Flat Load Profile Homes: Improving ZNEs?

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ABSTRACT

Volume builders of Zero-Net-Energy (ZNE) homes typically design them using increased energy-efficiency plus photovoltaics. Summer daily electricity-demand from such a ZNE home, plotted as a function of time produces a "load-profile" with a mid-day trough (excess generation sent into the grid) and a late-afternoon peak-demand mainly from air-conditioning. The 24-hr load-factor for a typical ZNE is low (<0.3), indicating low electric-distribution-system efficiency. Research shows that this distribution system problem can be mitigated in ZNE homes using a superb envelope and no air-conditioning or high-mass homes with controls to avoid on-peak cooling. Alternatively, adding thermal mass and batteries results in homes with constant, low utility demand. Without peaks or troughs, these Flat-Load-Profile (FLP) homes have the highest load-factors (>0.7), resulting in high-efficiency homes on a high-efficiency grid.

Home-energy-management systems coupled to a smart-grid provide the smart-grid access to FLP PV generation and storage, and to demand-responsive (DR) appliances. FLP homes improve grid efficiency, unlike typical ZNE's which decrease it. Further, FLP batteries can act as an energy buffer when needed, such as during cloud-events, PV-system failure, and grid transients. FLP-homes add value to utilities by eliminating summer-peak, increasing grid-stability, and providing buffering and DR. Typical ZNE homes decrease grid efficiency due to the trough and peak load profile.

FLP homes are compared with other ZNE approaches, including costs and benefits. Utility value for connecting ZNE, FLP and ZNE-FLP homes to the grid is evaluated, from which new utility-builder business models are suggested in support of FLP-communities.

Introduction

Over the past ten-plus years, the author has experienced an increased interest from builders in Zero-Net-Energy (ZNE)[1] and near-ZNE[2] homes. The focus of this work is entirely homes, but has parallels in the office building sector. Driving forces behind ZNE (herein "ZNE" includes "near-ZNE") homes include state energy policies,[3] solar and efficiency as a marketing tool,[4] and the potential benefits of summer electricity-peak reduction.[5] All of these market forces are going to increase the numbers and market penetration of PV systems in the US, and

[1] ZNE buildings produce as much energy from renewable sources as they consume, on a net, annual basis

[2] "Near-ZNE" homes: those that combine energy-efficiency to reduce energy requirements with a photovoltaic (PV) system to generate sufficient renewable energy to significantly reduce annual energy consumption and the resulting energy costs, but not enough to completely offset annual energy use. First uses were "Near-ZEH" or near-Zero Energy Home, likely during DOE "Zero Energy Home Program".

[3] California Big Bold Goal of 100% of new homes being ZNE by 2020; New Mexico's Zero Energy Home program combining State and Federal tax credits, Renewable Energy Credits, and marketing support

[4] Photovoltaic systems increase the sales prices of California homes (Wiser 2011)

[5] Residential AC is the largest contributor to peak (followed by Comm AC, Comm Lighting), but about equal to res cooking and cloths drying in energy use (Brown 2002)

particularly in areas with good insolation. In areas of the US with good insolation and hot summers, where compressor-based air conditioning is prevalent, there is a potentially serious problem looming as the number of communities of ZNE homes steadily increases: These homes reduce distribution system efficiency as this paper will show. There are many solutions to this problem, and they should be evaluated before the number of ZNE homes becomes large enough to have a significant effect on the distribution systems, and even sections of the electric grid.

A major problem with ZNE homes is that the daily electricity usage patterns are not temporally matched with the PV generation profiles. This ultimately results in reduced distribution system efficiencies. Typically, ZNE homes will use more energy than they generate during parts of each day, particularly during summer days in the late afternoons when electricity use for air conditioning peaks, coincident with the waning of electricity generation from the PV system. ZNE homes will also typically generate more energy than they use during other parts of the day, typically mid-day when the sun is high and the home electricity use, particularly from air conditioning, is not at its peak. During these periods when PV-generation is greater than the demand from the home, the excess electricity generated is sent "backwards" through a net-meter.

The resulting daily load shape (demand plotted against time of day) of ZNE homes has a characteristic trough-peak profile. The impact of this load-shape on distribution efficiency can be quantified by calculating the load factor for a distribution system connected to ZNE homes. ZNE homes have substantially lower load factors than those for efficient or typical homes without PVs, indicating that ZNE homes in sufficient volume will dramatically reduce distribution system efficiency. Different design and control strategies for ZNE homes can mitigate their reduced load factors, or even increase them, indicating opportunities for ZNE homes to improve the distribution system efficiency compared to average communities. Properly designed, homes can produce low and essentially flat electricity demand throughout the day. These flat load profile (FLP) homes produce high load factors that, in aggregate from a community of FLP homes, will improve distribution system efficiency. A high load factor should be a design goal for ZNE homes so that both the homes and their use of the distribution system, and ultimately the electric grid will be efficient, potentially above 80%. This will be even more important as communities move to electric vehicles.

Load Factors and Distribution Efficiency

Equation 1: Load Factor = Average Load[6] (kWh)/Peak Load (kW)

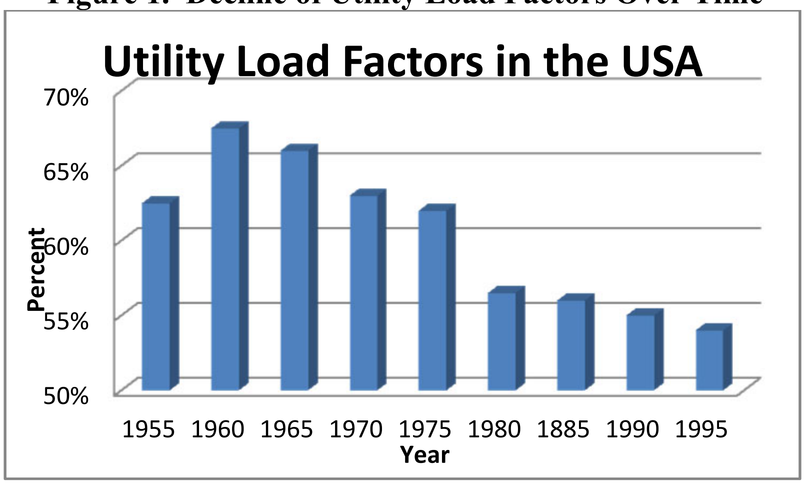
Why are load factors important? Load factor, calculated using equation 1, in this case using 24-hour demand data from homes, indicates the local distribution system ability to carry electricity: very low numbers indicate a very low efficiency and high numbers indicate a high efficiency, both a function of the peak in the calculated period (Patrick, 1999). A typical housing development has a load factor of about 0.5 (Ceniceros, 2006), and is designed according to the anticipated loads and a 50% efficient distribution system, plus a safety factor. However, as currently designed, producing troughs and peaks, near-ZNE and ZNE homes have low load factors because they have both a negative and a positive peak, or a deep, negative trough. The

[6] The electrical power usage can be averaged over various periods of time, in this case ranging from a day to, more typically, a year. Generally when the peak is cyclic, at least one full cycle (in this case a day) should be used to calculate the average.

same distribution system will need to transmit both peaks: one *to* the house for any remaining AC demand, and one *from* the house due peak generation. If all the homes on the distribution system are ZNE and have a load factor of 0.25, typical of ZNE homes, the wire for the distribution system will need to be larger, possibly up to twice the carrying capacity as that in the normal community – even though the homes are more efficient and have lower peak demands! The load factor alone is insufficient to determine the impact on distribution wire-size. Nonetheless, with a sufficiently large peak, trough or both, simulation results predict a significant impact load factor, indicative of a relative impact on distribution system sizing.

Two related problems with current designs of ZNE homes result in low load factors: 1) The infrastructure may to need to be larger than typical to support ZNE homes; 2) It is possible that utility engineers would size the distribution system for the peak demand rather than the peak transmission requirements – accounting for transmissions in both directions for communities of ZNE homes. This could result in the distribution systems' carrying capacity being sized too small for the lower load-factor ZNE homes.

Figure 1. Decline of Utility Load Factors Over Time



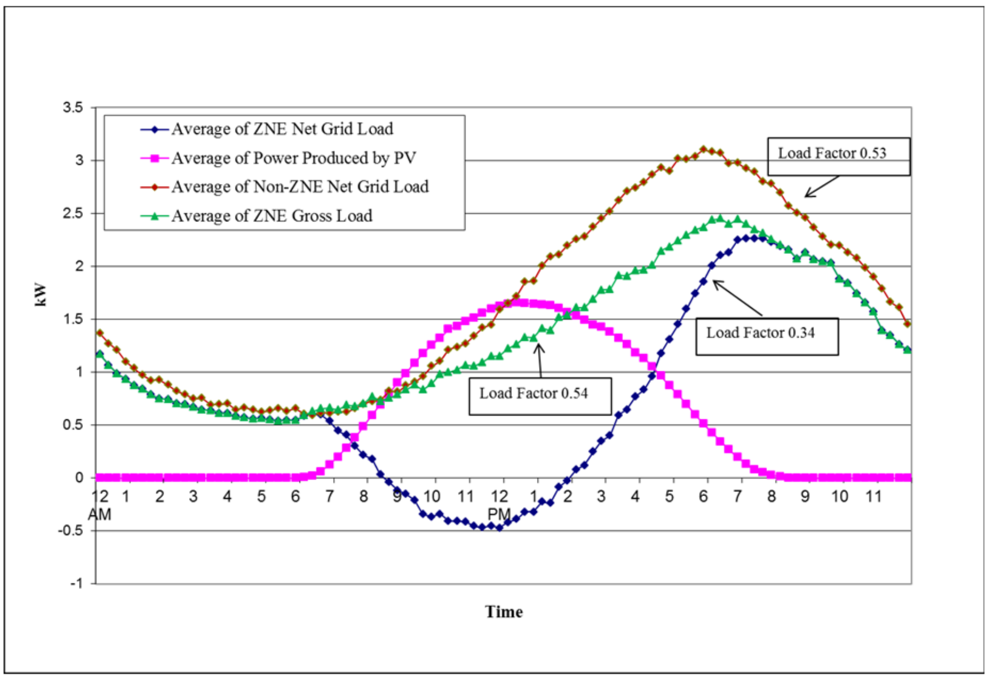
Data Courtesy of EPRI, 1998

There has been a constant decline in load factors over the span of 40 years from 1955 to 1995, as shown in Figure 1. Electricity demands have increased over the last 50 – 60 years, with a significant fraction of this load growth attributable to increased prevalence of vapor-compression residential air-conditioning, which is also largely responsible for summer afternoon peak demands in areas with hot summers. This growth in peak demand, compared to base load may be a major contributor to the decrease in load factors. The decline in load factors illustrates the need for careful building energy-efficiency design, to reduce energy use and greenhouse gases, to consider load factors with increasing use of renewables, and also to improve the operating efficiencies of the power plants and distribution systems.

ZNE and Load Factors

Average daily demand from a sample of "near-ZNE" homes is available as 15-min interval kW data from an existing community, Premier Gardens, located near Sacramento, CA (Hot-Dry summers). Figure 2 illustrates the average daily load profiles, for both gross electricity use (without PVs) and net (what the meter sees) from 18 Premier Gardens homes for the month of July 2005, which included the summer peak-day. Figure 2 also shows control home data from similar, neighboring homes built contemporaneously and to the SMUD Advantage Home Program requirement of 30% reduced cooling budgets compared to CA Title 24 minimums, and without PVs. This Premier Gardens data set covers three years and nearly 100 Premier Gardens homes and an equal number of control homes, and is the most comprehensive demand, energy, and bill data available for a near-ZNE community. Their load profiles demonstrate a mid-day trough due to excess generation being sent into the grid, and a late afternoon peak demand mainly due to space cooling from air-conditioning. All ZNE and most "Near-ZNE" homes built today are more efficient, and often have a larger PV system than the Premier Gardens homes. This means that the disparity of trough-to-peak is larger in ZNE homes than for Premier Gardens, and the load factor for ZNE homes will be lower than for Premier Gardens.

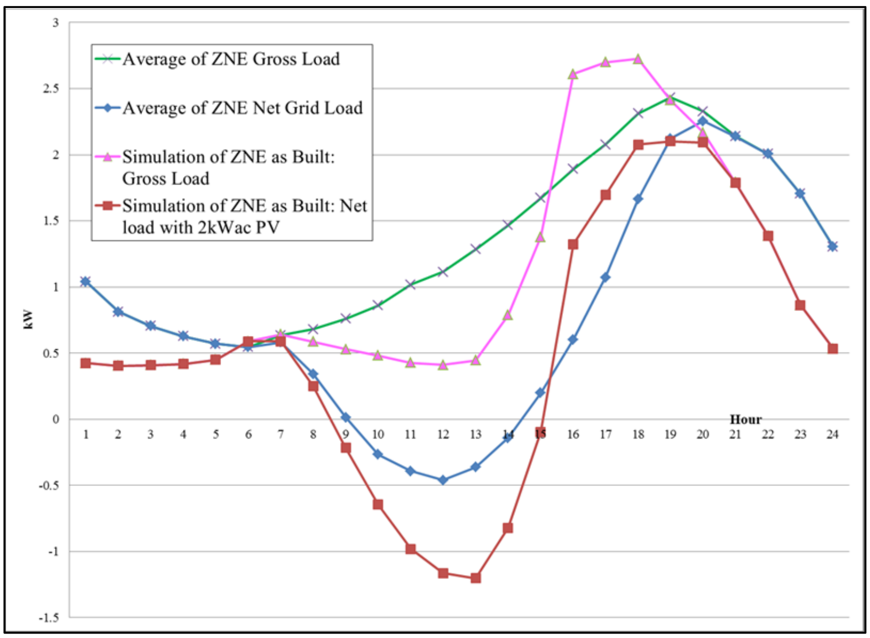
Figure 2. Average Daily Load Profiles and Corresponding Calculated Daily Load Factors from Near-ZNE and Control Communities From a Hot Summer Month



The efficiency of electricity-supply systems, from power plants to transmission lines to distribution systems can be evaluated by calculating the load factor. The load factor calculated for a summer day for a typical ZNE home is low (less than 0.3, indicating low electric-utility-system efficiency, approximately 30% efficient in this example, compared to a typical residential community with a load factor of around 0.5 or 50% efficient. This large decrease in load factor is due to the significant disparity between the mid-day trough and the late afternoon peak. As near-ZNE homes become more efficient, often with more PV, and approach or meet ZNE, the load factor continues to go down, going through zero and becoming negative. While measured data from ZNE homes is sparse, simulation data can be used to demonstrate both the low load factors, and how they can be improved so that future ZNE developments make the distribution system more efficient, rather than less.

While the low load factors of ZNE homes do not present a significant impact on our distribution systems today, because of their low market penetration,[7] as ZNE communities become increasingly common, the impacts on the distribution system will become significant. Figure 2 shows average data from ZNE homes, and the trough-peak load shape is prominent – it did not average out across a volume of homes. Aggregation of troughs and peaks and the resulting low load factor should be considered and mitigating steps taken in the design of ZNE homes and buildings. Now, while the market penetration of ZNE homes is low, is the time to improve ZNE designs so that they do not result in decreased distribution system efficiency. In fact, there are design approaches that result in increased load factors, rather than decreased. Simulations clearly show that designs resulting in FLP homes should be built and evaluated, given that they present the opportunity for ZNE homes to not only improve efficiency of the home, but also to increase efficiency of the distribution system.

Figure 3. Comparisons of Simulated and Actual Load Profiles for Premier Gardens Homes

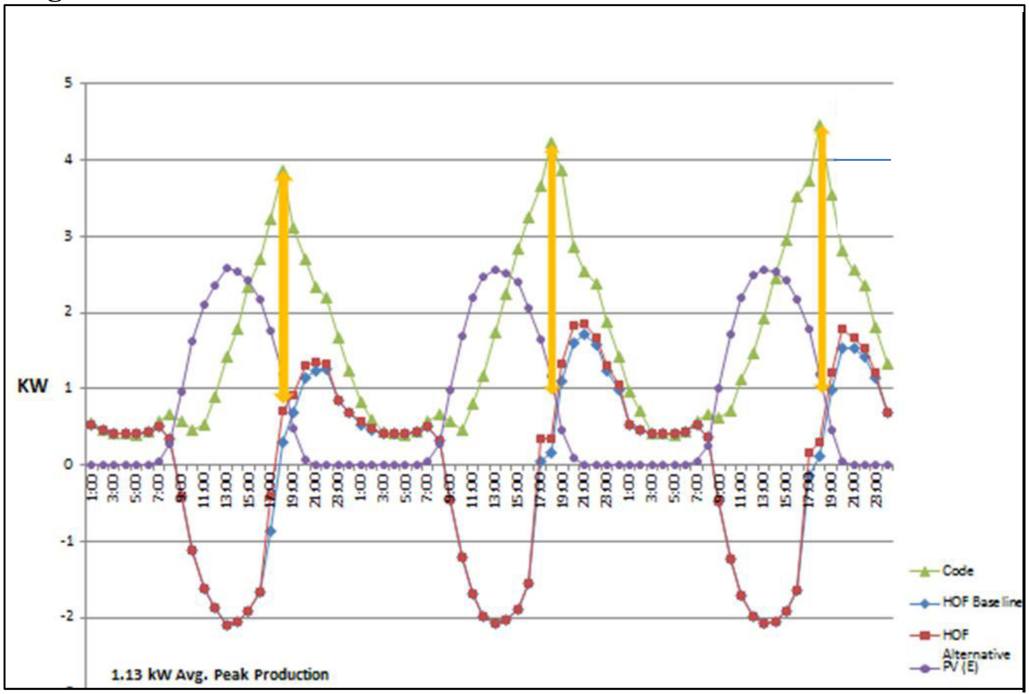


There are a number of different design approaches that can substantially flatten the load curve, improving the load-factor to 50% or even higher. These approaches include: current ZNE designs with added thermal mass and battery storage, excellent envelopes with geoexchange cooling, and very high-performance envelopes with some thermal mass that do not need nor have compressor air conditioning.

[7] GoSolarCalifornia March 2012:>65K installed res. PV systems, > 75K including pending, producing 363MW

Data like that from Premier Gardens is not available to evaluate these alternatives, so simulations are used. To give a simple, visual evaluation of this approach, simulations of a Premier Gardens home are plotted with actual data from the homes in Figure 3. While not a perfect match, the simulations provide a reasonable representation of the actual data, which has large variability due to occupant behavior.

Figure 4. Load Profiles and Load Factors for Current near-ZNE Homes



Courtesy SMUD Home of the Future

An example of a more efficient design, with a larger PV system (4.1 kW), is shown in Figure 4. These data are from new homes in SMUD's Home of the Future program, which are designed to be 80% more efficient than the current, 2008 Title 24, targeting a peak demand of approximately 1 kW. Comparison of load shapes shows the lower demand homes in Figure 4 have a deeper trough and lower peak. They also have a much lower load factor of near zero.

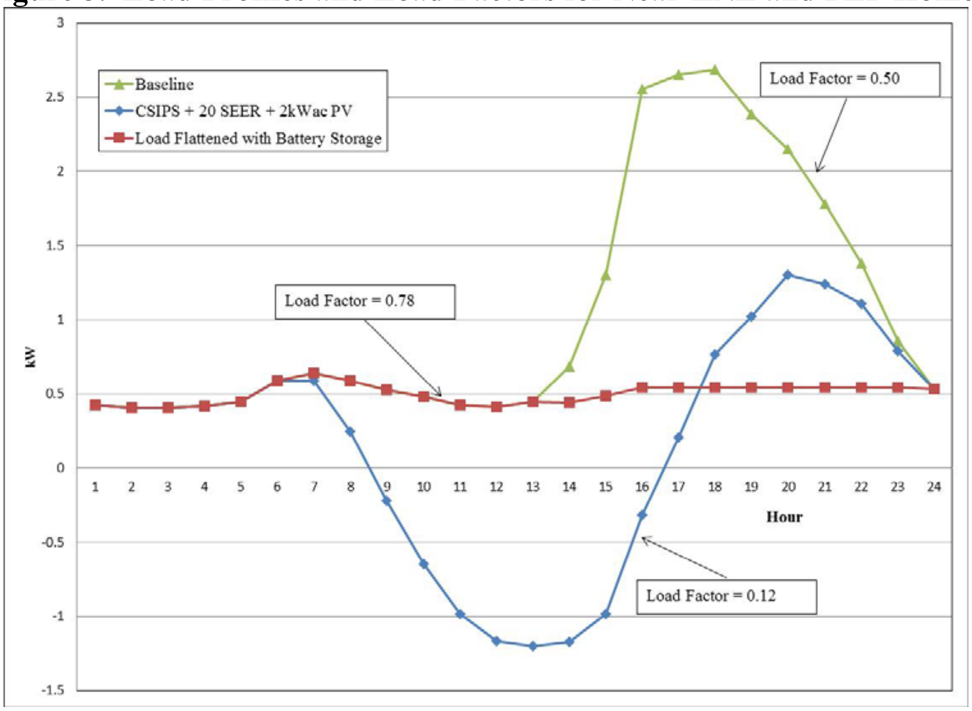
Figure 5 shows the change in load shapes and resulting load factors from near-ZNE homes (Premier Gardens simulation) with and without PVs, and with FLP improvements. To convert the homes to be FLP homes, the following features were added to the Premier Gardens home: additional mass (tile-covered slab replaced 80% carpet, and increased wall mass with improved wall insulation: C-SIPs[8]) and a 10 kWh battery system with 75% charge-discharge efficiency. As shown in the graph, the FLP demand curve is virtually flat, with an almost 0.8 load factor, compared with the near-ZNE load factor of 0.12.[9]

In addition to helping to flatten the demand from FLP homes, energy storage provides additional benefits – it is dynamic and can respond in ways that passive efficiency and mass cannot. For instance, clouds shading the PV array will temporarily reduce generation, and can

[8] C-SIPS: Structural insulated panels with cementatious panels rather than OSB.
[9] The lower near ZNE load factor in simulation resulted from a deeper trough than occurred in the actual data

produce a demand spike that could be mitigated by the battery array. Also, if the PV system fails, a smart system could use energy from the grid to charge the batteries during the night hours, for example, so that they can still be used to reduce, and even flatten the peak. The dynamic nature of this system should have value to the utility, especially if connected to and controllable by a smart grid.

Figure 5. Load Profiles and Load Factors for Near-ZNE and FLP Homes



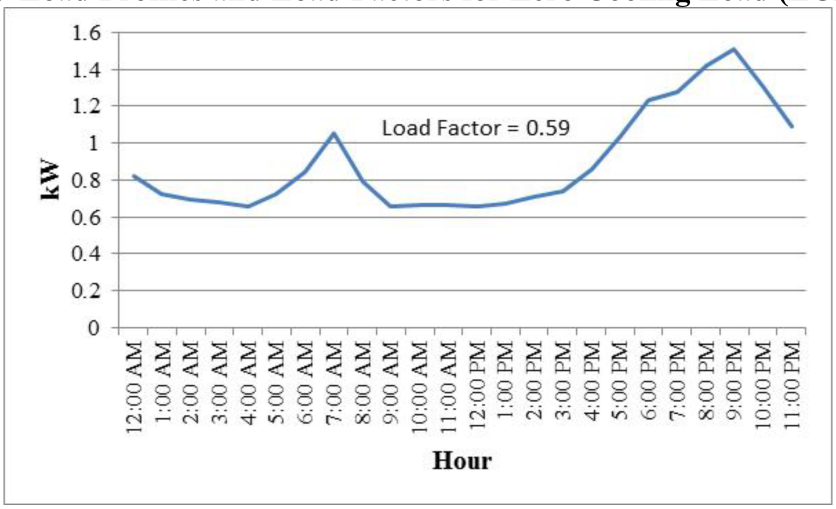
Another approach is to build a very high R-value envelope with very low air leakage and sufficient mass that night ventilation-cooling of the home eliminates the need for mechanical air conditioning. This "Zero Cooling Load" (ZCL) design approach was used in the Zero Cooling Load project, funded by the California Energy Commission PIER program (BERG 2012). The study found that with the excellent envelope and night ventilation-cooling, the occupants would be comfortable in all California climates except the desert.[10] This home has R-45 spray-foam insulation in staggered-stud walls, insulated slab, and R-25 spray-foam installed on the underside of the roof-deck. The load curve for a hot day in Sacramento (over 100 degrees), illustrated in Figure 6, is relatively flat, but has two demand spikes resulting from higher levels of miscellaneous electric loads, and ventilation fans. Without batteries for electric storage, there is no straightforward way to mitigate these spikes.

Homes with excellent envelopes and geoexchange cooling can have relatively flat load curves. A large monitoring study of retrofitted homes (Hughes 1998) measured relatively low energy consumption and a load factor of 0.5, without PVs. If PVs were added to these homes to make them ZNE homes, without some mitigating factor they will have mid-day generation troughs, resulting in low load factors. So, while this is a good approach to reducing both space conditioning energy use and demand, the remaining loads (cooking, drying, lighting,

[10] Comfort determined by ASHRAE Standard 55 as calculated using the EnergyPlus version of BEopt (BEoptE+)

miscellaneous loads etc.) remain to be offset by PVs or some other renewable source. To maintain a good or achieve a better load factor with PVs, battery storage would be needed to level excess generation and use it over time to keep the loads low and flat, producing a high load factor. Given that this approach ends up with the same peak-trough load curves, with low load factors, it will not be considered further in this study.

Figure 6. Load Profiles and Load Factors for Zero Cooling Load (ZCL) Home



Courtesy CEC PIER BERG ZCL Project

Benefits and Costs of FLP and ZCL Homes

Figure 5 illustrates the summer energy profile of a typical, energy-efficient new home, compared to a ZNE and FLP home in a Hot-Dry climate. The typical new home has its peak demand during the summer late afternoon. Power generation needs to be designed to meet this maximum peak, typically by dispatching additional power to the grid from “peaker plants.” Peaker plants tend to be relatively expensive to build, operate and maintain, inefficient and environmentally dirty, (per kWh generated) compared to plants that run continuously producing the power needed to meet baseline system loads. The higher generation costs incurred from dispatchable peaker plants are inherent in the marginal cost of power during peak periods, and the resulting demand charges in many of the commercial tariffs. Communities of FLP homes would not need peaker plants, eliminating the costs of their construction and generation. This would also eliminate their additional pollution, which ultimately will be monetized.

The ZNE home’s profile has a reduced and shifted peak, but also manifests a trough during the mid-day when the maximum PV production occurs, out of phase with the peak in demand which occurs later in the day. Although the homes have a very low net energy requirement, the disparity between peak and trough demand is as large, or sometimes larger than the disparity between baseline and peak for the code home (see Figure 4). As the market moves toward ZNE homes achieved by efficiency measures and PVs, the load factor will get progressively lower, and at a large community scale, unless an FLP strategy is adopted, the large-scale implementation of ZNE homes will result in the need for higher capacity distribution systems, increasing infrastructure costs.

For large communities of ZNE homes, the electric utility will still need to design for and manage an afternoon peak, albeit smaller, but they will also encounter a new phenomenon, the mid-day excess generation (the trough). This excess generation results in two issues: 1) the obvious one that it needs to find a use at a time of day when system demand is relatively low, and 2) the counter-intuitive finding that the combination of trough-peak results in a lower distribution system efficiency, as quantified in the load factor. FLP homes solve this problem by eliminating both the peak and the trough. The excess energy produced by the PV system is stored in a battery for a later use, essentially eliminating the troughs and peaks found in ZNE homes. The storage could also be in the distribution system, with benefits of scale and maintenance, but that solution may not solve the low distribution system efficiency between the houses and the storage. It is also a less flexible solution given that the batteries in the FLP homes could be controlled by an intelligent controller in the home (the Home Energy Manager, "HEM") making decisions when demand for electricity occurs simultaneously by the house and the grid.

FLP homes are a natural fit with a smart grid because a well-designed battery-storage device will have a HEM that manages the battery, DR, and communicates with the smart grid. Two-way communication with the grid allows the storage to be accessible to the grid as well as to the house. The energy that is generated throughout the day by FLP homes' PV systems is first used to satisfy the electricity loads in the home (including pre-cooling thermal mass, assuming an occupant allowing this energy-saving strategy). Excess generation would be stored in the batteries, and/or directed into the grid for peak reduction, mitigating a cloud passing by, temporarily mitigating loss of a PV system, or other grid events. The strategy would be programmed and carried out by the FLP HEM to optimize energy and costs according to tariff rules and options set by the homeowner.

The ZCL (zero-cooling load) homes provide a relatively high load factor due to the absence of compressor air conditioning. Their benefits result from an excellent envelope and proper management of the home, such as night ventilation-cooling. They do not have batteries or other energy storage, and in this example they do not have PVs.

Table 1. Incremental Cost Estimates for FLP and ZCL Homes

FLP: Total Incremental Cost	$22,000	ZCL: Total Incremental Cost	$17,000
Good Envelope		Excellent Envelope	
Efficient HVAC		No air conditioner (savings)	
Tile over Slab		Mechanical Ventilation	
2x 5/8" drywall		Efficient Ceiling Fans	
2.4kW PV System (rebate)		No PV (no cost)	
10 kWh Battery / Controller / Home Energy Mgmt System		No Battery or Home Energy Manager System (no cost)	

Courtesy CEC PIER BERG ZCL Project

Current total incremental cost estimates for FLP and ZCL homes, and key features of each are in Table 1. The costs are incremental in reference to current Title 24 or IECC codes. While the ZCL homes cost less to build, their performance is dependent upon the occupants properly operating the home, summer night-ventilation cooling in particular. There are too many electricity tariffs to determine which would have lower energy bills. Nonetheless, logic dictates that utilities would provide more favorable builder incentives and tariffs for FLP homes, because of their higher potential value to both the distribution system and the smart grid.

Utility Business Model

Utility peak demands are going up, load factors are going down, the builder market is moving toward ZNE buildings, and utilities are starting to implement smart grid technologies. An example utility dealing with this growth is Arizona Public Service (APS). Their future resource planning report (APS 2009) has a discussion regarding their concern and the need for addressing the growth in peak load demands for the utility, and various options and strategies they are exploring to meet those demands. These options and strategies include an increase in both energy efficiency as well as renewable energy generation (mainly solar energy). According to this APS report, in the 20 years from 1988 to 2008, their peak demand more than doubled (125% growth) from 3,240MW to 7,277MW. Further, APS predicts that the peak load demand will continue to rise exponentially, growing by over 56% from 7,300 MW in 2009 to 11,400MW in 2025.

Flattened electricity demand from FLP buildings would be a major step toward providing electricity reliably at lower costs. The high load factors from FLP buildings reflect that the utility's fixed costs are spread over more kWh of output, meaning a lower cost per unit of energy. Currently, distribution system load factors fluctuate due to a number of different variables. Some of the commonly known variables include: seasons, occupant behavior, and climate-driven air conditioning demands.

Elimination of residential peaks would reduce grid loading and increase the grid/generation/plant load factor. Eliminating the residential mid-day feed into the grid when not needed would reduce grid congestion and increase the grid load-factor. Both of these attributes of FLP homes would make the grid more efficient. In addition, the combination of generation, storage, HEMS, programmable communicating thermostat (PCT), other intelligent, communicating appliances and smart meters in FLP homes allow them to become an asset in dynamic load management. This combination makes FLP homes a passive asset to the grid under normal operating conditions when their load is managed locally by the HEMs and the load profile is low and flat. Under abnormal grid conditions, FLP homes could become active assets to grid management by allowing demand-control instructions through the smart meter to impact home demand (up or down) via HEMs control of temperature (HVAC), appliances and storage.

For homes in particular, anything that increases or decreases either or both the peak and the average energy used, changes the demand, the load factor, and reserve margins. Because the local system demand is not entirely predictable, load balancing has become necessary to maintain grid stability. In load balancing, modulatable and/or dispatchable power stations maintain a spinning reserve at all times, allowing grid operators to dispatch additional power with the rise in demand and vice versa. Utilities recognize that alternative methods to reduce or reverse the growth in peak demands must be explored. Likely the most important reasons are costs and system reliability.

Many utilities are implementing and/or evaluating Smart Grid technology, which can be both proactive and reactive to energy consumption and power requirements. The Smart Grid communicates with the electrical grid and the loads (e.g., HEMs), to make "intelligent" decisions such as curtailing loads or dispatching power, based on programming (e.g., based on tariffs) and on-going experience. Some of the first, simplest actions would be demand-response approaches to shed loads by disabling appliances such as residential air conditioners for limited periods of time. This demand response approach allows utilities to control the peak energy demand, but has a direct impact on customer comfort. Large penetration of FLP homes would greatly simplify the dynamics of loads from homes on the grid. These options are going to be progressively more valuable as the grid evolves to have intelligence, more and different renewable sources with their different generation-shapes and variations, and the upcoming loads from electric vehicles.

The business model emerging from this study of FLP homes is for utilities to develop incentives to strongly encourage builders to build FLP homes, and tariffs to encourage buyers to buy them. Implementation of such tariffs could be coordinated with updated tariffs, such as real-time-pricing, or time-of-use rates to discourage non-FLP, non-ZNE homes. A unique aspect of the proposed development of incentives for FLP homes is that they would be based on value to the utility, rather than a deemed societal-value, making them more sustainable, particularly for investor-owned utilities working to be as cost-effective and profitable as possible.

The actual value of FLP homes to the electric utility is difficult to estimate because the mitigated costs to the utilities are either confidential to the utility or not quantified at this time. Nonetheless, it is possible to make a rational argument for FLP homes being cost-effective, at least in California. Table 1 shows that the current incremental cost is about $22,000, including incentives ($28,000 without incentives). Table 2 provides the estimated value of the peak reduction (estimated to be 3.5 kW) to be $7,000, using a marginal cost for summer peak kW of $2,000/kW[11]. This leaves about $20,000 differential. Moving to the 2013 Title 24 code, which helps with any efficiency upgrades to get a low FLP, is estimated to cost approximately $5,000,[12] reducing the differential to about $15,000. This remainder should be more than compensated by the yet to be quantified value of the remaining benefits in Table 2.

Table 2: Benefits of FLP Home Needing Valuation

Benefit	Value per FLP Home
Peak Reduction 3.5kW	$7,000
No need for Peaker Plants	TBD
Communication with Smart Grid: DR and energy buffering capabilities	TBD
Distribution System Efficiency	TBD
Grid Stability	TBD
Reduced GHGs	TBD
Lower Reserve Margins	TBD
Total	> incremental costs, in volume

Conclusions

This study employed simulations to evaluate electricity load factors in near-ZNE, ZNE, and FLP homes. Load factors are a simple, but accepted measure of distribution system efficiency. The results show that the load factors decrease and go negative as the homes approach ZNE. This implies that large communities of ZNE homes will need larger

[11] Private communication from CA utility manager
[12] Private communication from California Building Industry Association

infrastructure, rather than the implicit understanding that infrastructure can be reduced in ZNE communities. These impacts of ZNE homes are not currently recognized as effecting distribution efficiency; however, if the load factors are correctly predicting reduced distribution system efficiency, as the market moves to ZNE, as California policy is driving it, ZNE design will become an important variable in the design of the local distribution system. An alternative is to design the ZNE communities as FLP as well as ZNE,

The varying demands on the grid currently require spinning reserve and dispatchable power plants. If all homes were FLP homes operating as illustrated in Figure 5, the summer afternoon peak would be gone and the demand would be essentially constant at about 0.5kW. This would eliminate the need for small dispatchable "peaker" plants serving residential communities, saving costs, reducing greenhouse gas production, and likely improving grid stability. Grid fluctuations would be lessened due to local generation coupled with storage and local load management by the FLP's HEMs. Optimally this approach could lessen the required margin or "spinning reserve," that is otherwise mostly wasted. The results of this study show that the wide-spread application of FLP homes could have a very important impact on the grid as a whole, as well as the total amount of energy used by homes. In addition, the benefits of FLP homes to electric utilities could drive a new business model, where incentives are based on improved profits rather than societal benefits.

We are left with the question: Are the remainder of the benefits in Table 2 and discussed in this study worth at least $15,000/home today to utilities, knowing that market acceptance would reduce this cost, probably by at least half, as the FLP market matures? The answer must be a resounding yes, assuming these homes perform as simulations predict. The next steps are careful measurements of distribution systems in ZNE communities, and simultaneous development and evaluation of FLP communities.

References

[APS] Arizona's Energy Future: APS Resource Plan 2009 through 2025 January 2009. http://www.aps.com/_files/various/ResourceAlt/Resource_Plan_-_Presentation_sFinal.pdf

Brown, Richard E, Jonathan G. Koomey. 2002. *Electricity Use in California: Past Trends and Present Usage Patterns*. (LBL-47992)

Ceniceros, Bruce, Vincent, B. 2006 *New Homes with Load Shapes to Make an Electric Utility Drool: How to Integrate Multiple DSM Strategies to Achieve Long Term Energy Performance Goals.* ACEEE Summer Study on Energy Efficiency in Buildings.

Hammon, Rob, Victoria Doyle, Adam Neugebauer. 2012. *Strategies to Eliminate Peak Air-Conditioning Loads*. California Energy Commission PIER Report for Project: PIR-08-021

Huges, Shonder. 1998. *The Evaluation of a 4000-Home Geothermal Heat Pump Retrofit at Fort Polk, Louisiana*. Final Report, ORNL, 1998

Patrick, Dale, Stephen Fardo. 1999. Electrical Distribution Systems, 2^{nd} Edition. Fairmont Press, Lilburn GA

Wiser, Ryan, Ben Hoen. 2011. *Photovoltaic Systems Boost the Sales Price of California Homes*. LBNL Report