for a total 65% less energy consumption from the baseline design of California title 24 energy standards. Based on a 6%, 30 year mortgage, the home owner is projected to save $145 per year for the PV Option home (6).

Many builders are marketing ZEH concepts including:

- Clarum Homes, East PA, Watsonville CA
- Morrison Homes, Sacramento CA
- Pardee Homes, San Diego CA, Orange Co CA, Las Vegas NV
- Peppertree Homes, San Diego CA
- Pinnacle Homes, Las Vegas NV
- Premier Homes, Sacramento CA
- Ponderosa Homes, Pleasanton
- Beezer Homes, Sacramento CA
- Veridian Homes, Madison WI
- Aspen Homes, Loveland CO
- Grupe Homes, Rocklin CA
- Centex Homes, San Ramon CA
- Shea Homes, San Diego CA
- McStain Neighborhoods, Longmont CO

Veridian Homes is a Building America success story. By taking a popular plan, examine the design, selecting new efficiencies, and producing prototypes, they are moving towards zero energy buildings in the Midwest.

Clarum Homes started with 20 ZEH homes in East Palo Alto CA. Now they are building 257 ZEH homes in Watsonville CA. Clarum will only build homes with energy and green building standards. Pardee Homes built 2,700 normal homes in 2004, 10 were ZEH, 3 had PV standard.

Builders are interested in marketing ZEH homes because it increases market differentiation, builders obtain a reputation for supplying a superior product, and sometimes builders get receive project entitlements (3).

3.3.1 Single Family Home Electrical Performance

An aerial photo of a Premier Homes neighborhood in Sacramento is shown in Figure 2. Performance of these homes is shown in comparison to an adjacent neighborhood in Figure 3. The average ZEH bill is $46.69 US less than the adjacent neighborhood home for the month of September 2004. Of particular interest is the variation in performance of the Premier homes, reflecting the occupant's behavior. Buildings can be design to use less energy, however the occupant's behavior is an important factor in actual residential energy consumption. Behavior needs to be

addressed to achieve ZEH goals and objectives. Real-time metering located inside the home providing both consumption and PV production has been effective in addressing behavior.

Fig. 2: Premier Homes Neighborhood in Sacramento, photo courtesy of SMUD.

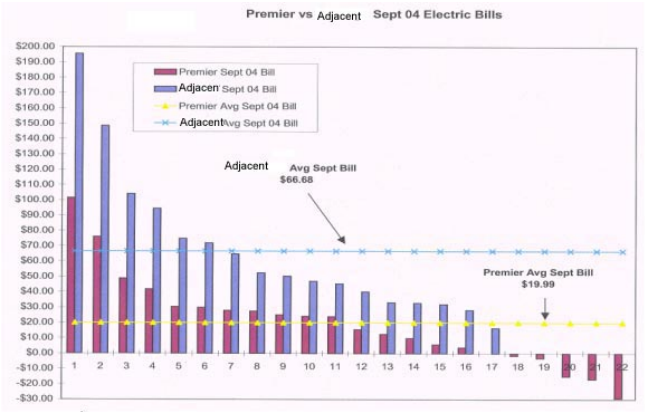

Fig. 3: Performance of Premier Homes, graph courtesy of SMUD.

4. CALIFORNIA RD&D EFFORTS

In 2004 the CEC PIER invested up to $10 million in a RD&D approach to reduce energy use and peak demand in the residential sector using more cost effective energy efficiency and PV strategies. The goals are to reduce energy use by 25% through improved efficiency, reduce utility bills by 70%, peak loads not exceeding 1 kW, with an incremental cost less than $5,000. The notice of proposed awards for the ZENH solicitation indicates the ranked order of awards as shown in the top three entries of Table 1. Below, specific information from the publicly available proposals is presented (7)(8).

4.1 Architectural Energy Corporation (AEC)

In the AEC proposal, Pulte Homes has signed a letter of commitment agreeing to build 75 ZENHs in their Ladera Ranch Development in South Orange County, in Southern California Edison (SCE) service territory near Los Angeles in California climate zone 8. The preliminary design is a single-story, 2,500 sq. ft. home with the following ZEH energy features:

1. R-38 Roof insulation with attic radiant barrier
2. Low air infiltration/tight envelope (requires 3rd party testing)
3. Quality installation of insulation required (requires 3rd party testing)
4. R-13+1" Foam (2x4) and R-13+1" Foam (2x6)
5. Dual pane spectrally selective glass. Glazing U-factor and SHGC equivalent to 0.39 (U-factor) / 0.31 (SHGC) – see sample home energy analysis for actual details
6. 0.90 % Furnace AFUE and 13 AC SEER with TXV
7. R-6 duct insulation value
8. Tight duct required (requires 3rd party testing)
9. ACCA Manual D design required – this will right-size the system
10. On-demand tankless water heater with an Energy Factor of 0.82 and insulation on all major hot water plumbing trunks.
11. Fluorescent lighting (all downlights)
12. Energy Star appliances, assumed to be 30% more energy efficient than those of the base Title 24.
13. 2.0 kW DC PV system

Total additional estimated costs for these measures are $16,953, which does not include $5,200, supplied from a California rebate for the PV system at $2.60 a watt. The proposal predicts the buyer will spend $598 less in the first year for the demonstration ZENH than for a base case house.

Other possible features that will be investigated include:

1. T-Mass pre-cast concrete walls by Dow Chemical
2. Optimum Value Engineering (OVE) wall construction
3. Compressorless cooling options
4. Night pre-cooling
5. Water-cooled AC compressor
6. Ducts in conditioned space
7. Buried ducts in attic insulation
8. 2.0, 3.0, 3.6, 4.8 kW DC or larger PV system
9. Movable shading
10. Movable insulation
11. Radiant Floors
12. Solar water heating

AEC indicates that they will select a package of the most cost-effective technologies for each house that meet performance goals and are acceptable to the production builder. The results from performance evaluations will be used to determine the benefits of ZENH to the utility and will form the basis of crafting an entire program of utility / homeowner cooperation in PV ownership and operation (9).

4.2 PowerLight

PowerLight's proposal includes many key partners including Suncrest Homes, JB Development LLC, Central Valley Housing Coalition, Oak Ridge National Laboratories, Fannie Mae, Bonneville Environmental Foundation, E3, Clean Power Research, DLR Consultants, Roger Levi, City of Brentwood, PG&E, Sharp Solar, Sunpower, Heliodyne, Xantrex, Fronius, SMA, Home Automation Inc., Integrated Metering Systems, Home Automation Inc. PowerLight's team members include, GeoPraxis (Multi family design, 80 unit development in Madera, California), Consol (Single family design), and Newport Design Consultants.

4.2.2 PowerLight Multifamily Housing

Under the preliminary design, PowerLight has selected a 1.5 kW building integrated photovoltaic (BIPV) system to be installed on the ZENH. The system will be installed and integrated with a concrete tile roofing system. The system will produce approximately 2,151 kWh annually, and reduce the demand of the residence during a peak day, on average over a four-hour period, by 0.9 kW.

4.2.3 PowerLight Single-Family Housing.
Suncrest Homes is the builder partner selected by the PowerLight team for a single-family project in Brentwood, California (273 home development, with a minimum 75 ZENH). Under the business model put forth in PowerLight's ZENH proposal, the PV system will be purchased by a third party, with the cost being recovered through the equivalent of a utility payment by the owner. Under the preliminary design, PowerLight has selected a 3.1 kW BIPV system to be installed on the ZENH. The system will be integrated with a concrete tile roofing system. The system will produce approximately 4,450 kWh annually, and reduce the demand of the residence during a peak day, on average over a four-hour period, by 1.9 kW.

To meet the targets put forth in 2008 and 2013, additional improvements in energy efficiency and BIPV will be investigated, including:

- Advanced building integrated PV
- Demand limiting controls
- Indirect evaporative cooled air conditioning
- Water cooled condensing features on conventional packaged air conditioners
- Compressor less air conditioning designs and features
- Solar thermal used for domestic hot water heating
- Advanced envelope design

4.3 Global Green

Global Green located in Santa Monica CA and Washington DC proposed 110 ZENH units, including a marketing campaign to the developer community. This includes a 55 unit multifamily development in Westlake/McArthur Park neighborhood of LA, climate zone 9 in LAWDP territory as well as a 56 multifamily development in City of Poway in SDG&E territory. The Global Green proposed business model includes rebates and innovative use of tax credit financing and third-party ownership / financing mechanisms. The project maximizes both the public benefits of reduced peak system load and increased generation of clean energy and the private benefits of long-term energy cost savings and stability to non-profit developers of the affordable housing project and their low-income tenants.

TABLE 1: ZENH NOTICE OF PROPOSED AWARDS

RFP # 500-04-501 Zero Energy New Homes (ZENH)			
Name	Requested	Match	Title
AEC	$2,904,938	$324,792	Utility-Focused Market Model for Zero Energy New Homes
PowerLight	$2,730,283	$3,888,758	Commercializing Zero Energy Home New Communities
Global Green	$732,000	$866,000	Affordable Multi-Family ZENH Project
SMUD	TBD	TBD	Affordable Zero Energy Homes

5. SOLAR TECHNOLOGIES

Sizes between 1 kW and 4 kW building applied PV and BIPV systems are included with ZEH, economically justified in locations where rebates or subsidies exist. Solar thermal is a challenged. As Rob Hammon indicates, builders want PV and want it to be inexpensive; they only care that solar thermal is inexpensive. The solar difference is that builders see PV in an aesthetic matter that can help sell homes. They don't feel that way about the solar water heater (3). As seen in the research and development awards from PIER, solar thermal is only in the more aggressive, later years of the research. The challenge is to convince buyer that solar thermal is a good thing. It is currently offered as

an option, but needs to be a standard in home design to gain acceptance.

The economics for tankless water heaters are attractive to builders because the simple venting can provide savings, there are space savings, and no standby energy losses. Tankless heaters with high capacity, and at least 80% efficiency using natural gas are needed. Some ZEH success has been obtained with tankless water heaters (gas or electric) that vary the burn based on the incoming water temperature and output temperature needs, combined with solar thermal collectors. A priming domestic hot water system can save water usage, and energy especially when considering supply and sewage pumping energy. This structured plumbing includes circulation loop, insulation on all hot water piping, controls with appropriate activation methods, short branches off a main trunk connect to fixtures, like sinks, showers, and baths.

6. RESALE VALUE & BUYERS ATTITUDES

NREL's Barbara Farhar has research ZEH markets including the resale value. Shea Homes at Scripps Highlands in San Diego, California, offers highly energy-efficient homes with solar water heating and, in some, solar electricity as a standard feature. Early in 2004, mail questionnaires went to 271 homebuyers in the 306-home Scripps Highland community (ZEH and highly energy-efficient homes) and 98 homebuyers in an adjacent 103-home community (conventional homes) who had lived in their homes for at least 6 months. Two different builders offered these homes. Respondents in the conventional homes comprise the comparison sample. Homes in the SheaHomes communities, which closed between April 26, 2001, and November 21, 2003, originally ranged in price from $437,900 to $840,938. The mean price was $601,984. Homes in the comparison community were sold from May 22, 2001 to November 10, 2003, and ranged in price from $473,990 to $875,000, with the mean price being $615,029. As of February 20, 2004, 16 homes had been resold by their original owners (10 in SheaHomes communities and 6 in the comparison community). Both the SheaHomes and the comparison homes have increased markedly in value, but, based on this very small sample the SheaHomes have increased more in value in a shorter period of time. The increase in value for the SheaHomes averaged $227,592, or 42%, in an average 18.7 months ownership whereas the increase in value for the comparison homes averaged $163,629, or 26% in an average 21.8 months ownership (10)(11).

A survey of potential homebuyers by DEG asked, "What is the likelihood that you would have considered buying a house that costs $8,000 more but that generates 40% of its own electricity?" Answers were: 2% not at all, 5% not very likely, 26% somewhat likely, 26% very likely and 41% I definitely would have looked (6).

7. POLICY RECOMENDATIONS

7.1 Local Community Efforts

In Winters California, the authors' home town, requirements for all new developments includes "…attainment of EPA Energy Star Standards in all units; low emission furnaces; avoidance of dark colored roofing; and a minimum of 10 percent solar photovoltaic homes". This reflects a community interest in the ZEH concepts, without the formal term.

7.2 Value

New developments require huge investments in peak electrical generation and distribution infrastructure. Value can be obtained by recognizing the reduced peak loads of ZEH communities, and as such, provide incentives to builders or buyers for the ZEH approach.

7.3 Siting

It has been suggested that PV be included in two story buildings, located as close to the top ridgeline as possible. The buildings should be located as far to the north of the south lot lines. Both of these recommendations are to reduce potential shading effects on PV from on-site and neighbor's trees. Attention to detail should ensure that no bathroom, water heater or furnace vent piping shade PV. No dormers or other architectural features should shade PV surfaces at any time of the year.

Orientations of roads in developments dictate the lot configurations. Roads that run true-north / solar-south facilitate long east-west lots; which allow for south facing unobstructed roofs. Windows situate on the south also have the best opportunities for effective shade strategies as shown above in Figure 2.

8. CONCLUSIONS

Location specific energy efficiency measures, combined with solar technologies, can provide substantial reductions in residential utility payments. California justifies PV systems in locations experiencing high utility costs where rebates combined with efficiency packages cost less in 30-year mortgage payments than utility bills.

Regional climate and utility costs justify energy efficiency components. Solar is primarily in subsidized markets.

Occupant's behavior is an important factor in energy consumption in residential buildings. Real-time information on energy consumption, and production changes habits.

9. ACKNOWLEDGMENTS

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