7,000 kWh to Zero in Eight Years Flat:

A Strategy for Net Zero Energy Residential Buildings by 2020

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In memoriam

Dr. C. Byron Winn

1933 - 2011

Educator, scientist, solar energy advocate and friend

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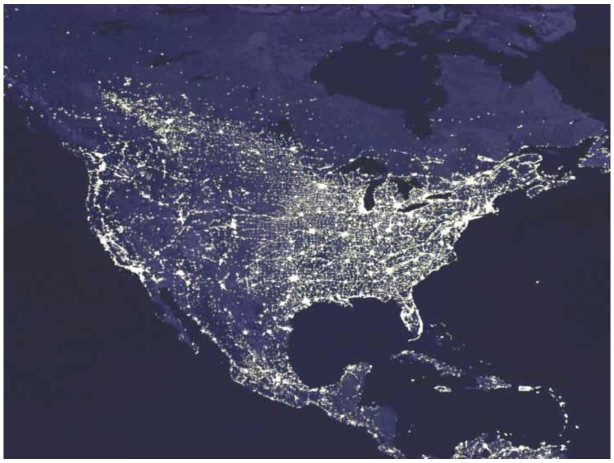

Unquestionably the hand of humanity has reshaped the face of the earth and the biosphere. Satellite images of the earth at night make this self-evident to the naked eye. Satellite imagery in the ultraviolet spectrum illuminates the changes over decades of the ozone layer. Time lapse photography of the ice caps and glaciers and ice cores containing ancient air going back millennia tell a similar story about CO_2 and global warming.

Societies and governments have formed to accomplish what individuals are incapable of doing individually: defend against common threats and promote the common good. These threats may appear invisible: whether it is an enemy across the sea or a microbe in the water or an invisible gas that damages lungs or another gas that heats up the entire planet.

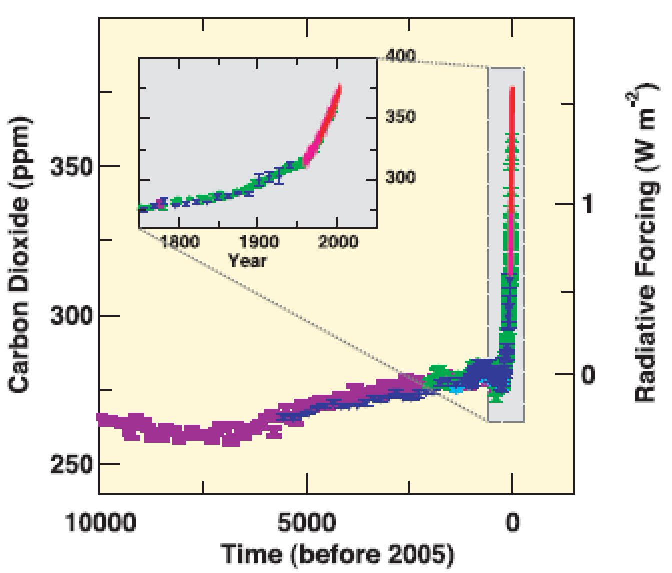

Figure 1: Atmospheric CO2

Societies have successfully responded to these invisible threats. The cholera epidemics that swept through London in the mid 1800's were traced to bacteria in drinking water. At a great expense, the sewer systems and water treatment systems around the world were created to for the common good. Similarly after the smallpox epidemic killed 300 Million people worldwide in the 20th century, a worldwide effort was made to vaccinate all people in any proximity to the virus. The smallpox virus was successfully removed from circulation in the late 1970's.

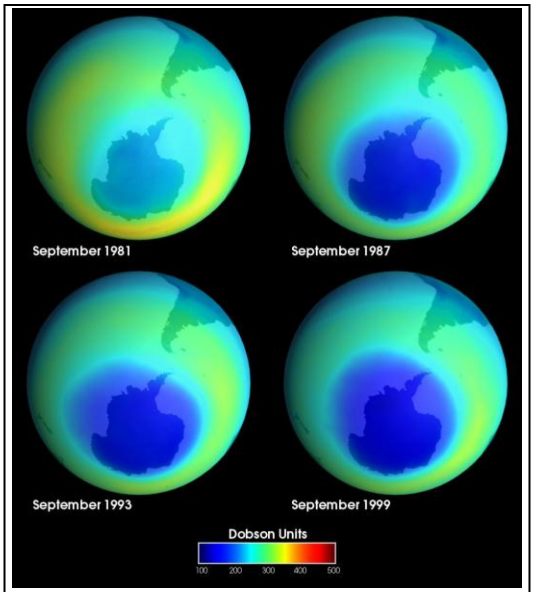

Figure 2: Loss of Ozone Layer

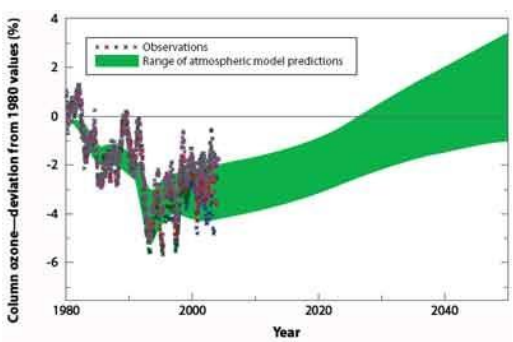

Figure 3: Ozone Recovery

Societies have also risen to the challenge of finding a balance between material progress and environmental protection. An example worth noting is the history of Chlorofluorocarbons, gases used in aerosol cans as propellant and in air conditioning systems as refrigerant. These gases, once released into the atmosphere were destroying the stratospheric Ozone layer at an alarming rate. Loss of the stratospheric Ozone layer was diminishing its protective effect of filtering out most ultra-violet radiation from the sun. Higher levels of ultra-violet radiation result in more skin cancer, and crop damage. An international effort to protect the Ozone layer resulted in the Montreal protocol which has been phasing out chemicals that damage stratospheric Ozone. This effort required a great expense to develop replacement refrigerants and new propellants. However it also spurred innovation in the effected industries. Recent measurements indicate that we have turned the corner on stratospheric Ozone loss and the Ozone layer has been recovering.

With this backdrop of humanity responding to shared threats, the State of California has taken a leadership position on reducing greenhouse gases. Greenhouse gases include Carbon Dioxide is produced when any element containing carbon is burned including any of the hydrocarbons found in coal, oil, and natural gas. As shown in Figure 4, carbon reductions through energy efficiency reduce life cycle expenditure and result in a creation of wealth for society.

When hydrocarbons are burned they also generate a variety of other pollutants which impact human health and agricultural productivity. Thus regardless of one's position of the validity of reducing greenhouse gases to mitigate climate change, pursuing all cost-effective energy reduction measures is a "no regrets" option that increases societal health and societal wealth. With the passage of AB 32 California state government is on record committing state policy to reduce greenhouse gas emissions to 1990 levels in 2020. With this background of a state mandate to reduce greenhouse gas emissions and recognizing that residential and commercial buildings are responsible for 22 % of greenhouse gas emissions, the California Public Utilities Commission has set goals that all new residential construction be Zero Net Energy by 2020 and all new nonresidential construction be Zero Net Energy by 2030.

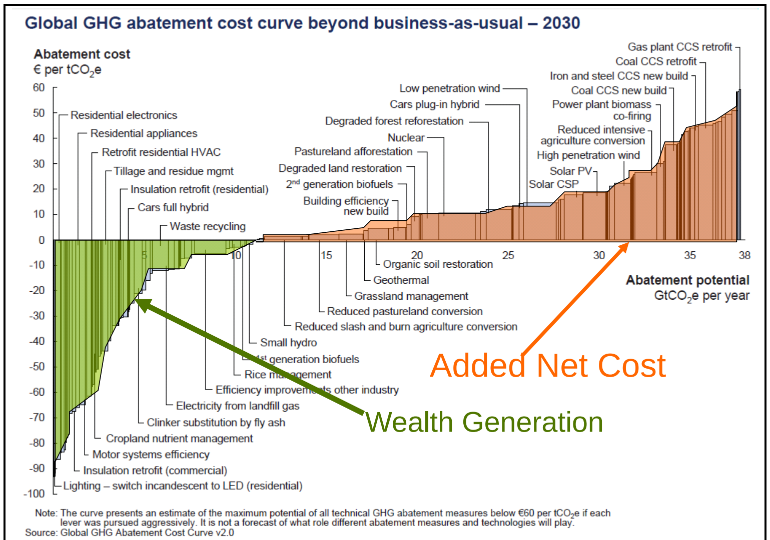

Figure 4: Carbon abatement cost curve (NPV €)

Though the implementation of Zero Net Energy Homes agenda primarily takes place in the business and technology spheres, a successful transition will most likely have its largest impacts in the social and political environment under the rubric that it is possible to prosper while living within one's means. The first step will be energy autonomy of our homes, then of our businesses than then of our transportation infrastructure. If such a vision is implemented California will not only have established its leadership on greenhouse gas reduction but also leadership on a new economic model in world with increasingly valuable fuels and increasingly valuable atmosphere and water. A working model of such a transformation will be in high demand elsewhere.

The time for this transition is now. Interest rates are low so it costs less to invest in technologies that make recurring payments over the long term. New construction activity has been the lowest it has been in 70 years with only 45,000 dwelling units built last year and 36,000 units built the year before as compared to the 1998 to 2007 average construction rate of 148,000 units/yr.

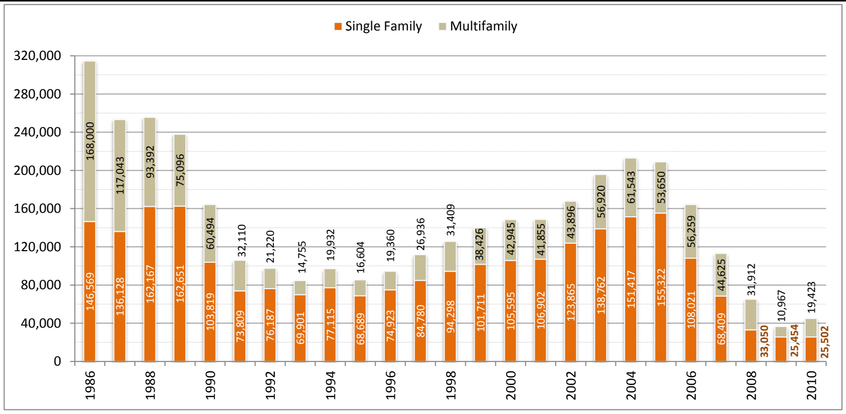

Figure 5: California single family and multifamily housing starts 1986-2010 [1]

Thus this is a prime time to transform the market; an aggressive ZNE program now, over the next three years would cost approximately $630 Million.[2] A similar program with similar market penetration under average market conditions would cost $2.1 Billion[3]. Currently in the middle of this recession, there is an oversupply of photovoltaic production capacity, prices have been dropping precipitously. Efforts now could transform the residential construction market for a lower cost than any time in recent history, help stimulate the housing industry with a clearly superior product (ZNE residences), increase construction employment by approximately 4,000 FTE construction jobs over the long term and place California on the road to a more sustainable economy.

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[1] (CBIA 2011)

[2] Assuming 20,000 multifamily dwelling units and 25,000 single family homes per year, 40% participation and a $5,000/dwelling unit and $10,000/single family home incentive cost and 50% overhead. This is a ballpark estimate to be updated by results from the IOU pilot programs.

[3] Assuming 40,000 multifamily dwelling units and 100,000 single family homes per year over a 3 year period

2. Executive Summary

The CPUC policy directive[4], "*All new residential construction in California will be zero net energy by 2020"* has reset expectations on the levels of energy efficiency and renewables in future residential construction. With hundreds of homes that are zero net energy or near zero net energy, this goal is technically feasible. The focus of this paper is to describe the steps to realize this goal statewide in California. This document is a call to action by all participants in the new home construction market and California policy makers. If California is to achieve the ZNE goal in 8 years, California policy makers must systematically review of all the steps to ZNE and promptly deliberate on which should be adopted, modified or rejected and implement the policy without delay.

1. Create a clear definition of what is a zero net energy (ZNE) home. A proposed definition is, *"A ZNE home is one that has California Whole-House Home Energy Rating of Zero or less."*

Figure 6: A Zero Net Energy Home has a California Whole-House Home Energy Rating of Zero or less.

2. Refine the CPUC policy objective to "All new residential construction in California will be zero net energy <u>or equivalent to zero net energy</u> by 2020." This modification recognizes that even though most situations can be ZNE, there will be sites or situations where ZNE is difficult or even undesirable. This allows for the objective to be achieved without watering down the definition of ZNE.
3. Conduct studies that quantify the benefits and costs of the ZNE policy. Experience has shown that for disruptive concepts like ZNE to take hold, a broad base of support has to appreciate that the potential benefits are worth the disruption and increased first cost of homes. These benefits can be summarized as: cleaner air, increased health, increased wealth (lower life cycle cost), energy

[4] California Public Utilities Commission, California Long Term Energy Efficiency Strategic Plan, September 2008. (CPUC 2008)

security, reduced T&D physical plant but increased control capability, more labor-intensive energy system (more jobs), building energy capital (efficient buildings and renewables) to displace energy liabilities (inefficient buildings and recurring extraction of resources).

4. Create a legislative mandate for ZNE homes. This mandate can be administrative if this is an explicit part of the CARB Climate Change Action Plan as authorized by AB32 or can be in the form of new legislation that specifically mandates ZNE buildings.
5. Improve and update the ZNE new home rating infrastructure. ZNE has value in the market if it is readily recognizable and has consumer confidence. Nothing undermines a green rating more than examples of "green washing" where the rated home does not live up to expectations. The California Whole-House Home Energy Rating must be simple to use, provide reliable results and able to reflect the energy impact of most if not all technologies used to achieve ZNE.
6. Require ratings on existing homes so ZNE homes are differentiated in the market. Existing home ratings can be as simple as an evaluation of energy bills to yield an effective energy score. A home energy rating on the MLS (multiple listing service) provides consumers with a better estimate of the total cost of ownership before they look at the home.
7. Develop a policy and timeline for the widespread deployment of residential on-site renewable energy generation. Evaluate how rate structures can encourage or discourage ZNE homes, such as: feed-in tariffs, relative balance between fixed versus consumption based utility rates, and real time pricing of incoming and outgoing power. Similar issues apply to rate structures for exported power from common areas of multi-family buildings.
8. Set a top-down path to ZNE in the state building code (Title 24) with specific goals for reduced energy consumption achieved though efficiency and increased use of on-site renewable energy. As a first step, require that the 2016 update to Title 24 adopt all cost-effective efficiency measures and to include requirements for on-site renewable generation that is equivalent to the additional savings from cost-effective high efficiency equipment that is prohibited from being a code mandate due to federal preemption.
9. Develop rules for ZNE equivalency that provide credit associated with reduced transportation (location), reduced water consumption, and installation of renewables off-site.
10. Establish reach codes that are easily adoptable by local governments that are motivated to reach ZNE faster. This gives advance notice to industry where the market is going and allows various groups to test out enhanced building standards in advance of their statewide implementation.

11. Since over half of residential electricity consumption is by appliances that are not regulated by the building code, reduce appliance energy consumption through appliance standards, and appliance efficiency incentives.
12. Federal appliance efficiency regulations have placed a cap on the required equipment efficiencies in the California appliance and building efficiency standards. The California delegation to Congress should be taking a leadership position that the federal standards place a floor but not a ceiling on energy efficiency. Learn from other states that have successfully adapted to federal preemption and adopt energy codes that are effectively requiring higher equipment efficiencies.
13. Sponsor forward looking research on new products: characterizing the energy impact of emerging products, design practices, customer acceptance and use. Besides traditional definitions of efficiency also consider how energy consumption information and utility rate structure impacts occupant behavior.
14. Aggressively expand market transformation programs that are designed to market ZNE homes, increase the use of advanced building concepts and commoditize ultra-efficient technologies.
15. Conduct and apply backwards looking research on how well we are characterizing and applying existing technologies, how well appliance and building codes are being disseminated and enforced and identify fixes to shortcomings uncovered.
16. Identify and remove obstacles to energy efficiency. This includes covenants against clothes lines, or even light colored roofs.
17. Identify and quantify the total impact of ZNE on the energy delivery system including licensing and relicensing of power plants, effect on T&D system capacity requirements and how this interacts with likely trends (smart metering, real time rates, smart grid, growth of electric vehicle loads, etc.)
18. Remove regulatory barriers to the use of renewables.

3. A Path to Net Zero Energy Homes

One of the four key objectives of the California Long Term Energy Efficiency Strategic Plan[5] is: "All new residential construction in California will be zero net energy by 2020." This goal is technically possible as there are a number of examples of zero net energy homes as documented by the DOE Building America program. Such homes are typically very efficient (having HERS scores less than 70) and make up the remainder with solar electric, photovoltaic (PV) systems mounted on the home or nearby.

However technical feasibility is not the same as political and economic willingness to pursue a path that requires a significant investment in efficiency and renewable resources. If zero net energy is considered an "aspirational goal" and not a policy goal, it is doubtful that much progress will be achieved. The following sections outline the steps required to implement the directive to assure all new homes are net zero by 2020, approximately how much it would cost and the benefits that such a strategy would provide.

3.1. More Specific Definition of ZNE

The official California Public Utility Commission (CPUC) definition of Zero Net Energy was an integral part of the Big Bold Energy Efficiency Strategies (BBEES) as contained in the Long Term Energy Efficiency Strategic Plan (CPUC 2008)[6] :

> *A ZNE home employs a combination of energy efficiency design features, efficient appliances, clean distributed generation, and advanced energy management systems to result in no net purchases of energy from the grid. The CPUC has defined "Zero Net Energy" at the level of a single "project" seeking development entitlements and building code permits in order to enable a wider range of technologies to be considered and deployed, including district heating and cooling systems and/or small-scale renewable energy projects that serve more than one home or business.*
>
> *WHAT IS ZERO NET ENERGY?*
>
> *Zero net energy is a general term applied to a building with a net energy consumption of zero over a typical year. To cope with fluctuations in demand, zero energy buildings are typically envisioned as connected to the grid, exporting electricity to the grid when there is a surplus, and drawing electricity when not enough electricity is being produced.*
>
> - *The amount of energy provided by on-site renewable energy sources is equal to the amount of energy used by the building.*

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[5] California Public Utilities Commission, California Long Term Energy Efficiency Strategic, September 2008. (CPUC 2008)

[6] Section 2 – Page 13. (CPUC 2008).

- *A ZNE building may also consider embodied energy – the quantity of energy required to manufacture and supply to the point of use, the materials utilized for its building*

From discussion with CPUC staff, the definition of Zero Net Energy was necessarily ambiguous; this plan had details to be worked out and the definition of ZNE was one of them. Nonetheless the concept of ZNE has captured the imagination of many people and has been a game changer in terms of long term expectations. The CPUC initial definition had the following key components and ambiguities:

- A ZNE home is very efficient and reduces energy consumption enough so that the total energy consumed results in no net energy consumption from the "grid."
- Amount of energy used by the building is equal to the amount of energy produced by on-site renewable generation.
- On-site renewable generation is defined as generation that is part of the "project" seeking development entitlements.
- This definition is silent on whether all sources of energy are to be included (does this included natural gas and other fuels?) and what is the metric for comparing between natural gas imported and on-site renewable energy (typically electricity) exported.

In defining Zero Net Energy there are two major audiences:

- A policy audience that includes the California state agencies that are entrusted with carrying out the environmental and energy directive of the state legislature and the governor: California Air Resources Board (CARB), the California Public Utilities Commission (CPUC) and the California Energy Commission (CEC).
- The general public. The general public must "vote with their wallets" in purchasing ZNE homes and the concept must be easy to understand and recognizable public good. If the public does not accept the value of ZNE, the public policy cannot be sustained.

Key to defining a definition of ZNE is whether there is a compelling advantage to defining Zero Net Energy in the same manner of other states or even other countries. With a single definition it is easier to reap the benefits of economies of scale from a national ZNE program. Builders who operate in multiple states could make use of the same materials describing a ZNE home. The United States is characterized by its population being fairly mobile, a nationwide ZNE "brand" would benefit from efforts in other states having spill over into California and vice versa.

Having a definition of ZNE that resonates with the general public's basis understanding of the concept is very important. What message is most important and most likely to motivate purchase of a ZNE home?

- A ZNE home is "carbon neutral"

- A ZNE home results in no utility bills or at least low utility bills

- A ZNE home consumes no more energy at the meter than it produces with PV
- A ZNE home consumes no more energy at the power plant than it produces with PV

California not only has a policy to reduce energy consumption but also to minimize peak demand. Peak electrical system demand is what drives the building of additional power plants and the sizing of the transmission and distribution system. Minimizing peak electrical demand also helps reduce greenhouse gas emissions. During times of peak demand, the cost rises and power generators operate their least efficient power plants which emit more carbon per unit of electricity generated. Historically valuing peak demand has been difficult as it has been hard to identify without an understanding of the entire electrical system and a detailed costs of serving peak demand. The State of California has done this since the 2005 Title 24 standards though the concept of Time Dependent Valuation (TDV).

This report proposes that the basis of trade-offs in determining ZNE be based on TDV, which we are calling the Societal Cost of Energy. The rationale for this nomenclature is described in Section entitled *Societal Cost of Energy (TDV) definition of ZNE*. The next couple of sections describe other competing metrics for defining ZNE and the pros and cons of these other metrics.

Source Energy definition of ZNE

Source energy is similar to TDV in that different energy sources are valued differently. Until the introduction of TDV, trade-offs in California's Title 24 building efficiency standards were based on a 3 times source energy multiplier for electricity so that a kWh of electricity was considered to be equivalent to 10,239 Btu.[7]

The residential performance approach of the 2009 International Energy Conservation Code (IECC) allows either source energy or energy cost as the basis for performance trade-offs. If source energy is used then electricity has a source energy multiplier of 3.16 and natural gas has a source energy multiplier of 1.1 [8]

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[7] Source multiplier of 3 times the unit conversion of 3.413 Btu/kWh = 10,239 Btu/kWh. See *Table 1-B—Source Energy Conversion Rates*, Section 102 – Calculation of Source Energy Consumption. 2011 Title 24, Part 6 Building Efficiency Standards. http://www.energy.ca.gov/title24/archive/2001standards/2001-10-04_400-01-024.PDF

[8] **405.3 Performance-based compliance.** Compliance based on simulated energy performance requires that a proposed residence (*proposed design)* be shown to have an annual energy cost that is less than or equal to the annual energy cost of the *standard reference design.* Energy prices shall be taken from a source *approved* by the *code official*, such as the Department of Energy, Energy Information Administration's *State Energy Price and Expenditure Report. Code officials* shall be permitted to require time-of-use pricing in energy cost calculations.
Exception: The energy use based on source energy expressed in Btu or Btu per square foot of *conditioned*

The European Union has adopted the Energy Performance of Buildings Directive which requires that "by 31 December 2020, all new buildings are nearly zero- energy buildings." Net Zero buildings for the European Union are defined as follows (EU 2009):

> *"... a net zero energy building is where, as a result of the very high level of energy efficiency of the building, the overall annual primary energy consumption is equal to or less than the energy production from renewable energy sources on site".*

Note that the metric of interest is "primary energy" another term for source energy. This metric recognizes that it takes several times more units of fossil fuel energy to generate one unit of electrical energy delivered at the site. Even fossil fuels delivered on site may have an adder to account for the energy required for processing, storage and transportation. Within the European Union there are different source energy multipliers as different EU member countries have different mixes of electricity generation.

As a result, though source energy is used by many rating organizations including the EU and ResNet,[9] the source energy multipliers differ so the ratings will not be directly comparable. The policy intention is similar which is to value different sources of energy differently based upon their total use of non-renewable energy.

An example, if site energy were used instead of source energy, this might give the incentive to use electric resistance furnaces instead of natural gas fired furnaces as the thermal efficiency of an electric resistance furnace is essentially 100% while a standard natural gas furnace has a thermal efficiency of around 80%. The site energy metric would credit the electric furnace for using less energy even though a little more than 2 times as much energy back at the power plant (and approximately twice as much emissions as from a thermal plant) was used to generate the electricity that served the furnace.

The source multiplier for electricity is a function of the mix of generation resources used in generating electricity and the losses incurred in transportation. These values could get complex as each utility might want to have their own source energy multiplier.

The pros for basing ZNE on source energy are:

- Source energy is used by many rating systems in North America and in Europe

floor area shall be permitted to be substituted for the energy cost. The source energy multiplier for electricity shall be 3.16. The source energy multiplier for fuels other than electricity shall be 1.1. http://publicecodes.citation.com/icod/iecc/2009/icod_iecc_2009_4_sec005_par002.htm

[9] ResNet values natural gas in electricity units by assuming that it would be otherwise burned in a combined cycle gas turbine with an overall efficiency (including T&D) of 40%. Inverting this one can see that the relative value of electricity is 2.5 units of gas for each comparable unit of electricity. Personal communication with Philip Fairey, FSEC.

- The calculation can be quite simple with different multipliers for the few energy sources typically used in homes
- Provides an appropriate signal for using lower thermodynamic quality energy sources (gas versus thermally generated electricity) for heating.

The cons for basing ZNE on source energy are:

- There can be as many source energy multipliers as there are utility companies. These multipliers will not be universal and thus the rating will not be universal.
- Source energy multipliers could change over time. As an example, the California utilities will be required to have at least 33% of their electricity generation mix to be from renewable energy, as a result one would expect their source energy multiplier to decrease. This could be addressed by using a long term forecast to create the source energy multiplier.
- Values natural gas less than electricity, perhaps not appropriate signal if medium term goal is to replace all fossil fuels with solar generated sources.
- Source energy ignores the fact that peak electrical demand results in higher emissions per kWh of electricity produced (higher heat rate) as less efficient power plants are brought on line during peak periods. Peak electrical demand is what drives the investments in power plant capacity and T&D capacity and thus has a huge financial and societal cost.

Site Energy

"Site" energy was also considered as it is clearly defined. However, electricity and natural gas are sold in different energy units and these energy sources have different source energy content, environmental impacts and costs. The thermodynamic quality of electricity is higher than natural gas. Unit for unit electricity can heat more (including combustion losses), light more, and create more motive power. A ZNE definition based on site energy sets the bar significantly higher for homes with gas space heating and gas water heating (90% of our building stock). As shown in Figure 7, for a home that was able to reduce Title 24 Part 6 loads by 15% each code cycle, the costs of a photovoltaic (PV) system sized for the site energy definition of ZNE would be twice the size of a PV system sized to meet the societal cost definition of ZNE.

An argument for using a site energy definition is that it is simpler to use and more closely matches what the consumer receives on their energy bill. However, in the California (and the rest of the US electricity is sold in units of kWh and natural gas in units of therms or ccf (hundred cubic feet).

Current new buildings	PV kWh	PV kW	PV Cost $/house	First Cost $ Million/yr
Site energy ZNE	17,501	11.7	$52,502	$5,250
Source energy ZNE	10,264	6.8	$30,791	$3,079
Societal Energy ZNE	8,056	5.4	$24,168	$2,417
(Elec) Grid neutral	6,645	4.4	$19,935	$1,994
48% reduction T-24 (4 cycles 15% reduction)	**PV kWh**	**PV kW**	**PV Cost $/house**	**First Cost $ Million/yr**
Site energy ZNE	11,581	7.7	$34,744	$3,474
Source energy ZNE	7,324	4.9	$21,972	$2,197
Societal Energy ZNE	5,835	3.9	$17,505	$1,750
(Elec) Grid neutral	5,195	3.5	$15,586	$1,559
66% reduction all end-uses	**PV kWh**	**PV kW**	**PV Cost $/house**	**First Cost $ Million/yr**
Site energy ZNE	5,834	3.9	$17,501	$1,750
Source energy ZNE	3,421	2.3	$10,264	$1,026
Societal Energy ZNE	2,685	1.8	$8,056	$806
(Elec) Grid neutral	2,215	1.5	$6,645	$665
Elec vehicle extra	3750	2.5	$11,250	$1,125

Figure 7: PV Cost Implications of different ZNE definitions with low PV price estimate ($4.50/W)

Thus when we are interested in a single energy value, conversions have to be made between electricity and natural gas. Developers of energy codes have struggled with trade-offs of different fuels for years. Both the Title 24 and ASHRAE 90.1 building energy efficiency standards settled on an energy cost basis for making trade-offs between electricity and natural gas. ASHRAE 90.1 has ECB (energy cost budget) and Title 24 has TDV (time dependent valuation - where valuation was in present valued dollars). Electricity cannot be easily stored and the cost of electrical infrastructure is based on serving the top few hundred hours of loads. A site energy metric also does not capture the societal impact of peak demand and the resources required to meet these peaks.

Since the combustion losses occur back at the power plant for electricity generation, a site energy comparison of natural gas combustion versus electric resistance heating would treat electric resistance heating as using less site energy and thus less energy intensive for the purposes of a ZNE definition using site energy. This is contrary to California state policy which recognizes the increased resource impact from electric resistance heating and discourages its use.

Embodied Energy and Transportation Energy

Some have called for the ZNE concept to be all inclusive and to value not just the operational energy of the building but also the embedded energy in all products in the building and the embedded energy in water consumption. Some have called for going even further and including the building's site as part of its embedded energy – those buildings built near bus and rail lines and are in walkable neighborhoods having less transportation energy than those on the edge of urban sprawl.

Energy embodied in building materials

The classic report on this topic Energy Use for Building Construction (ERG, Hannon & Stein 1976), calculated the direct and indirect energy use embodied in building materials. The result of this analysis is that there are huge amounts of energy embodied in building materials. As an example, residential homes are calculated to contain approximately 700,000 Btu/sf of embodied energy, or for a 2,000 sf house 1,400 Million Btus. In comparison a modern California home consumes approximately 110 Million Btu/yr of source energy. Thus the embedded energy in building materials is comparable to approximately 13 years of operational energy. More recent studies indicate that the embodied energy for homes could be twice as high. (RMIT 2001)

Thus accounting for embodied energy would put the home approximately 13 years "in the hole" in terms of offsetting the embodied energy of constructing the home in the first place. Another way to think about this is to assume that a photovoltaic system has a life span of around 30 years. Considering that a typical PV (photovoltaic) system generates approximately 1,500 kWh/yr for each kW peak capacity, the amount of renewable generation to offset the embodied energy in a 2,000 sf home over 30 years would require an additional 3 kW of PV using a source energy multiplier of 3. Even if we assume that the installed costs will drop to the level of costs in Germany where the installed cost is around $4.50 per watt, this would require approximately an additional $14,000 investment to say one was zero net energy including embodied energy.

In addition, calculating embodied energy is not a simple task if one is trying to differentiate between different products and tracking things such as the source of all of their components. In addition, there is the added complexity of what is true embodied energy when one includes the projected longevity of building components.

Virtually all of the people interviewed about whether or not ZNE should include embodied energy responded that embodied energy should <u>not</u> be included in the definition of ZNE.

Energy embedded in water

The energy expenditure in delivering, treating, distributing water and finally treating waste water are significant. As the CEC (2005b) notes: *"water-related energy use consumes 19 percent of the state's electricity, 30 percent of its natural gas, and 88 billion gallons of diesel fuel every year – and this demand is growing."* Table 1 illustrates that the embedded energy in water is significantly different depending upon what part of the state the water is being used. However, the supply of potable water is diminishing and the need is growing. Thus the embedded energy cost in water is but a fraction of the value of water and a fraction of the value associated with saving water.

Table 1: Embodied Energy in Water Supply and Treatment (CEC 2005b)

	Northern California kWh/Million gallons	**Southern California kWh/Million gallons**
Water Supply and Conveyance	150	8,900
Water Treatment	100	100
Water Distribution	1,200	1,200
Wastewater Treatment	2,500	2,500
Total	**3,950**	**12,700**
	kWh per typical dwelling unit (@100,000 gal/yr)	**kWh per typical dwelling unit (@100,000 gal/yr)**
Embodied Energy consumption per dwelling unit (kWh/yr)	395	1,270

What is worth noting here is that in Northern California, energy consumption for wastewater treatment is over half of the total embodied energy. What this indicates is that the use of graywater (watering one's garden with water discharged from sinks and showers) not only saves the embodied energy associated with the need for less potable water for landscaping but has an even larger embodied energy impact associated with reduced water sent to the sewer.

Currently, the average newly built home in California consumes approximately 6,600 kWh/yr. Assuming that a typical home consumes approximately 100,000 gallons per year of water (2/3s indoor and 1/3 outdoor), the embodied energy associated with water consumption is approximately 6% of total home energy consumption in Northern California and 19% in Southern California. Though most people recognize that water consumption is a serious issue for California, when we asked whether the embodied energy in water consumption should be included in a definition of Zero Net Energy, the overwhelming majority said no, this should not be part of the definition of ZNE.

Energy embedded in site or location (Transportation)

As shown in Figure 8, under levels of fleet efficiency (25 mpg) on would expect within the next decade, one would have to reduce the energy consumption of single family homes (including appliances) by 50% to match the type of source energy savings that result from locating the home in a transit oriented development (TOD) with higher housing densities, access to mass-transit and that are pedestrian and bike friendly. This transportation savings is in comparison to conventional suburban development (CSD) with lower housing densities which may not have any access to mass transit, and any retail within walking distance.

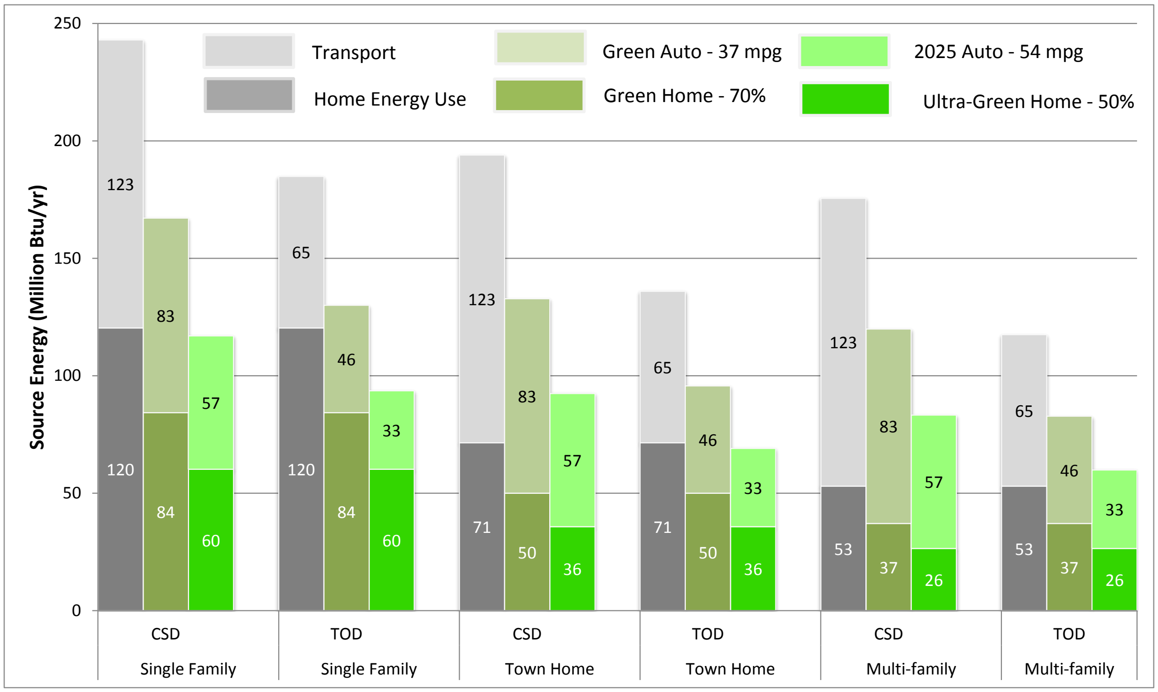

Figure 8: Building and Transportation source energy consumption for Conventional Suburban Developments (CSD) and Transit Oriented Developments (TOD)

These values were calculated using the vehicle miles traveled per household (VMT/Hh) in Holtzclaw et al. (2002), where the CSD VMT/Hh is one standard deviation above the average in Los Angeles and San Francisco and the TOD VMT/Hh is one standard deviation below the average. Average VMT/Hh is 24,500 mi/yr for conventional suburban developments and 11.600 mi/yr for transit oriented developments. In TOS developments, each household is commuting 3.000 mi/yr by public transit which only consumes 2,184 Btu/passenger-mile. Much of the analysis here in Figure 8 builds off of the methodology and presentation of Jonathan Rose Companies (2011) but this analysis is based on California residential source energy consumption whereas the Rose building analysis was based on US site energy consumption.

Figure 9 takes the energy results from the energy comparison and applies the cost of energy to illustrate that transportation is currently our largest energy expenditure and living in transport oriented developments substantially reduces energy costs. Gasoline at $4/gallon costs $32/MMBtu as compared to $9.45 per MMBtu for natural gas.[10] Site electricity at $0.153/kWh[11] costs $44/MMBtu but this is $15 per source MMBtu.

[10] 2010 California average residential natural gas cost per mcf. http://www.eia.doe.gov/dnav/ng/xls/NG_PRI_SUM_DCU_SCA_M.xls

[11] California average residential electricity price for 2011. Table 5.6.B. *Average Retail Price of Electricity to Ultimate Customers by End-Use Sector, by State, Year-to-Date through January 2011 and 2010*. http://www.eia.doe.gov/cneaf/electricity/epm/epmxlfile5_6_b.xls

Transportation Cost and Energy Cost at $4 per gallon and $2 per ride public transport, does not include cost of parking or incremental cost of maintenance or insurance with increased mileage. Annual transport savings between CSD and TOD is twice that of transition from standard single family home to one that saves 30% of total energy consumption. The differential is only greater for other building types.

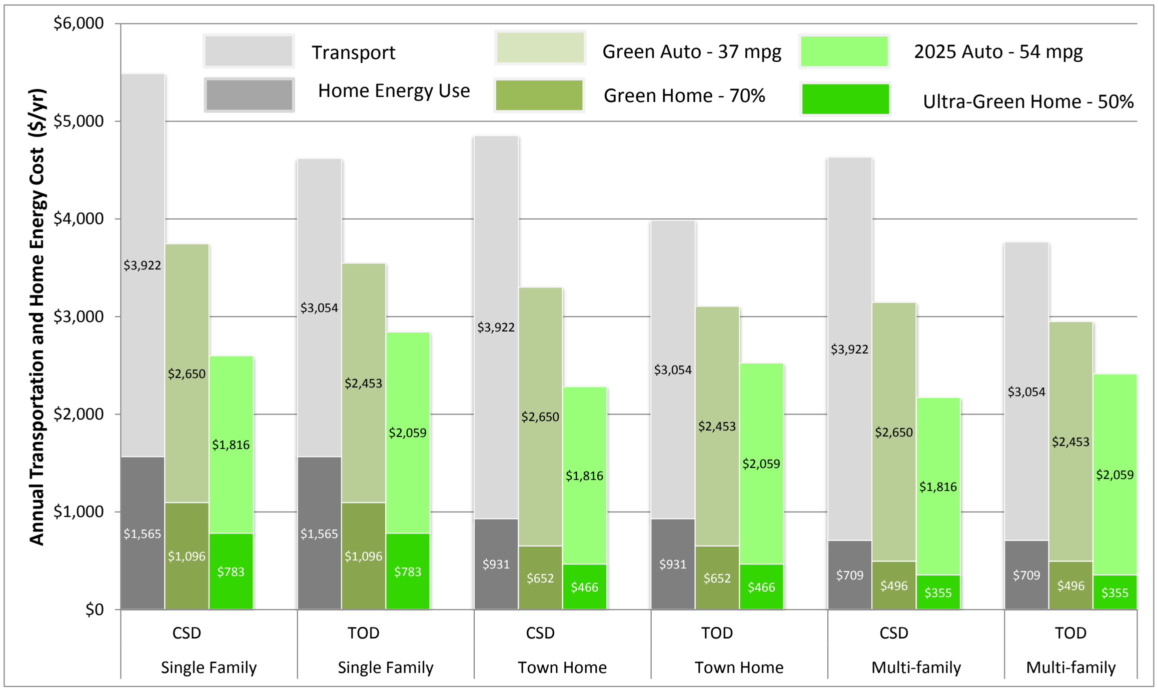

Figure 9: Annual Building and Transportation energy cost for Conventional Suburban Developments (CSD) and Transit Oriented Developments (TOD)

As cars become more efficient, the operating cost decreases to the point where mass transit becomes more expensive unless one starts internalizing the societal costs of maintaining the road and highways and more complete evaluation is conducting including investment costs and maintenance costs. The ultimate conclusion of this exercise is that we need to increase the location efficiency of developments and the energy efficiency of our building stock.

Though the embedded energy would significantly set the bar higher, the advocates of this definition suggest that the policy goal be reset to "50% of total ZNE including embedded energy." ZNE is a transformative concept that is not quite captured by "near ZNE." There have been calls to set the bar even higher for ZNE buildings where it is based on a site energy definition or inclusion of other indirect forms of energy consumption associated with buildings. These higher standards for ZNE run the risk of the goal being unattainable and the goal becomes "aspirational" or "advisory" i.e., with no teeth and no hard policy milestones.

If the state of California wants to hit the 2020 target for buildings, we should start with ZNE being based on the energy consumed by use of the building. Once the State of California has clearly hit this target, then it is reasonable to start considering the additional energy consumption due to 1) embodied energy, 2) the energy costs of water, 3) transportation, and 4) other services. These important other forms of energy consumption should also be addressed in other venues, such as product life cycle assessment and enhanced water conservation in CALGreen,[12] and transportation planning in CEQA.[13] As will be discussed in a later section, the concepts of location efficiency and embedded energy are critical elements of a policy requirement that all new homes be zero net energy <u>or equivalent</u>.

Societal Cost of Energy (TDV) definition of ZNE

If one were to develop a definition of ZNE based on Societal Cost of Energy this would require the least change to how energy is currently valued and tracked for a number of policy arenas. In this case, we are using the term Societal Cost of Energy to be another name for Time Dependent Valuation (TDV) which is used by the California Energy Commission as the basis of energy trade-offs in the Title 24 building efficiency standards and a similar concept is used by the California Public Utility Commission to evaluate the cost-effectiveness of energy efficiency programs operated by the Investor Owned Utilities (IOUs). The California Whole-House Home Energy Rating is also based on TDV.

TDV is essentially a long term forecast of the value of energy based upon the costs of providing energy to the end-user; this includes energy commodity costs, transmission and distribution costs. TDV values electricity costs during times of electrical system peak demand (typically hot summer weekday afternoons) as capacity and energy costs are highest during these times. Similarly natural gas and propane costs are more expensive during the winter than the summer. Recently the estimated long term cost of carbon has been added to the TDV values. As a result, TDV can be thought of as the societal cost of energy.

Though TDV was developed in terms of the present value of energy over a long period of time, the Title 24 use of TDV divides these values by the average of cost of natural gas so that the units of energy consumption are in terms of kBtu (thousand British thermal units). On average the cost of one energy unit of electricity is 3.8 times higher than an energy unit of natural gas; thus electricity is valued more per unit of energy than natural

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[12] *California Green Building Standard (CALGreen)* California Code of Regulations Title 24 Part 11. http://www.bsc.ca.gov/CALGreen/default.htm

[13] As required by SB 375 Steinberg. Statutes of 2008, "Transportation planning:" http://www.leginfo.ca.gov/pub/07-08/bill/sen/sb_0351-0400/sb_375_bill_20080930_chaptered.pdf

gas.[14] Because electricity cannot be stored easily and peak demand dictates the sizing and thus the cost of electrical distribution, electrical costs vary by a factor of 20 to 1 (2,000%), whereas the long term costs of natural gas fluctuates within a given year by a relatively modest 30%.

TDV is a powerful policy tool because it has been able to quantify the long term cost impacts of energy decisions. It is able to make trade-offs between different fuels and trade-offs between energy savings and demand reductions. But since the value of energy varies on an hourly basis, it is not straight forward for the general public to calculate TDV unless they are using one of the California energy code or California home energy rating tools. There is no TDV anywhere else so it is hard to compare a zero TDV home in California with a similar home in any other state. The analytic power of TDV can also be a curse since it is hard to describe TDV in simple terms for the general public. The simplest description is that it represents the societal cost of operating the home over 30 years, - this concept is muddied by presenting TDV in terms of TDV kBtu energy units. This is described in more detail in Appendix E: Societal Energy Cost (Time Dependent Valuation of Energy or TDV) or in the description of TDV on the CEC website. (E3, 2011)

The pros for basing ZNE on Societal Cost (TDV) are:

- TDV based energy code performance method calculation tools and California Whole-House Home Energy Rating tools already exist. TDV is currently the basis of these ratings. ZNE would be just a 0 rating on the California Whole-House Home Energy Rating or Title 24 performance method compliance results.
- Compatible with current policy objectives that include demand reduction and valuing carbon reductions
- TDV is able to value the trade-offs between on-site renewable energy exports and delivered electrical and natural gas from the utility distribution system.

The cons for basing ZNE on TDV are:

- Harder to explain to the general public
- Requires hourly energy results to calculate. Would not be readily calculated from an energy bill
- No comparable system of energy valuation in any other state or other country.

The main arguments against time dependent valuation is that it is hard to explain to the general public and it is hard to calculate. The hard to calculate concern is handled by the pre-existing California Whole-House Home Energy Rating software and the Title 24 performance method software that conducts these calculations “under the hood” of these

[14] CEC, 2013 TDV factors version 3

software without user intervention. If ratings for homes were automated using billing data it is conceivable that TDV information could also be available to every customer that has a “smart meter” which is collecting consumption data on an hourly basis. Thus every home could have an updated societal cost rating of their home at any time they went on-line to check on their energy consumption and energy bill. Ideally this would also be compared to benchmark data for homes in the same area of a similar vintage.

The term time dependent valuation was coined while we were developing a new energy valuation methodology to replace source energy that was the earlier basis to the Title 24 standards. The old source energy value was based on a constant value of electricity and natural gas. The new TDV’s were time varying and thus time dependent valuation described the difference between the new values and the old source energy values. TDV as a term communicates that the values vary with time; however it doesn't indicate that the valuation is cost based or that it contains a valuation of Carbon.

Societal cost of energy includes energy cost, the cost of infrastructure (demand), the cost of overhead and profit and an approximation of the societal cost of carbon. Ultimately the shorthand description of TDV is that it values energy based on policy decisions of societal value. Thus for the purposes of explaining the California Whole-House Home Energy Rating, I recommend that the rating is described as making trade-offs between electricity and gas imports and electricity exports in terms of societal cost.

Onsite renewable energy

The question was raised whether it was acceptable if an owner could purchase Renewable Energy Credits (RECs) in lieu of generating their own on-site renewable energy. Renewable Energy Credits are tradable certificates of the renewable energy sources. Often an owner of a renewable energy source will sell their renewably produced power into the wholesale electricity market and then separately sell the renewable energy certificates into a separate market that is selling these certificates to people who need these credits for a renewable portfolio standard, for Green Building certification or potentially to be called Zero Net Energy.

The consensus from interviews we conducted for this paper and from a CPUC sponsored definitions roundtable was that RECs should not be allowable method of designating a home, as zero net energy, but that other more dependable offsets would be available. However as discussed below, the concept of “equivalence” may resolve all of these issues.

Also the consensus was that renewable does not include “geothermal” heat pumps or solar thermal domestic water heating as a renewable resource. Geothermal heat pumps, solar domestic water heating, solar driven absorption cooling, etc., all reduce energy consumption on-site and reduce needed imports of energy from off-site. But currently, these sources cannot usefully export energy off-site and are treated as energy efficiency measures.

A ZNE building must export as much societal value of on-site renewable energy as was imported. At this time, the only form of on-site renewable energy we can envision being exported is electricity, and thus on-site renewable energy exports would be in the form of photovoltaic-generated electricity, solar-thermal generated electricity, micro-hydro generated electricity or wind-generated electricity injected back into the grid. Biofuels, fuel cells and landfill gas would not be included as an on-site renewable resource, as they results in local emissions and are not renewable in the sense of the useful energy transformation of local solar and wind energy.

Recommended definition of ZNE

"A ZNE home is one that has California Whole-House Home Energy Rating of Zero or less."

Underlying this definition is that:

A ZNE home is one for which the *societal value of energy* consumed by the building over the course of a typical year is less than or equal to the societal value of the *on-site renewable energy* generated.

Where,

Societal value of energy	=	the long-term projected cost of energy including the cost of serving peak demand and varies from hour-to-hour to account for peak demand and other fluctuating costs including projected costs for carbon emissions, e.g., the time dependent valuation (TDV) of energy
Building	=	The contiguous property "receiving development entitlements and building code permits.", e.g., a single building, or set of buildings on one site, such as a housing development, multifamily building, campus, etc.
On-site	=	On-site is defined for new construction as located on the property for the "project receiving development entitlements and building code permits."[15] For existing buildings we define on-site as "located on the contiguous property under control of the building owner."
Renewables	=	Photovoltaic-generated electricity, solar-thermal generated electricity, micro-hydro generated electricity and wind-generated electricity

[15] (CPUC 2008)

3.2. CPUC Policy Objective of ZNE or Equivalent

In interviewing a number of key stakeholders about a definition of Zero Net Energy, there was the recurring theme of modifying the common sense definition so that definition would be compatible with the CPUC policy goal of all new homes being ZNE by 2020. The simple common sense definition of a ZNE home is one that is extremely efficient and has either roof mounted PV or a small wind turbine on site generating enough power in a year to serve the remaining loads. Examples where ZNE equivalent is not feasible includes:

- Building a home in the shade of a 300 year old tree.
- Building an infill project which is shaded by surrounding buildings
- A high rise multi-family project which does not have enough roof space to provide sufficient on-site renewables

Redefining the 2020 Zero Net Energy goals in terms of "ZNE or equivalent" helps address all of the concerns about exceptions to the ZNE rule. Not every building can be ZNE, but every building can be ZNE equivalent. Thus the policy must have flexibility for all applications and have a method of offsets or equivalency so the net energy outcome is still preserved. However, a "ZNE equivalent" building should not have the bragging rights of being called ZNE, as that would weaken the brand and value of ZNE for all the people who are making buildings that are truly ZNE. In fact the "ZNE equivalent" building would be one that met the requirements of the 2019 Title 24 energy code by some other means than being ZNE.

Our initial thought on equivalency is that it would take the form of paying for the installation of a new renewable energy system on another California building.[16] By making sure the residual energy consumption is served by systems on a building site, we help assure that one of the other objectives of the BBEES is accomplished, i.e., the volume of on-site installed renewables systems are large enough to maintain the economies of scale that are driving down system costs.

Many issues would have to be carefully considered as the state gets closer to the development and adoption of the 2019 Title 24, part 6 standards. For example, conditions that would allow equivalency via off-site renewables, details around geographical location and the timing of construction for qualifying off-site renewables systems. We expect that implementation of many of the intermediate steps towards the realization of ZNE goals will help inform the rules on ZNE equivalency.

Equivalency may also include concepts such as providing credits for equivalent reductions in transportation energy, embodied energy and other considerations. If

[16] TDV allows for accounting of equivalency at any location in California; however, there are likely to be policy reasons for restricting the location of the alternative renewable energy system.

equivalency is adopted by the State agencies as part of the plan for the 2019 Title 24, research needs to be undertaken now to help develop the rule sets for calculating equivalency.

The concept that by 2020 all new residential construction is Zero Net Energy or equivalent, builds on the existing framework of the Title 24, part 6 building energy efficiency standards. The building efficiency standards have a prescriptive path which assures compliance as long as all requirements are met. The building efficiency standards also allow the prescriptive approach where a building simulation is conducted on the proposed building design; if the proposed building is simulated as using less energy that a similar building complying with all of the prescriptive requirements, the proposed building satisfies the building efficiency regulations. Thus the ZNE building is analogous to the prescriptive requirement and the equivalent portion of the proposed ZNE policy is analogous to showing compliance using the performance approach.

3.3. Quantify benefits and costs of the ZNE policy.

The Zero Net Energy strategies are a key part of the CPUC Long Term Energy Efficiency Strategic Plan (CPUC 2008), and the CEC & CPUC joint Energy Action Plan (CEC, CPUC 2008). ZNE strategies have reset the goal for bringing the benefits of increased energy efficiency to the state of California. These strategies are intended to help achieve the goals as written into the AB32 (Global Warming Solutions Act). However currently there is no legislation[17] that formalizes the ZNE policy thus this policy is an interpretation of the authority granted to state agencies by AB32. Public support for the policy has to be developed. In a nutshell the questions will likely boil down to: how much will it cost and what are the benefits for me?

Zero Net Energy is a disruptive concept as it requires up front investments for on-site energy production and changes the operation and purpose of the electricity grid from a one way provider of electricity to a storage medium and load scheduling mechanism.

Builders are nervous about change after the housing bubble has decimated the industry, they are concerned that zero net energy buildings cost more build yet the prices they can charge for housing is set by the existing buildings stock – half of which was built before there was any energy code. Developers are concerned that rules for ZNE may place added restrictions on how many houses can be placed on a piece of land and limit the houses that do not have good access to renewable resources (wind and sun). Realtors are wary of anything that slows down the real estate transaction, liability associated with any claims about the building (why aren't my bills zero?), and efforts to require an energy rating at time of sale. Utilities are concerned that sales of their product could be

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[17] Passage of AB2112 "ZNE Homes" would have given explicit authorization of the ZNE policy. See *Appendix G: Text from AB 2112 (Saldana/Lieu) ZNE Homes*

diminished while being required to pay a retail price for excess renewable electricity sold by homeowners.

Experience has shown that for disruptive concepts like ZNE to take hold, a broad base of support has to appreciate that the potential benefits are worth the disruption to a number of industries and increased first cost of homes.   These benefits can be summarized as: cleaner air, increased health, increased wealth (lower life cycle cost), energy security, reduced T&D physical plant but increased control capability, more labor-intensive energy system (more jobs), building energy capital (efficient buildings and renewables) to displace energy liabilities (inefficient buildings and recurring extraction of resources).

Cleaner air

In addition to the wealth created by more efficient use of energy, a key motivation for energy efficiency programs has been to reduce the environmental impacts associated with energy production. ZNE homes combine the environmental benefits of reduced energy consumption with the benefit of a relatively benign source of electricity, solar energy. Though there has been a significant amount of progress and controversy around California's policy decision to reduce greenhouse gases, there is a significant side benefit of reducing combustion emissions, they also other air pollutants besides CO2, such as ground level Ozone and particulates.

California's ground level Ozone problem

As shown in Figure 10, over half of California's counties do not comply with the US government's ambient air quality standard for ground level Ozone. In addition, most of the central valley and the LA basin are designated as having "extreme" or "severe" Ozone pollution problems[18].

[18] Extreme Area has a design value of 0.187 ppm and above. Severe Area has a design value of 0.127 up to but not including 0.187 ppm. http://www.epa.gov/airquality/greenbook/define.html

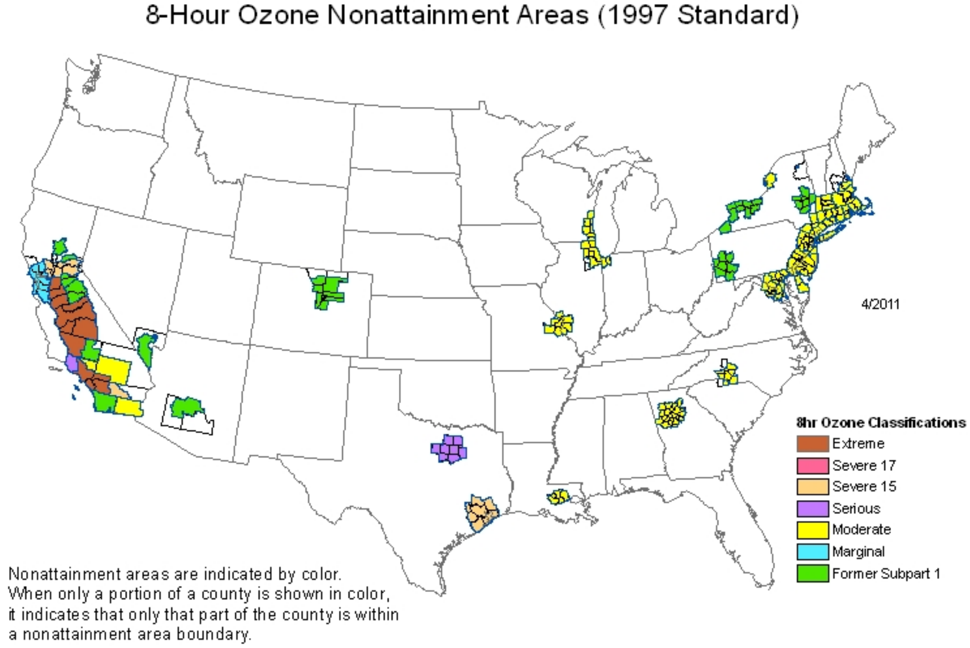

Figure 10: California leads US in ground level ozone pollution[19]

The following summary from the USEPA describes the negative impacts associated with high amounts of ground-level Ozone.[20]

Breathing ozone can trigger a variety of health problems including chest pain, coughing, throat irritation, and congestion. It can worsen bronchitis, emphysema, and asthma. Ozone also can reduce lung function and inflame the linings of the lungs. Repeated exposure may permanently scar lung tissue.

Healthy people also experience difficulty breathing when exposed to ozone pollution. Because ozone forms in hot weather, anyone who spends time outdoors in the summer may be affected, particularly children, outdoor workers and people exercising. Millions of Americans live in areas where the national ozone health standards are exceeded.

Ground-level or "bad" ozone also damages vegetation and ecosystems. It leads to reduced agricultural crop and commercial forest yields, reduced growth and survivability of tree seedlings, and increased susceptibility to diseases, pests and other stresses such as harsh weather. In the United States alone, ground-level ozone is responsible for an estimated $500 million in reduced crop production each year.

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[19] US Environmental Protection Agency. The Green Book Nonattainment Areas for Criteria Pollutants. 8-Hour Ozone (1997).National maps. http://epa.gov/oaqps001/greenbk/map8hr.html

[20] USEPA *Ozone: Good up high, bad nearby.* http://www.epa.gov/airquality/gooduphigh/ozone.pdf

Unlike concerns associated with global warming, reduction of ground-level Ozone has an immediate impact on the health and wealth of California and is not as dependent on the actions of others outside of California.

However, as shown in Figure 11, only 6% of ground level Ozone production is associated with in state power generation and combustion by gas appliances. The vast majority of Ozone generation is due to combustion engines whether they are in cars, trucks or even ships.

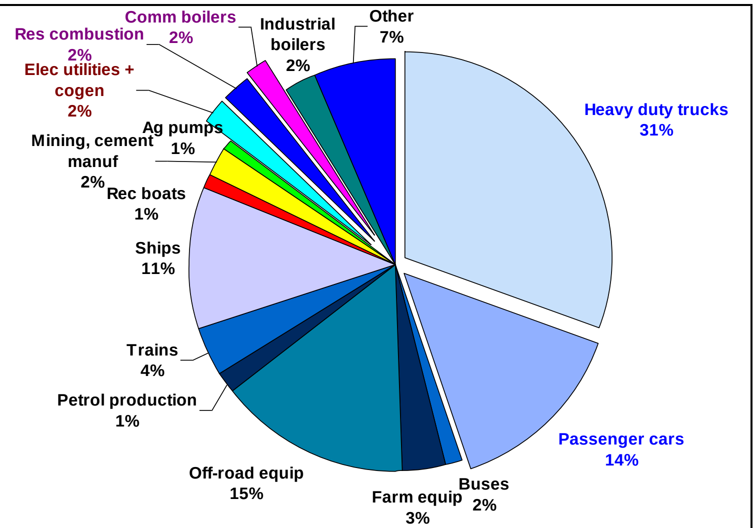

Figure 11: ZNE Buildings affect 6% of California NOx Emissions[21]

It should be noted that passenger vehicles are responsible for 14% of the total Ozone emissions in California. This is a fairly significant portion of the Ozone problem. Trade-offs between building energy and transportation energy though location efficiency might be considered as one of the areas where buildings can qualify as "ZNE equivalent."

Given that electric vehicles essentially eliminate this local source of Ozone, the expansion of ZNE homes and buildings would free up electrical generation for the electrification of the transportation sector. A significant increase in the use of electric vehicles would provide a means of storage of on-site renewable generation when generation exceeds home electricity consumption. Thus ZNE homes have the opportunity to make inroads on reducing Ozone emissions in the state especially when considered in conjunction with electric vehicles.

[21] California Air Resources Board. http://www.arb.ca.gov/app/emsinv/t25cat/cat_top25.php

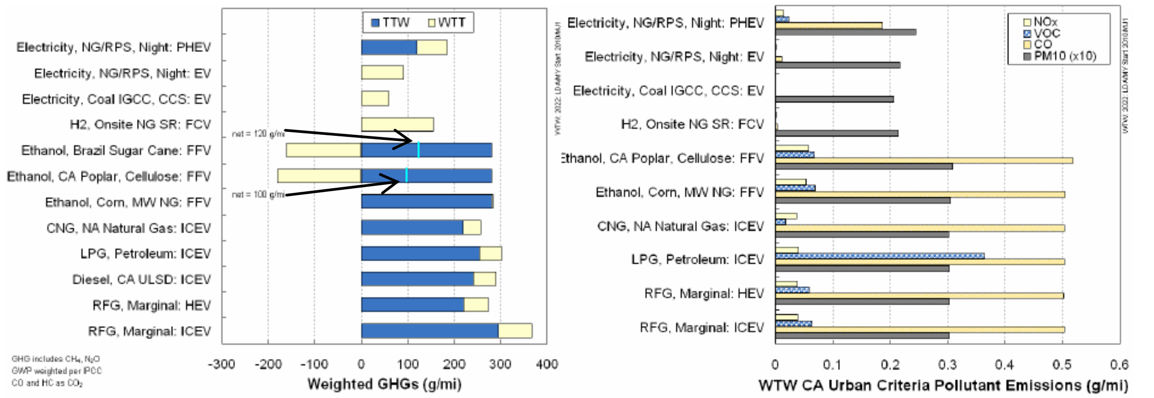

Figure 12: a) 2022 Greenhouse Gas Emissions[22] b) 2022 Pollutant Emissions[23] for Year 2022 Passenger Car Options (new stock)

As shown in Figure 12 a) of all of the vehicle technologies evaluated by the California Energy Commission (2007) only electric vehicles (EV), hydrogen fuel cell vehicles (FCV) and cellulosic ethanol powered vehicles (cellulose FFV) were able to reduce greenhouse gas emissions by two-thirds as compared to the internal combustion engine vehicle (ICEV) on the bottom of the graph. However when one considers local air quality impacts, Figure 12 b) illustrates that the ethanol powered vehicles have local NOx, VOC and CO emissions that are comparable to gas powered internal combustion vehicles. Oxides of Nitrogen (NOx) and Volatile Organic Compounds (VOC's) react when exposed to sunlight to generate ground level Ozone. Thus electric vehicle technology including hydrogen fuel cell vehicles (EV & FCV) is well-positioned to help California meet its greenhouse gas reduction goals and make progress towards compliance with ambient air quality goals for Ozone.

[22] Figure ES-6 (CEC 2007) TTW = Tank-To-Wheels (vehicle efficiency), WTT = Wheel-To-Tank (fuel cycle)

[23] ibid Figure ES-10, WTW = well to wheel (total energy including fuel cycle)

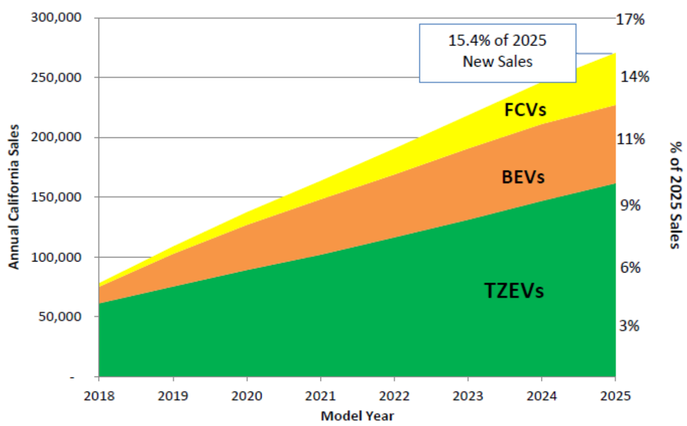

Figure 13: Projection of Mix of Zero or Near Zero Emission Vehicles[24]

To this end there have been efforts to make the transition to electric vehicles. The CEC estimates in its energy demand forecast that there will be 1.5 Million electric vehicles on California's roads by 2020 and that this will add 4,400 GWH of new load upon the electricity system. (CEC 2009b) Thus implementing the ZNE goal for new homes by 2020 will free up electrical generation capacity for electric vehicles (BEVs – battery electric vehicles, and TZEVs transitional electrical vehicles – primarily plug-in hybrids). If the current proposed rule for zero emissions vehicles is adopted, the relative mix of zero emissions vehicle technologies is projected as illustrated in Figure 13.

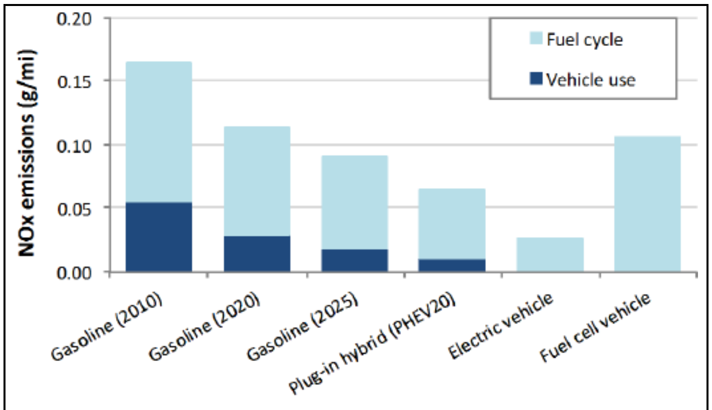

Figure 14: Well To Wheel (WTW) NOx emissions[25]

Of the three technologies projected to help meet California's zero emissions vehicle goals, fuel cell vehicles (FCV) do not use significant amounts of electricity in processing hydrogen. The lowest cost method of hydrogen production does not use electricity but steam reforming using fossil fuels. Though hydrogen fuel cell vehicles produce little local Nitrous Oxide emissions, according to CARB (2011) their global emissions are significant, approximately 4 times that as the NOx emissions from the electrical grid in 2025 that would be serving battery storage electric vehicles.

Though the most immediate impacts on an emissions reduction program would be the local benefits associated with urban air pollutants (Ozone, Carbon Monoxide and

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[24] p. ES-4 (CARB 2011) FCV = fuel cell vehicle, BEV = battery electric vehicle, TZEV = transitional zero emissions vehicle (plug-in hybrid)

[25] P. 75 (CARB 2011)

Particulates), concerns about global warming has been the impetus behind redoubled efforts to reduce energy consumption. Assembly Bill 32: Global Warming Solutions Act (AB32 2006) has as its goal, a reduction of greenhouse gas emissions to 1990 levels by the year 2020. AB32 has given to the California Air Resources Board and other state agencies the authority to pursue this agenda which is spelled out in the Climate Change Action Plan (CARB 2008).

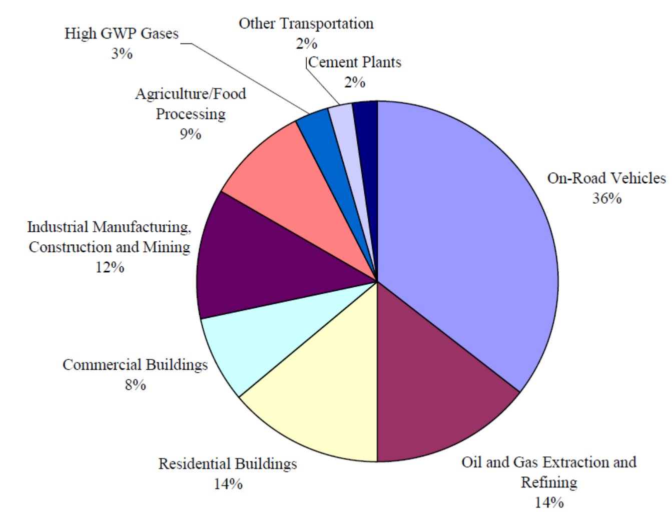

Figure 15: California's Greenhouse Gas emissions by end-use demand.[26]

As shown in Figure 15, residential buildings account for 14% of statewide GHG emissions. However all the housing stock constructed in the last 10 years accounts for only 11% of the total residential building stock i.e. on average new construction accounts for around 1.1% of housing stock per year. Thus if a ZNE requirement for all new residential construction is in place by 2020, the impact 10 years later would be a reduction of 1.4% (11% of the 14%) of California Greenhouse Gases – only if these homes replace existing homes. Thus the lessons learned from new construction have to be applied to existing residences. As discussed earlier a Zero Net Home initiative must also address consumer electronics and appliance energy usage; something that would affect all of the building stock in a comparatively short time.

Increased health

As described above zero net energy buildings reduces the 6% of Ozone production associated with in state power generation and combustion by gas appliances. It also frees up electrical generation capacity for the electrification of the transportation sector where passenger vehicles are responsible for 14% of the total Ozone emissions in California. Quantifying the health impacts of a transformation of California's energy economy is an important portion of developing the political will to see the policy goal to full implementation.

Zero Net Energy Buildings are a subset of the larger goals for Green Buildings and ultimately a Green Economy. Green buildings have an underlying ethic or goal of

[26] Page 13 Climate Change Action Plan (CARB 2008)

preserving ecological health and the personal health of the building's inhabitants. Thus green buildings are envisioned as very energy efficient since this reduces the net impacts of energy consumption on environmental health (GHG's, Sox, NOx, particulates in addition to the effects of mining etc.) In addition to caring about the societal health of one's neighbors that live near the sources of energy extraction and production, green buildings have a goal of reducing environmental hazards to the health of the home's occupants. Thus green building standards go beyond the minimum safety requirements associated with the Toxic Substances Control Act and attempt to address building materials that health experts agree are likely sources of illness. Thus green building standards including the California Green Building Standard, also known as CALGreen,[27] have building requirements that limit the use of chloroform, ethylene dichloride, methylene chloride, perchloroethylene, trichloroethylene, volatile organic compounds and formaldehyde.[28]

There is an interaction between efforts to protect the health of occupants and to save energy. The Title 24 building efficiency standards require continuous mechanical ventilation with the assumption that this will keep indoor pollutants below concentrations associated with long term health effects. However this ventilation air increases the heating and cooling loads of the home. If the homes and the furnishings in the home are manufactured out of "greener" products (inert or does not emit harmful substances), these ventilation rates can be reduced and save even more energy. Thus a goal for both green homes and ZNE homes is that principles of pollution prevention are applied and less toxic components are built into the home. We recommend that health benefits of the air emission reductions from ZNE and the indoor air quality benefits of green homes is studied and well documented; this will support Green Building policy on a societal basis and useful for the marketing of homes on an individual basis. This is an area where the California Air Resources Board can take a leadership position.

Increased wealth (lower life cycle cost)

The history of the Title 24 building energy efficiency standards has been one of continually lowering the life cycle cost of homes with each code cycle. In addition, the performance approach of the standards has allowed sufficient flexibility that the market has regularly identified even lower cost methods to achieve the energy targets in version of the standards. In addition, products and materials required by code were manufactured in volume, became commoditized and Californians were able to reap the benefit of lower cost high efficiency equipment and building components.

[27] Title 24, part 11.

[28] Ibid, Section 4.504 "Pollutant Control"

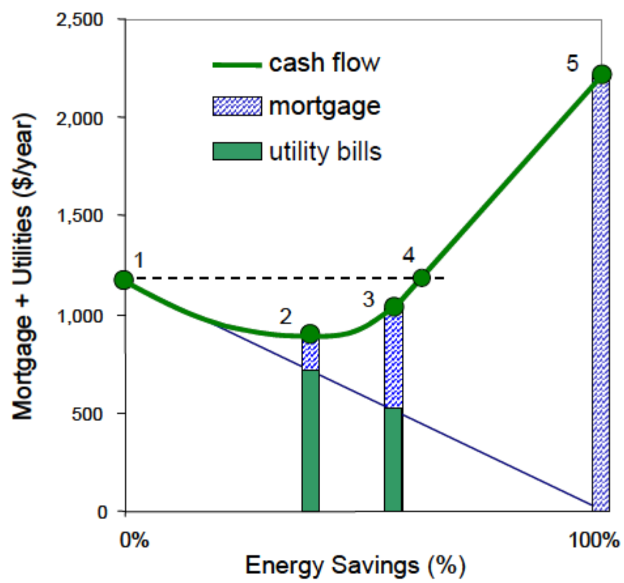

Figure 16: Conceptual plot of annualized Life Cycle Costs on the path to ZNE. (NREL 2008)

The life cycle cost of ZNE homes can be characterized by the conceptual plot in Figure 16; increasing investments energy efficiency increase energy savings and correspondingly decrease utility costs. If energy efficiency investments are sorted by most cost-effective to least cost-effective and applied in sequence, one can apply them down to point 2 – the point of minimum life-cycle cost. Up to point 2 all incremental energy efficiency measures are saving more life cycle cost than the cost of financing the measure. This conceptual model posits that after the attractive energy efficiency measures have been exhausted, eventually the law of diminishing returns will apply such that it is cheaper to add on-site renewable generation than an exotic energy efficiency measure. This is represented by point 3, where further grid energy savings is represented by a flat line with a fixed slope of $/kWh for renewable power. Renewables can be added up to point 4 and the low energy house can be considered cost-effective as the utility savings resulting from the combination of energy efficiency and renewables pays for all of the added amortized first cost. Even if the renewables are not cost-effective by themselves, they can be cost-effective as part of a package that includes both efficiency and renewables. In this model, a ZNE home is achieved at point 5, where utility bill costs are zeroed out and utility bill savings only partially offset added mortgage costs.

With a baseline house being one that is compliant with the 2006 IECC (International Energy Conservation Code) the findings of the NREL (2008) study were that homes could save approximately 40% to 50% of their energy through efficiency measures, and have a lower total cost of ownership than the base case house in most climates before it made sense to start adding photovoltaics.

It should be noted that even with a policy objective of ZNE homes by 2020, the 2013 proposed Title 24 building efficiency standards fell short of what could be justified from a cost-effectiveness basis. The rationale was that increasing the first cost of homes more than by more than $3,500 was politically infeasible. The general concept has been to minimize disruption to the building industry by slowly ramping up the stringency of the standards. In addition to minimizing disruption, the costs of the efficiency measures in the last code cycle declines and in some cases the cost of the additional efficiency measures also decline as these more aggressive efficiency measures are increasingly applied in utility incentive programs and for purposes of differentiating buildings as green or above average performance. If the ZNE target is going to be within reach by 2020, there has to be a mandate that the California Energy Commission adopt all feasible and cost-effective energy efficiency measures in the 2016 standards. This will move the cost/efficiency curve to point 4 in Figure 16, where the life cycle cost of the home is the same pre-code and post-code except the post-code building saves a lot more energy.

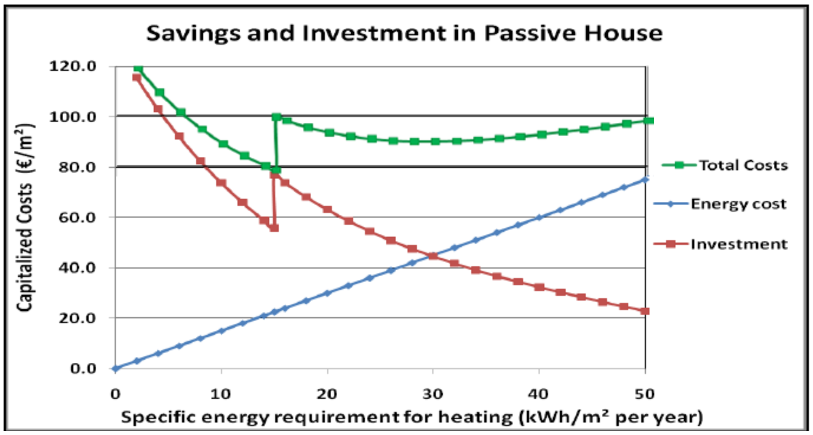

Figure 17: Cost-effectiveness curve with discontinuity from elimination of heating system. (OECD/IEA, 2008)

A similar but different view of this same concept of optimizing energy efficiency includes situations where the synergies between measures can result in the reduction in equipment costs and in this case go beyond a tipping point where entire energy systems such as a ducted heating system can be eliminated. This was demonstrated in the development of the Passive House standard. Figure 17 illustrates the underlying cost considerations that went into setting the Passive House standard to 15 kWh/m^2. This point was selected as it was anticipated that once energy consumption had dropped this low, the need for a central heating system was obviated and thus this level of energy efficiency would be close to the minimum life cycle cost for the home.

Similar concepts have been proposed for California homes where more stringent envelope requirements would be proposed for coastal climates as this could be cost-justified by the ability to eliminate air conditioning. Work is underway in the residential energy code compliance and simulation software, CALRES to develop a thermal comfort model that will provide the confidence to builders and potential homeowners that the cost of the air conditioning system is not necessary when advanced envelop concepts are employed in the relatively mild coastal climate zones. Over time it is expected that advanced in construction practices and materials will expand this approach to most climate zones.

Thus developing a database of ZNE buildings and their impacts on total cost of ownership are important so that the costs and benefits of ZNE buildings are well understood. Sharing information where synergies between efficiency and renewable energy measures can reduce the amount of required equipment will be needed to accelerate the dissemination of new design practices and construction methods.

Energy security

Though photovoltaics (PVs) don’t generate electricity when it doesn’t shine nor wind turbines produce electricity when the wind doesn’t blow, over the course of a year, the annual output is a relative stable known quantity. The long term costs for ZNE homes are known since most of the energy costs but maintenance costs are up front. The same kind of price stability can’t be claimed for other energy sources.

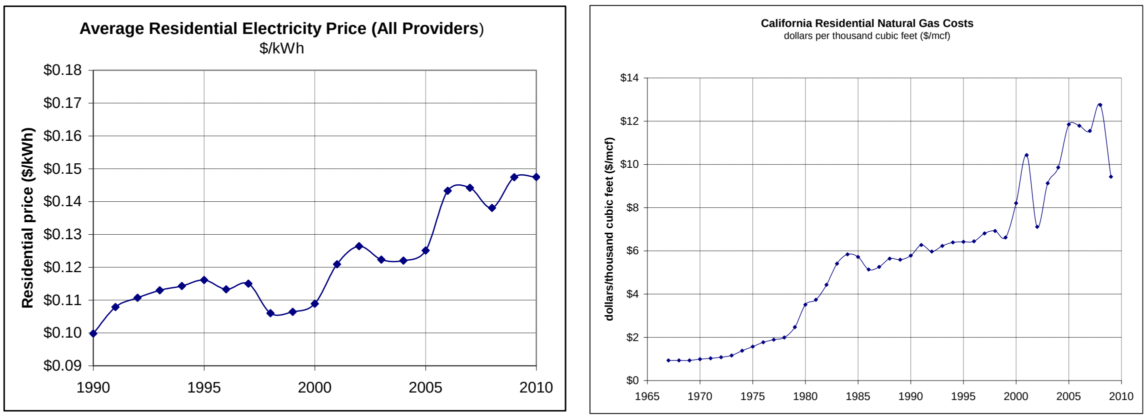

Figure 18: a) Res electric cost ($/kWh)[29] b) Residential natural gas costs ($/mcf)[30]

The energy sources primarily used in residences, electricity and natural gas, have fluctuated over time and over the long terms have risen. Most of the new fossil fuel based conventional electricity capacity will likely be fired with natural gas. In the short term we have witnessed relatively dramatic drops in natural gas price driven by the reduction in demand associated with the recession and markedly increased potential supply associated with shale gas production due to technology innovations i.e. horizontal drilling, and hydraulic fracturing, “fracking.”

Figure 19 indicates that regardless of the scenario taken the national average price of natural gas has dropped by approximately 50% since 2008. Under all scenarios the price will rise over the long term but not likely to the levels seen just a few years ago. However, this is the well head price so that the actual price reduction seem by the user will be less as the costs of transmission and distribution likely have not changed much. Everything else being equal, slow economic growth coupled with rapid gas technology deployment will result in lowest natural gas prices and high rates of economic growth combined with slow technology adoption will result in relatively higher demand and lower supply and thus result in higher prices.

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[29] http://www.eia.gov/cneaf/electricity/epa/average_price_state.xls

[30] http://energyalmanac.ca.gov/naturalgas/historical_residential_yearly_prices.html

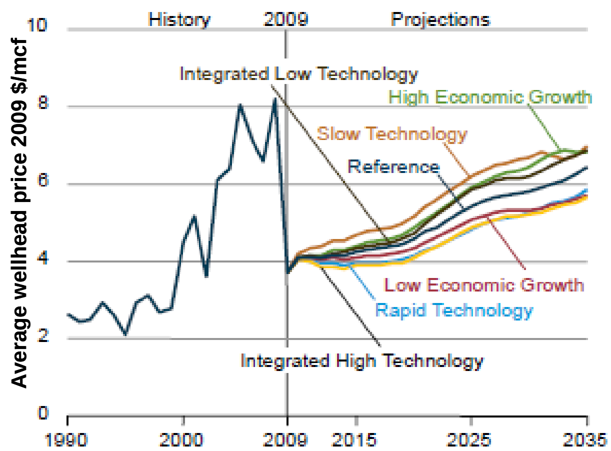


Figure 19: Forecast of wellhead gas price (2009$/thousand cf) in lower 48 under different scenarios (EIA 2011)

Under all scenarios, it is expected that the real (adjusted for inflation) price for natural gas will increase. The increasing worldwide demand for energy and the increased effort to extract gas results in a long term price increase.

Thus conventional forms of energy have costs that fluctuate and have some uncertainty as prices are affected by the global energy market. Zero Net Energy Buildings are shielded from the vagaries of the energy markets to some extent as they are not purchasing that much energy. However, for ZNE homes without battery storage, there will be times where the on-site renewable electricity generation exceeds the electrical load of the home. State policy for net metering and pricing of exported electricity will impact the cost recovery of on-site renewable energy systems and will impact how much zero net energy is embraced.

If ZNE is defined in terms of all energy sources, and is not a short hand term for "grid neutral" homes that are consuming natural gas will be expected to export more electricity value than they consume. The ZNE goal will seem to be anti-consumer if the consumer is generating more electricity value than they consume and the rules are developed so that it is impossible to be net electricity revenue generator. The idea of "donating" electricity to the grid after the electricity bill is zeroed out is likely an unpopular one. However that there should be some cost for grid services is reasonable but there will likely be some significant negotiations over what is a reasonable cost for grid services.

The Smart Grid as low cost "storage"

Current visions of the energy infrastructure in future with ZNE homes is one which is providing substantially less energy but is still a key element. Natural gas is still providing water heating on days when the sun is not shining, albeit with tankless condensing water heaters that use 30% less energy. In the near and medium term the grid is a "large battery" that purchases electricity during the day when PV generation exceeds the modest electrical loads during the day and sells low cost off-peak power. Given that new residential construction accounts expands the building stock by around 1.1% per year, it will take a long time before ZNE homes will significantly alter the electrical load shape.

Some are concerned about what net metering portends for the financial viability of utilities if they are paying retail for power that they ordinarily would be paying wholesale. My expectation is that if flat rates are used, purchasing electricity produced on hot afternoons and selling power at night for the same price will result in a margin for the owners of the power grid. If time differentiated rates are used then some margin would have to be built in over the long term.

Some are concerned that the definition of Zero Net Energy implies the expectation of zero utility costs. If someone builds a ZNE home and they are fully off-grid, they also have zero utility costs. However being grid connected allows the homeowner to avoid the large cost of battery storage and increased renewable energy system sizing to ride through times when the sun doesn't shine of the wind doesn't blow or even short duration mismatches between building loads and renewable energy generation. This narrative will have to be communicated to both owners of ZNE homes and the rest of the customer base of the electricity system.

If one envisions a future with onsite renewables exporting to the grid, upgradeable set back thermostats (UST) modifying setpoints based on the cost of energy and plug-in vehicles charging off-peak, one can envision a sophisticated "smart grid" that can do more with less. Energy flows are modified on the supply side and demand side so that power plants operate at maximum efficiencies and can be brought off-line in a predictable staging of supply and load and so that peak loads on individual circuits are leveled out and minimized. Areas with transmission and distribution bottlenecks could be specifically incented for renewable production credits. This isn't the traditional power grid and the opportunities and pitfalls need to be fully understood.

Labor-intensive energy system

An energy infrastructure that includes ZNE homes and buildings is one where a significant fraction of energy generation is displaced by advanced efficiency techniques and technologies and where energy generation is increasingly renewable and distributed. This is in marked contrast to the traditional energy infrastructure that is extremely centralized into a few plants, and large transmission corridors. The ZNE paradigm is one that requires enhanced design up front, more care in construction details and an entire new class of "green collar" renewable energy system installers with skill sets that combine light carpentry and electrical installation.

Statewide implementation of ZNE new homes creates job opportunities for the construction trades, one of the hardest hit sectors of the economy. These are jobs that have to take place on site and thus cannot be outsourced. This investment in local labor is paid for with reduced energy payments that fundamentally are based on imports from outside of California.

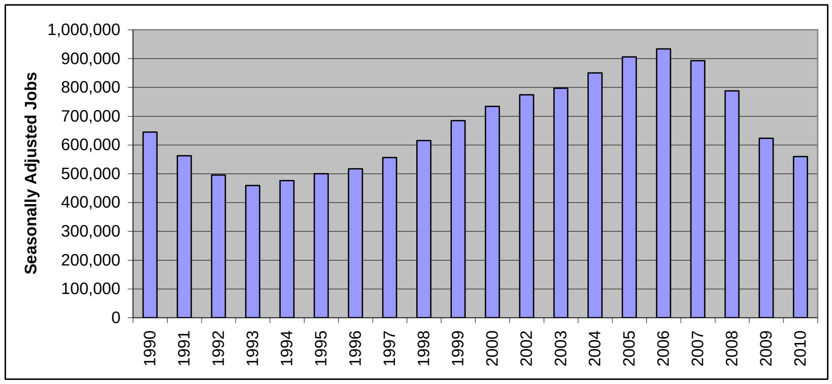


Figure 20: California construction employment 1990 -2010[31]

As described in the introduction there isn't a better time to make the transition to a zero net energy economy. Interest rates are low so it costs less to invest in technologies that make recurring payments over the long term. New construction activity has been the lowest it has been in 70 years. As was shown in Figure 5, only 45,000 dwelling units were built last year and 36,000 units built the year before as compared to the average construction rate over the prior 10 years of 148,000 units/yr. Thus this is a prime time to transform the market; an aggressive ZNE program now, over the next three years would cost approximately $325 Million.[32] A similar program with similar market penetration under average market conditions would cost $1.1 Billion. Currently in the middle of this recession, there is an oversupply of photovoltaic production capacity and a concerted effort could convert this opportunity to propel the experience further. Efforts now could transform the residential construction market for a lower cost than any time in recent history, help stimulate the housing industry with a clearly superior product (ZNE residences), increase construction employment and place California on the road to a more sustainable economy.

A Zero Net Energy basis for new homes will result in a permanent increase in construction employment of around 3,000 extra full time equivalent construction jobs as ongoing utility costs are exchanged for increased labor and materials costs in new homes. The conservative basis of this estimate is as follows. If we consider a long term average construction rate of 110,000 single family homes and 38,000 dwelling units, the labor impacts of installing the energy efficiency measures in the 2013 standards is estimated to be approximately $174 Million (along with $213 Million in added material costs and a savings of $48 Million in reduced HVAC costs associated with reduced loads if HVAC systems are downsized). At a fully loaded rate of $60/hr labor costs and 2,000 h/yr the cost of each FTE is $120,000 (including mark-up). From this a very conservative estimate of construction labor costs, the structural increase in construction employment

[31] California Employment Department **Employment by Industry Data** http://www.labormarketinfo.edd.ca.gov/?pageid=166

[32] Assuming 40% participation and a $6,000/dwelling unit program cost

from a similar extra round of standards is 1,450 full time construction employees not including those people supported by the overhead mark-up.

We have identified two sources for labor hours associated with residential photovoltaic system. The CEC (2001) photovoltaic design guide estimated that, "An experienced crew can install a 2 kW non-battery PV system in two-to-four person-days." A NREL (2011) presentation estimated that the electrical side of a 5 kW installation required about 25 person hours and the mechanical side (racks and mounting the roof) took about 40 person-hours). When this is converted into a person-hours per kW estimate, the CEC estimate is between 8 and 16 person-hours per kW and the NREL estimate is 13 person-hours per kW (DC peak kW). From Figure 7, using a societal valuation basis for the definition of ZNE it is feasible to consider that for single family homes the required PV would be between 2 and 4 kWp. Thus taking the average size of 3 kWp per single family home the labor hours are around 39 person hours per home if we use the NREL estimate of 13 person-hours per kWp. If we assume that the labor hours are approximately half of that for each multi-family dwelling unit, the labor impact is 19.5 hours per dwelling unit. Multiplying this by long term average construction rate of 110,000 single family homes and 38,000 dwelling units, yields 2,515 extra full time construction jobs associated with installing photovoltaics on new homes. Thus in combination with the 1,450 extra jobs associated with energy efficiency measures and the 2,515 extra jobs associated with photovoltaic installation, the state of California nets an additional 3,965 full time construction jobs, not including the indirect effects of jobs created by the overhead or multiplier effects generated by these jobs.

Replacing energy liabilities with energy capital

The ZNE strategy calls for investing in the energy efficiency and renewable generation capacity in new homes so that any home post-2020 has zeroed out the societal cost of operating the home. In contrast, current homes and especially older homes require energy inputs that stretch across state and national boundaries. These energy costs will likely rise over time and require an investment in transmission infrastructure to serve a rising population. These are energy liabilities because they require ongoing payments to maintain comfort. This is in contrast to zero net energy buildings where a significant amount of the energy capital remains in the home where it provides recurring payments in energy and comfort. This level of energy autonomy places more control in the hands of individuals and less in the hands of out of state interests.

3.4. A Legislative Mandate for ZNE homes

Legislation is the engine that drives policy. Currently the ZNE strategy is a strategy that supports AB32 and other objectives. Though the state has greenhouse emission goals, and ZNE is a method of helping achieve these goals, it is not explicitly required though legislation. Some opponents of ZNE requirements for homes in 2020 have indicated that there is not currently a ZNE legislative mandate. Efforts to more clearly establish the link between legislation and the ZNE goal will be increasingly important as energy codes require increasingly more stringent measures in the last two code cycles before the 2020 deadline.

The 2020 mandate for ZNE residential construction was proposed by Assemblyperson Saldana, but ultimately was turned down by the Senate Housing and Transportation committee. (AB 2112, 2008) If this bill had passed, it would have been law and would have created a mandate for all new homes to be ZNE. Since there are other laws that also regulate energy efficiency of homes, the language had to be crafted so that it did not conflict with other requirements of energy codes such as the codes have to be cost-effective and did not create an undue economic harm to the state. The text of this legislation is attached in *Appendix G: Text from AB 2112 (Saldana/Lieu) ZNE Homes*. Learning the lessons from this legislation by understanding the arguments against this legislation and having responses to each concern could improve the process of developing consensus for another run at developing such a mandate.

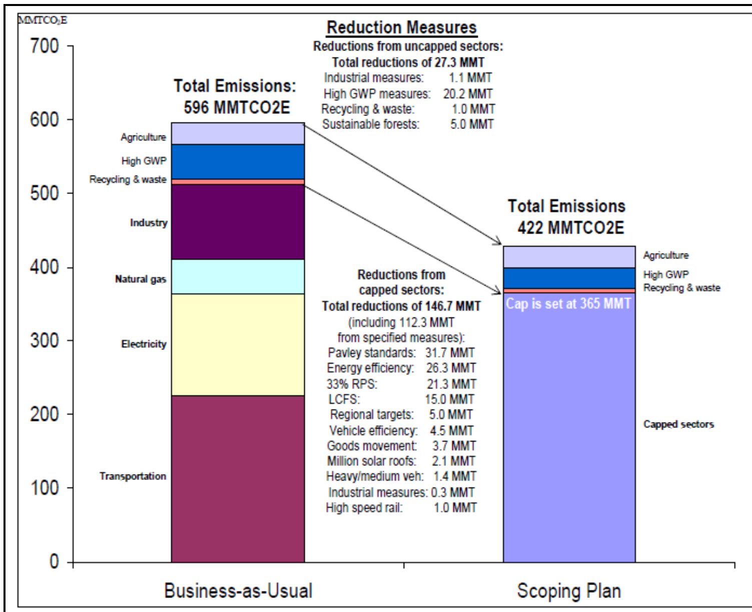


Figure 21: Climate Change Scoping Plan Reductions by Sector by 2020

Another approach towards developing a mandate for ZNE is to encourage that the administrative implementation of AB 32 "Global Warming Solutions Act" be more specific in how the greenhouse gas reduction are to be achieved. AB 32 has been approved by the California state legislature and was signed into law by the Governor in 2006. The primary mandate in this legislation was to drive down greenhouse gas emissions by 2020 to the emissions levels that are comparable to those in

1990. Over these 30 years, the population in California is 40% greater (similar to the global population growth) and with expectations of high levels of material wealth.

However the challenge is so great and the goals are so broad that implementation is left up to State agencies how to tactically accomplish the goals. The California Air Resources Board has been designated as the lead agency for developing the Climate Change Action Plan.

Table 7: Energy Efficiency Recommendation - Electricity
($MMTCO_2E$ in 2020)

Measure No.	Measure Description	Reductions
E-1	Energy Efficiency (32,000 GWh of Reduced Demand) • Increased Utility Energy Efficiency Programs • More Stringent Building & Appliance Standards • Additional Efficiency and Conservation Programs	15.2
E-2	Increase Combined Heat and Power Use by 30,000 GWh	6.7
	Total	**21.9**

Table 8: Energy Efficiency Recommendation - Commercial and Residential
($MMTCO_2E$ in 2020)

Measure No.	Measure Description	Reductions
CR-1	Energy Efficiency (800 Million Therms Reduced Consumption) • Utility Energy Efficiency Programs • Building and Appliance Standards • Additional Efficiency and Conservation Programs	4.3
CR-2	Solar Water Heating (AB 1470 goal)	0.1
	Total	**4.4**

Figure 22: Climate Change Scoping Plan Efficiency Recommended Energy Reductions[33]

As shown in Figure 22, the AB 32 Climate Change Scoping Plan calls for a reduction in electricity by 32,000 GWH/yr and 800 Million therms/yr due to energy efficiency in buildings and appliances. The Scoping Plan outlines the measures that are needed to implement the scoping plan and this includes the move towards Zero Net Energy Buildings.

[33] http://www.arb.ca.gov/cc/scopingplan/document/adopted_scoping_plan.pdf

The plan's summary of efficiency measures are as follows:[34]

Key energy efficiency strategies, grouped by type, include

Cross-cutting Strategy for Buildings

- *"Zero Net Energy" buildings*

Codes and Standards Strategies

- *More stringent building codes and appliance efficiency standards*
- *Broader standards for new types of appliances and for water efficiency*
- *Improved compliance and enforcement of existing standards*
- *Voluntary efficiency and green building targets beyond mandatory codes*

Strategies for Existing Buildings

- *Voluntary and mandatory whole-building retrofits for existing buildings*
- *Innovative financing to overcome first-cost and split incentives for energy efficiency, on-site, renewables, and high efficiency distributed generation*

Existing and Improved Utility Programs

- *More aggressive utility programs to achieve long-term savings*

Other Needed Strategies

- *Water system and water use efficiency and conservation measures*
- *Local government programs that lead by example and tap into local authority over planning, development, and code compliance*
- *Additional industrial and agricultural efficiency initiatives*
- *Providing real time energy information technologies to help consumers conserve and optimize energy performance*

From the above, it is readily apparent that ZNE homes are part of the plan. In addition, the energy efficiency portion of the Scoping Plan references the CPUC California Long Term Energy Efficiency Strategic Plan. This strategic plan has four big bold energy efficiency strategies (BBEES), and the first strategy is:

"All new residential construction in California will be zero net energy by 2020."

All documentation of the AB32 Scoping Plan and the Energy Efficiency Strategic Plan points in the direction of the 2020 Zero Net Energy homes goal as state policy for helping to reduce greenhouse gas emissions as mandated by AB 32. Greater clarify of the state's

[34] p. 42 ibid

intent would be realized by CARB, CEC and CPUC publishing a policy statement that they interpret the AB 32 mandate to include the requirement that all new homes built by 2020 to have a net energy consumption of zero net energy or equivalent. This would help establish that the zero net energy goal is state policy and is more than an aspirational goal. The 2011 IEPR goes a long way towards this objective with the following:[35]

"California's energy efficiency policies include achieving all cost‐effective energy efficiency; reducing energy use in existing buildings built before the advent of building and appliance efficiency standards; and making all new residential construction in California "zero net energy" (a combination of greater energy efficiency and on‐site clean energy production to reduce building energy use to "net zero") by 2020 and all new commercial construction zero net energy by 2030."

3.5. ZNE New Home Rating Infrastructure

The California Whole-House Home Energy Rating (earlier known as HERS II) is proposed as the basis for defining a home as Zero Net Energy. Under this proposal a rating of 0 or less qualifies a home to be considered ZNE for the purposes of building efficiency incentive programs, and for marketing purposes this rating can be used to call a home a "California certified Zero Net Energy Home."

$$\text{HERS Index} = \frac{TDV_{Rated} - TDV_{PV}}{TDV_{Reference}} \times 100 \tag{1}$$

The HERS index as shown in Equation (1) is from the California Whole-House Home Energy Rating manual (CEC 2009a). A couple of things are worth noting about this index:

- The units are in TDV (time dependent valuation) units as the building simulation is primarily based on the Title 24 software and ACM (alternative compliance method) rule set for the performance method.
- The output of the PV system reduces the proposed building energy consumption. If more on-site renewable electricity is generated than is needed to serve electricity loads, the excess exported to the grid is treated as negative energy consumption. Electricity exported to the grid is valued equally as energy imported (i.e. electricity exported on a hot summer afternoon results in a larger

[35] P. 8 (CEC 2011)

TDV reduction than the same amount of energy exported during the morning with lower temperatures and lower TDV values).

- Both the reference home and rated homes include energy consumption from items that are not modeled in Title 24. part 6 (the building efficiency code) ACM; it also includes other end-uses such as white goods, interior lighting
- This HERS rating has been relative to a reference building that represents one that it minimally compliant to that year's energy code. This metric should be changed as it is not desirable that the rating changes depending upon the year the rating is conducted. This changing baseline is not very useful for comparing buildings that are rated during different code cycles. This concept of a setting a fixed baseline or a constant rating method is similar to the zEPI (zero Energy Performance Index) that has been promoted by Charles Eley and others.

As the primary metric of ZNE homes the California Whole-House Home Energy Rating is the linchpin to certifying and marketing that a given building is truly ZNE and not a form of "greenwashing" the true energy impact of the home. Thus this rating system has to be carefully evaluated that it is reasonable accurate, easy to use and the process of getting a rating is relatively quick and straightforward.

<u>Confidence in the rating.</u>

SMUD (Sacramento Municipal Utility District) is not using the rating as they are not convinced that the TDV energy valuation file for climate zone 12 is providing a reasonable representation of their energy costs. They are concerned that the energy component cost of TDV is based on a statewide temperature rather than the local temperature. They feel that the climate zone 12 TDV's should be based on the rolling average temperatures (degree cooling hours) in climate zone 12 and be less linked to the temperatures in the other climate zones.

Another issue that has been brought up that some of the equipment models in the ACM are in need of updating (the heat pump water heating model is one example, its efficiency is unaffected by ambient air temperature). Conversations with the software vendors and energy analysts will uncover the list of issues that need to be addressed.

<u>Simple to Use Rating Process</u>

The HERSII rating rules were originally conceived as a rating for existing buildings and an energy audit tool for existing homes. The software rule set has a significant amount of detail around bill matching and methodology for ranking energy efficiency measures. This tool was intended to provide consumer protection for audit programs so consumers could see default energy upgrade recommendations in addition to those proposed by the building performance contractor.

For a ZNE new homes program, the rating tool should be fully integrated with the performance approach so the Certified Energy Analyst can develop in one step, the performance documentation for compliance with the building code and generate the building rating documentation. In all likelihood a HERS inspection is required for both the code and HERS documentation being approved.

3.6. Existing Home Ratings

The HERS rating was conceived as whole building energy auditing tool. It requires a blower door test, duct testing and a detailed computer simulation model. This type of rating not only indicates the building's energy consumption but also the relative breakdown of energy consumption by various end-uses. This detail is then instrumental in assisting the homeowner in selecting energy upgrades that provide sufficient value.

It appears that there is a need for another type of rating, one that can be filled out from knowing the address, the square footage and having the energy bills. This minimal level of data can provide a normalized estimate of energy consumption for comparison to other buildings and to provide a potential buyer what their total cost of ownership (mortgage plus utilities) will be the for the home. This simplified rating sets the stage for purchasing the more detailed audit rating and purchasing energy upgrades during the purchase and financing decision.

The benefit of the simplified rating is that all homes can have date certain ratings in advance of the financial transaction of the home purchase. In a discussion with a representative of the California Association of Realtors (CAR) their biggest concern about ratings is that they not be something that slows down the process of selling a house or getting a loan approval. Thus CAR is amenable to a date certain rating (rating has to be obtained by a certain date) and they are opposed to a time of sale rating requirement.

3.7. On-site Renewable Energy Policy & Timeline

Zero net energy homes as defined here have high levels of energy efficiency with the residual amounts of energy consumption served by on-site renewable energy systems. For most urban and suburban situations, the only realistic form of on-site generation is solar thermal and solar photovoltaic systems. Wind systems are mostly impractical on small lots where noise, safety and zoning issues significantly limit their use.

The path toward ZNE homes has been one of expanding the scope and the stringency of energy efficiency of home appliances and building features while removing barriers to the use of solar thermal and solar photovoltaic systems. The technologies behind solar thermal systems are fairly well characterized with primary expected cost decreases coming from market maturity and the reduction in overheads associated with selling a low volume product.

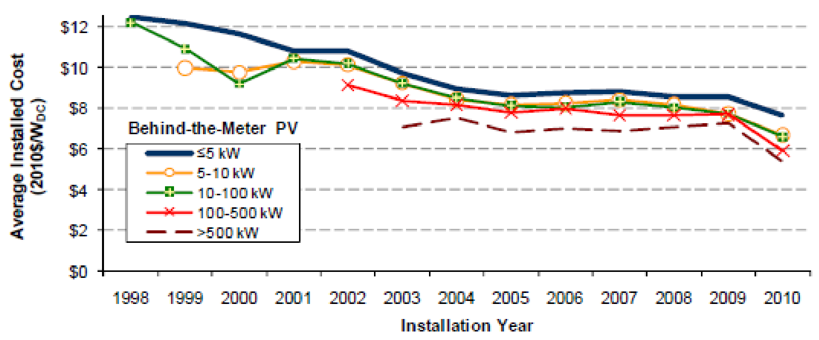


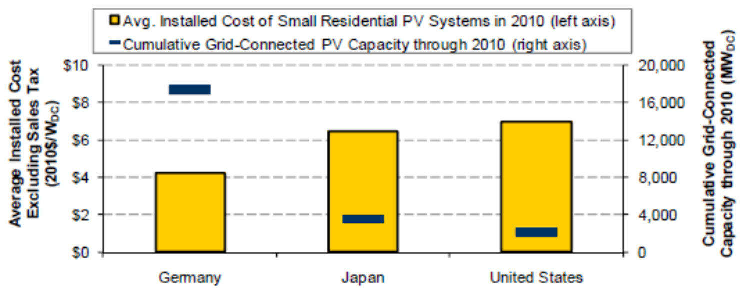
Figure 23: Installed costs of photovoltaic systems in the United States, 1998-2009[36]

Solar photovoltaic systems on the other hand have enjoyed relatively fast declines in cost. The "Tracking the Sun" series by LBNL has been following the declining installed costs of photovoltaic systems. As shown in Figure 23, the total installed costs of US residential photovoltaic systems have declined by 33% over the course of 11 years. In addition, Figure 24 illustrates that installed costs of photovoltaic systems in Germany are approximately 45% lower than the costs in the United States. Germany also has approximately 6 times the installed capacity of the United States. This implies that with further support of the photovoltaic industry, California homes may be able to benefit from the "experience curve" where markets and businesses get increasingly more efficient at delivering a product.

In addition, photovoltaics rely on relatively new material science processes that still have opportunities for efficiency improvement and material processing cost improvements. In addition the balance of system components (most notably inverters) have similar supply curve cost efficiency opportunities.

Inverters are also the "weak link" in the system as life spans of this critical component are often less than the useful life of the rest of the components in the installed photovoltaic system. Currently there is not a good metric or test method for predicting the longevity of one inverter versus another. In addition, some inverters drop off-line during grid under –frequency or under-voltage events and must be manually reset so that some inverters can be off-line for months without their owners realizing it.

[36] P. 17 (LBNL 2011)



Notes: Data for Germany and Japan are based on the most-recent respective country reports prepared for the International Energy Agency Cooperative Programme on Photovoltaic Power Systems. The German and U.S. cost data are for 2-5 kW systems, while the Japanese cost data are for 3-5 kW systems. The German cost data represents the average of reported year-end installed costs for 2009 ($4.7/W) and 2010 ($3.7/W).

Figure 24: Comparison of Average Installed Costs (Pre-Sales Tax/VAT) for Small Residential PV Systems in Germany, Japan, and the United States[37]

Photovoltaic systems are extremely sensitive to shading as shading one cell in a series string of effectively knocks out the power delivery of the entire string of cells. Thus providing unshaded solar access is of prime importance for making use of this resource. To prepare the market for solar photovoltaic systems, the 2013 Title 24 energy code is including language about "solar ready" roofs or sites. Ultimately the solar ready roof requirements will result in housing designs with simpler roof forms with less gables and less obstructions such as plumbing vents, ventilators etc. on the south facing roof.

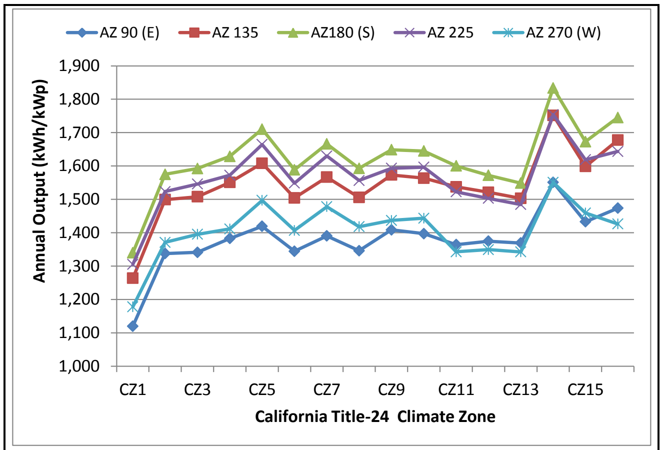


Figure 25: Production per peak kilowatt (kWp) by climate zone and azimuth.

The annual production of energy (kWh/yr) from a photovoltaic system with a nominal peak rating of 1 kilowatt (kWp), is plotted in Figure 25 with respect to climate zone and azimuthal angle as measured clockwise in plan view from due North. The simulation tool used for this calculation was the CECPV version 2.4 photovoltaic simulation software combined with the recently updated 2013 Title 24 versions of the weather files.[38] These simulations include the impact of solar radiation and temperature on photovoltaic system output and include inverter losses during production and standby losses at night. The systems modeled are flat panel static systems (not using concentrators or tracking) mounted at a 20° tilt angle above horizontal or roughly a pitch angle of 4:12 as might be found on a typical roof. The simulation did not account for shading from nearby trees or other obstructions, something

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[37] P. 20 (LBNL 2011)

[38] My thanks to Patrick Saxton of the California Energy Commission for running these simulations.

that can significantly reduce the value of photovoltaic systems. However with careful home and subdivision design, the impact of obstructions can be minimal.

Systems in climate zone 1 on the cloudy north coast near the Oregon border produce about 20% less electricity than the rest of the other climate zones. Systems in climate zone 14, the high desert, generate about 15% more electricity than the rest. No surprisingly, those systems that are facing a compass direction (azimuthal angle) of due South (180°) have the largest energy production. Of the directions we evaluated, those systems facing due East (90°) or due West (270°) have the least energy production, on the coast (CZ2 though CZ9) east facing systems have slightly less output due to foggy mornings. Though the east and west facing systems produce roughly the same amount of energy, the societal value of energy produced by west facing systems is noticeably higher. The rationale for this finding is described below.

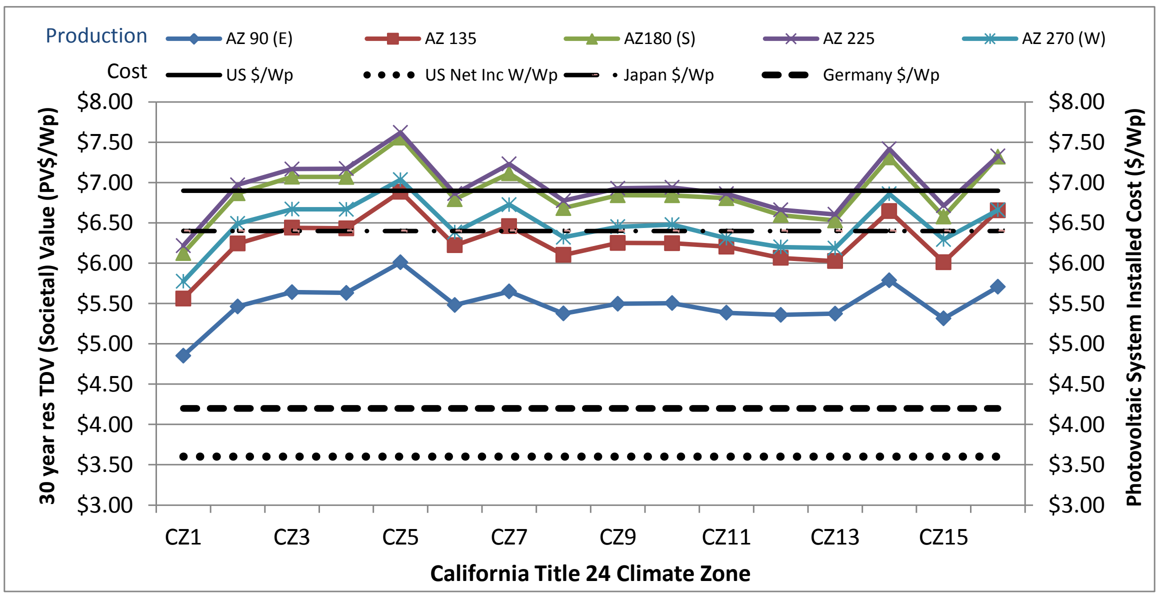

Figure 26: Societal Value of Electricity Production and Installed Cost of Photovoltaic Systems

Figure 26 plots both the societal value of photovoltaic generation and the installed costs of small scale residential photovoltaic systems. When the societal value of energy produced by photovoltaics are greater than their costs (first costs + maintenance costs), then these systems are cost-effective. The societal value of photovoltaic generation is simply the hourly production values multiplied by the hourly societal costs (time dependent valuation factors) of electricity as have been developed for the evaluation of the Title 24 building efficiency standards and as is used for evaluation trade-offs between measures in the Title 24 performance approach. Since the solar industry is used to thinking about costs in terms of dollars per peak Watt (Wp), the calculations here are all performed in terms of societal value (present valued dollars discounted over 30 years) per peak Watt.

Since the value of electricity is extremely high during the hot summer afternoons, a west facing panel that produces more of its electricity late in the afternoon generates around 20% more societal value than an east facing panel which generates more of its electricity in the morning. It is for this reason that "solar ready" homes are to have unobstructed designated "solar ready" roof areas facing between 110° and 270° from due north.

The four horizontal lines plotted on Figure 26, represent the installed costs of residential photovoltaic systems as documented in the LBNL report "Tracking the Sun IV" (LBNL 2011). The installed costs we are using in descending order are[39]:

- US total installed costs before incentives and taxes = $6.90/Wp,
- Japan total installed costs before incentives and taxes $6.40/Wp
- Germany total installed costs before incentives and taxes $4.20/Wp
- US total installed net costs to the consumer after incentives = $3.60/Wp,

What is interesting about this analysis is that it indicates that consumers who are taking advantage of the incentives and tax credits associated with photovoltaics will be saving money as compared to the present valued cost of buying electricity to meet their loads as long as they can sell back to the grid all of the power at retail rates. In addition, if we can emulate the experience in Germany and realize the benefits of the economies of scale that Germany has enjoyed, photovoltaics would be cost-effective relative to the societal cost of energy – again assuming that the value of excess electricity produced by the system can be sold back into the grid at retail rates. Germany has taken the policy path of paying for photovoltaic generation at above retail rates called "feed-in tariffs."

Regardless of the ability to sell energy back into the grid, this analysis indicates that purchasing enough PV to reduce one's consumption of electricity without being a net generator is close to cost effective on a societal basis now in some climate zones and roof orientations without incentives. This analysis also indicates that photovoltaics are cost-effective on a societal basis to consumers with the current array of incentives.

If one carefully reads the CPUC Long Term Energy Efficiency Strategic Plan, the definitions for ZNE are somewhat ambiguous. Though the term used is zero net energy, some of the definitions could easily be construed to mean grid neutral. The difference between ZNE and grid neutral definitions are that a zero net energy home exports as much on-site renewable electricity as the total energy (electricity and natural gas) imported, whereas a grid neutral home exports as much on-site renewable electricity as the total electricity (not including natural gas) imported. If the CPUC is expecting that

[39] Costs without incentives are from page 19 (LBNL 2011). The post-incentive consumer net costs are discussed on page 35-36 (LBNL 2011), "In 2010, the capacity-weighted average net installed cost was $3.6/W and $3.0/W for residential and commercial PV, respectively – again, based only on those systems that received state/utility cash incentives and ignoring the potential value of REC revenues generated over the life of the system."

the owners of new homes should be required to install as much photovoltaics as to offset both their natural gas and electricity consumption, it is reasonable for the CPUC to figure out a rate structure that allows one to recoup the cost of this additional on-site renewable energy generation capacity.

The current net metering rule set allows one to export electricity to the grid and to have their bill reduced equivalently to the amount of electricity exported. However, if one generates more electricity in a year than one uses, the excess electricity is "donated" to the utilities and there is no recompense for the extra energy exports. If the state policy goal is that homes are Zero Net Energy and not just grid neutral, some thought has to be given to the possibility of homeowners making money on the net electrical generation opportunity while at the same time keeping the utilities financially viable.

Another tariff rule that is also a barrier to on-site renewable generation is that related net metering of photovoltaic systems on multifamily buildings. The current rule is that a separate PV system must be installed and separately metered for each dwelling unit. A significantly lower cost and resource efficient system would be one where a single large PV system is metered and the amount attributed to each dwelling unit is "virtually metered." This virtual metering is allowed for affordable housing multifamily projects but not for market rate multifamily projects.

In summary, photovoltaic systems can be cost-effective to the consumer by the 2020 target date if efforts are pursued to further motivate expansion of the photovoltaic industry and drive costs down. Setting a cost target and developing a plan to achieve the cost target is a key portion of a ZNE strategy. This will likely involve incentives to spur further activity along the "learning curve," but will also involve a gap analysis, R&D on technologies and processes to fill these gaps, and removing barriers to photovoltaics, which is discussed in the following sections.

3.8. Top-down Path to ZNE in Title 24

The most obvious method of achieving that all homes are net zero energy is to mandate them though the Title 24, Part 6 Building Efficiency standards. All new homes must receive a permit and must comply with Title 24. So that the change would not be abrupt from the current status quo, significant efforts would need to be taken starting now as there are only 3 code cycles left (2013, 2016 and 2019). A gradual increase in energy efficiency and a gradual increase in requirements for photovoltaic systems help the market adjust and allow economies of scale to drive prices down, not just for photovoltaics but also for solar thermal water heating and advanced energy efficiency technologies.

In addition to Title 24, Part 6; California has recently adopted a new building standard, Title 24, part 11, the California Green Building Standard (CA GBS) that contains added environmental requirements such as reuse of gray water and reducing toxics in building materials. This standard has three levels:

- Mandatory requirements – required for all low rise residential and nonresidential buildings.
- Voluntary Tier 1 – more stringent environmental requirements and energy requirements, in the last version of CALGreen these were 15% more stringent than the building efficiency standards (T-24, Pt. 6).
- Voluntary Tier 2 – even more stringent environmental requirements and energy efficiency requirements in the last version of CALGreen these were 30% more stringent than T-24, Pt. 6.

Though Tier 1 and Tier 2 are voluntary, some cities have chosen to adopt these more stringent Tiers and render them mandatory for homes built in their cities. The motivation for these higher tiers are various but often involve adopting these more stringent codes as part of cities' greenhouse gas action plan. Though the CA GBS is relatively new, expectations are that Tier 1 is representative of what the Building Efficiency Standards (T-24, Pt. 6) will roughly look like for the next code cycle and Tier 2 will be a premonition of Title 24, part 6 two code cycles out.

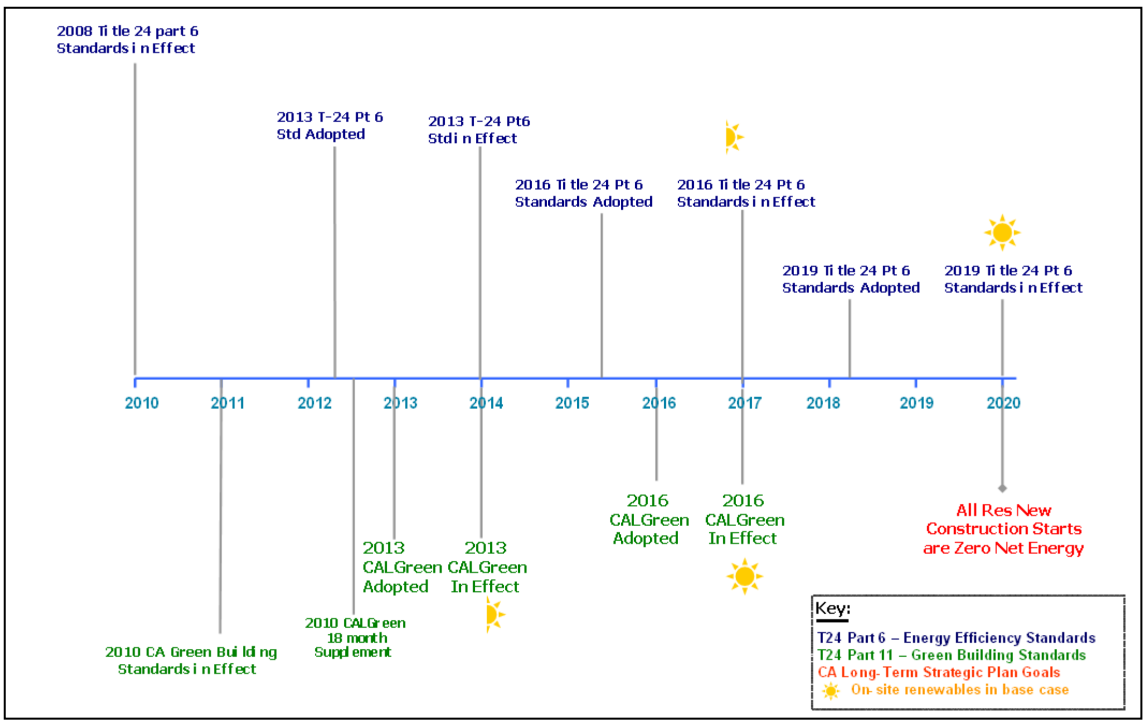

Figure 27: Building Standards Timeline to Net Zero Homes

Figure 27 provides a timeline of the next three code cycles in advance of the 2020 zero net energy milestone for residential buildings. This timeline illustrates a gradual reduction of energy usage and a gradual increase in solar energy production required by the codes. This gradualist approach is projected as the method of least disruption to the

California building market. The proposed roll-out of more stringent standards would focus on the least cost opportunities first (more stringent energy efficiency) and that solar energy will be increasingly required, first in the CA GBS voluntary tiers, and later on in T-24, Pt. 6.

Building energy code (Title 24) is only part of ZNE

Historically for the last couple of code cycles residential energy consumption has been reduced by 15% per code cycle. However, a belief that a path to net zero could be accomplished through modest incremental gains each cycle would likely result in a suboptimum level of investment in energy efficiency. With major end-uses tabulated for new buildings built after 2001, Figure 28 illustrates that only 46 % of electrical consumption in the home is due to products that are regulated by the building code.

Over half of home electricity consumption not covered by T-24

End-Use	kWh/yr	
Not covered by T-24	**3,612**	
Dryer	187	
Clothes Washer	109	
Dish Washer	73	
First Refrigerator	707	
Additional Refrigerator	313	
Freezer	138	
Range/Oven	105	**54%**
Television	645	
Microwave	122	
Home Office Equipment	17	
Personal Computer	602	
Well Pump	28	
Miscellaneous	568	
T-24 + Preempted	**1,106**	
Conv. Space Heating	37	
Heat Pump Space Heating	13	
Aux Space Heating	0	**17%**
Central Air Conditioning	876	
Room Air Conditioning	47	
Water Heating	133	
T-24	**1,927**	
Furnace Fan	164	
Attic Fan	14	
Evaporative Cooling	43	
Solar Water Heating	0	
Pool Pump	234	**29%**
Spa	25	
Outdoor Lighting	284	
Spa Electric Heat	28	
Lighting	1,136	
Total	**6,645**	

End-Use	Therm/yr	%
Not Covered by T-24	**51.4**	
Dryer	16.2	**14%**
Range/Oven	31.7	
Miscellaneous	3.5	
T-24+ preempted	**309.0**	
Primary Heat	175.8	**83%**
Conv. Gas Water Heat	133.2	
T-24	**10.2**	
Pool Heat	5.6	
Spa Heat	2.9	**3%**
Auxiliary Heat	1.6	
Total	**370.5**	

Not Covered by T-24
Plug loads are installed after building inspection and are not covered by T-24

T-24 + Preempted
T-24 is preempted from requiring higher equipment efficiency but T-24 can impact the loads on equipment (envelope eff, controls etc.)

Covered by T-24
Loads and equipment efficiency can be regulated by T-24

Figure 28: 2009 Residential Appliance Saturation Survey (RASS) Components of Energy Consumption for New (post 2001) Homes

Of the loads that are possible to regulate, federal preemption limits 17% of total electrical loads from state equipment efficiency regulation (i.e. only the heating and cooling loads on these devices can be controlled by the California energy code, but the equipment efficiencies must match the Federal minimum efficiencies). Interior lighting is the largest single electrical end-use, but only the portion that is hard-wired can be regulated by the Title 24 building energy efficiency code.

Making use of the 2009 RASS (Residential Appliance Saturation Survey) data for new homes built after 2001, and assuming that a 15% per cycle reduction of T-24 covered loads was possible per cycle, over 4 cycles (2008, 2013, 2016, 2019), would result in a the affected components of energy consumption being reduced to 52% (0.85^4 = 0.52). This would result in electricity consumption being reduced from 6,600 to 5,200 kWh/yr-home and natural gas consumption being reduced from 370 to 281 therms/yr-home. This is a significant reduction in energy consumption, but is not optimized in terms of energy efficiency.

3.9. ZNE Equivalency

Earlier this paper has described why it makes sense to recast the residential big bold strategy as follows: "All new residential construction in California will be zero net energy or equivalent to zero net energy by 2020." Without the concept of equivalency, the simple to understand concept of Zero Net Energy would be watered down to account for all sorts of exceptions so the policy requirement would be achievable for all new residential construction. Every new residential dwelling unit can have high levels of energy efficiency but not all dwelling units have access to a sufficient area of solar exposure to generate the residual amount of on-site renewable energy to be net zero. So what is equivalent to a zero net energy home? What are the societal benefits we are trying to get out of ZNE?

We think this can be summarized as: carbon reduction, air quality, reduce the size of the energy infrastructure and promote distributed renewable generation. The relative importance of these things will undoubtedly be debated and thus the nature of trade-offs should be started soon. There are other aspects to building housing that impact the long term energy consumption of the occupants.

The most evident consideration on equivalency is that it would take the form of paying for the installation of a new renewable energy system on another California building. This is similar to environmental offsets where one can conserve so much sensitive habitat as an offset for building in other sensitive areas. By making sure the residual energy consumption is served by relatively small systems on a building site, we help assure that one of the other objectives of the BBEES is accomplished, i.e., the volume of on-site installed renewables systems are large enough to maintain the economies of scale that are driving down system costs. Thus paying into a fund that helps defray the cost of utility scale renewables may not help achieve the goal on driving down the costs on building scale renewables. Part of the desire to have distributed renewable generation is to also reduce the loads on the transmission and distribution infrastructure.

However there are perhaps less obvious but also very important other energy offsets that might be considered as equivalent including:

- Location efficiency (see the section on Embodied Energy and Transportation Energy)

- Water efficiency
- Other technology deemed to provide equivalent benefit

Many issues would have to be carefully considered as the state gets closer to the development and adoption of the 2019 Title 24, part 6 standards. For example, conditions that would allow equivalency via off-site renewables, details around geographical location and the timing of construction for qualifying off-site renewables systems. We expect that implementation of many of the intermediate steps towards the realization of ZNE goals will help inform the rules on ZNE equivalency. Thus research on equivalency and how it meets the multiple motivations of ZNE should be initiated soon as these issues will likely take some time to sort out.

One of the issues is whether equivalency is something that can be applied right away (e.g. for an infill project with high location efficiency or where an off-site renewables project might be cheaper) or whether equivalency is something that can only be applied after the designer has shown that ZNE is not feasible or counter-productive.

3.10. Reach Codes

Historically there have been some jurisdictions that have set their building efficiency standards to a higher level than the state building standards. These jurisdictions have "reach" codes that are often adopted so the city can be meeting their greenhouse gas objective or other environmental goal. Title 24, part 6 (building efficiency standards) specifically has a procedure in place so that local governments can adopt and enforce their own energy code if they can show that it is indeed equal or more .stringent than the state energy code.[40] Many of the cities who have adopted such a reach code of selected Build It Green, a checklist based standard that includes a third party inspection.

CALGreen, the California Green Building Standard (Title 24, part 11) started out a voluntary standard and currently has two portions: a mandatory portion and a voluntary portion. The mandatory portion is required of all new California buildings. The mandatory standard is primarily focused on water conservation, site issues and limiting toxic materials in building construction. The voluntary portion can be used as a procurement standard or as a rating to differentiate a building as being "green." However cities can adopt the voluntary portion of the standard and make it mandatory for their city. The voluntary portion of the standard has two tiers: the tier 1 of the standard has additional water and toxics requirements it also requires that the home exceed the performance approach by 15%. Tier 2 is more stringent and requires that the home exceed the performance standards by 30%.

Moving forward however it makes sense that the tier 1 be representative of the minimum efficiency level that would quality for a utility whole home efficiency incentive, tier 2

[40] Section 10-106 Locally Adopted Energy Standards. Title 24, Part 6.

reach codes be representative of what the required energy code (T-24, part 6) will be in one code cycle out and a new ZNE tier be representative of the what the energy code would be is 2020 (2 code cycles from the 2013 standard). Tier 1 would be representative of a code that that has adopted a major cost-effective efficiency measure (such a ducts in conditioned spaces) and tier 2 would be representative of all cost-effective measures plus renewable energy savings that is equivalent to the savings from all cost-effective high efficiency equipment that are currently federally preempted. The reach code voluntary tiers acting as preview of the next building efficiency standards requirements is graphically represented in Figure 27 in the earlier section on a *Top-down Path to ZNE in Title 24.*

3.11. Appliance Efficiency and Standards

As is shown in Figure 29, approximately 66% of electricity loads and 99% of natural gas loads are preempted by federal appliance standards. Federal preemption prohibits selling products that are less efficient than the federal equipment efficiency regulations but federal preemption also prohibits states from setting higher efficiency standards in state appliance regulations and in state building codes.

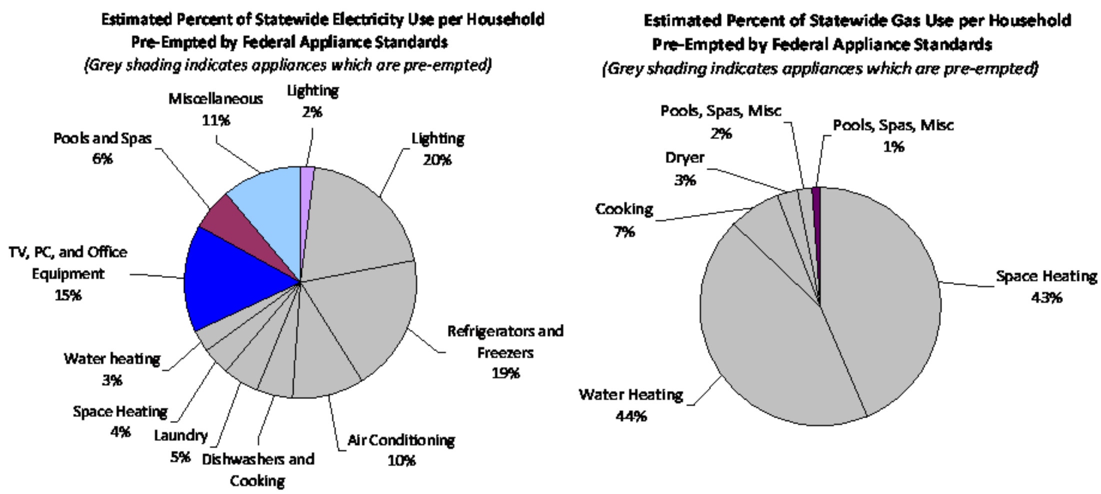

Figure 29: Residential equipment energy consumption pre-empted by Federal Appliance Standards

Given that appliance energy consumption is such a large part of overall residential energy consumption, all efforts to reduce appliance energy consumption must be pursued. This would include interventions in state energy standards, federal energy standards and in appliance markets as described below:

1. Develop stringent state appliance efficiency regulations for appliances that are not currently covered by federal efficiency regulations such as: televisions, computer equipment (computers, monitors, printers, servers etc.), pool and spa equipment.
2. Collect appliance efficiency research and advocate for higher efficiency standards at federal appliance rulemakings. For some commercial equipment, one can also advocate within the Standard ASHRAE 90.1 mechanical committee. Once higher efficiencies are adopted for commercial equipment, state codes can recognize these hither efficiencies and DOE has to make a determination to adopt the ASHRAE standard of a higher efficiency standard.
3. Transform the market for higher efficiency appliances through research, demonstrations projects, marketing and incentive programs

Additional appliance savings are possible by making sure appliances are turned off and disconnected when they are not used. Thus plug load controls based on occupancy sensing of time based schedules can reduce energy consumption. Thus plug load controls were proposed for this last standards update but were rejected as there was not sufficient evidence that they were cost-effective. Thus field research on the energy savings and cost effectiveness of residential plug load controls is needed to take this technology in to the building efficiency code.

3.12. Collision with Federal Preemption

As the State of California tries to adopt the most cost effective path towards zero net energy homes, it is thwarted by Federal preemption of energy efficiency standards. The National Appliance Efficiency and Conservation Act (NAECA) explicitly preempts State regulations which would require higher efficiency appliances either in State appliance efficiency regulations or as part of a State building efficiency code.[41] This has been a huge barrier to adopting more stringent cost-effective appliance or building efficiency standards

The Federal appliance efficiency standards are updated approximately on a 10 year cycle. In addition, once the standards are adopted, they do not take effect for at least another 3 years. The Federal appliance standards are limited to considering what is cost effective for the entire country and thus will typically fall short of what can be cost-justified in California. Modification of the preemption terms of NAECA so that it is only the floor for energy efficiency but not the ceiling, would provide significant assistance towards fulfilling our goal of cost-effective net zero energy

California is not alone in its efforts to transition to higher levels of energy efficiency. The financial and environmental benefits are attractive to other states as well. At this

[41] § 6297. Effect on other law http://www.law.cornell.edu/uscode/html/uscode42/usc_sec_42_00006297----000-.html

writing 11 other states have state water efficiency or energy efficiency appliance standards. [42] As the state with the largest population, California has 53 out of the 435 seats in the US House of Representatives. The first step is for the California delegation to Congress to speak with one voice that limiting the right of states to set higher efficiency standards is not in the national interest and thus should be modified. The next step is to develop alliances with other states that also have their energy efficiency and greenhouse reduction plans thwarted by federal preemption. Finally this consortium should write and pass modifications to the NAECA and EPACT that would allow states to have appliance and energy codes that exceed federal minimums.

The following describes common arguments for federal preemption and responses to these comments.

Comment: *If states can set their own standards this will lead to a proliferation of standards. Potentially there could be 50 different state standards; this would make stocking equipment extremely difficult.*

Response: Developing a state appliance standard takes a significant amount of resources, so this is not done lightly. In addition, a state that is pursuing a higher efficiency standard is doing to transform the market for that product. If possible advanced standards make use of pre-existing high efficiency levels such as those that are developed by efficiency organizations such as CEE (Consortium for Energy Efficiency) or those promulgated by other states. If this is the main concern one could address this by requiring that higher level standards have to be adopted by areas representing at least 10 Million people. Smaller areas could also adopt the same standard adopted by a larger entity for form a collation of several smaller states to adopt a standard.

Comment: *Extremely high equipment standards could significantly change the trade-off in the replace or repair decision. Thus this could delay replacement for an extremely long time and economically damage equipment manufacturers who are counting on a replacement sales. In addition this could hurt efficiency goals as the extremely old piece of equipment could consume significantly more energy than the moderately efficiency piece of equipment allowed by the federal standards, if a more stringent equipment standard were adopted, less equipment would be upgraded and thus less overall energy savings.*

Response: This argument is made for larger pieces of equipment where it is worthwhile to repair equipment. This does not apply to smaller pieces of equipment where the relative cost of repair and where increased innovation reduces the value of the older technology (like old computers, TVs etc.) If this is the main concern this could be addressed in the energy code themselves where separate standards apply to new

[42] States that have their own standards include AZ, CT, DC, GA, MD, NV, NH, OR, RI, TX and WA. Many of these states are adopting the same higher standard. Appliance Standards Awareness Project (ASAP) *State Standards*. http://www.appliance-standards.org/states

construction versus alterations. Thus there is perhaps a compromise position that addresses this issue without preempting requirements for new installations.

Responding to Federal Preemption in State Building Codes

When the federal energy regulations were developed the legislators foresaw that states would want to exceed the federal minimums when they had good cause. As a result, this legislation has language to the effect that states can petition the Department of Energy for a waiver to federal preemption. So far there have been three waivers submitted and none have been successful. The process is extremely slow, the requirements are very onerous and it is unlikely we would get a response prior to 2020 for a petition initiated now.

However a number of states and the IECC (International Energy Conservation Code) have developed a method to require higher than minimum federal equipment efficiency requirements. The approach is to have multiple paths to compliance so that for each approach that uses higher efficiency equipment there must be another approach that uses standard efficiency equipment and uses similar amounts of energy.[43] In the 2012 IECC there are three pathways to compliance:[44]

1. High efficiency HVAC equipment (if this requirement was by itself this would violate preemption)
2. Lower lighting power density lighting requirements
3. Provision of 0.5 W/sf of renewable generation.

For the 2016 Title 24, part 6 building codes, we recommend that a similar approach be pursued. Such an energy code would include all cost-effective energy efficiency measures along with an amount of prescriptively required photovoltaics that can be displaced with higher equipment efficiencies that can be shown to be cost effective. Regardless of which path is taken for compliance the state achieves its goals.

- If the designer selects the path with equipment that only meets the federal equipment minimum efficiencies and also installs an on-site renewable energy system, this furthers the state goals as this helps prepare the building industry for ZNE homes and helps create the volume demand that drives down prices.
- If the designer selects the path with higher equipment efficiencies (the lower cost path), this results in similar net TDV energy consumption, increases the volume of the high efficiency products sold and ultimately helps drive the prices down for high efficiency equipment.

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[43] USC Title 42 §6297(f)3(E) text can be accessed in the Appendix C: Federal Preemption section in the appendix of this report or at http://www.law.cornell.edu/uscode/html/uscode42/usc_sec_42_00006297----000-.html

[44] Section C406 *Additional Efficiency Package Requirements*. 2012 IECC

Both of these efforts propel the market forward towards what will ultimately be required for ZNE homes. This helps buy time for the ultimate showdown with preemption in 2019. During the intervening years, progress made helps built a constituency among all participants in the market for letting California solve its energy and environmental problems and lead the world towards a green energy future.

3.13. Forward Looking Research

The first step to pursuing an R&D agenda that supports energy innovation is having the funding that makes this possible. The Public Interest Energy Research (PIER) program has in the past sponsored energy research that has ended up in California homes. With the expiration of the public goods charge, PIER's funding is drying up. The program is able to sponsor a last round of solicitations with an uncertain future. If the public goods charge is not reauthorized or other funding source not found the PIER program will dissolve.

Starting up the organizational structure elsewhere would take time and create a gap in continuity of the current research program. Thus developing a new funding mechanism for PIER is a critical step for achieving the research discussed below.

Energy research is needed on new products: characterizing the energy impact of emerging products, design practices, customer acceptance and use. Besides traditional definitions of efficiency also consider how energy consumption information and utility rate structure impacts occupant behavior. The following list reflects residential energy efficiency issues that came up during the 2008 Title 24 code development process

- Follow-up on ducts in conditioned space - field survey of costs and methods of implementing this measure. How are designers addressing atmospheric furnaces or should they be used at all? Series of example plans and if possible performance information.
- Research on cathedral ceilings: moisture issues in ventilated and unventilated cathedral ceilings, impact of cathedral ceilings on appraisal value and sales price.
- Infiltration testing in multi-family buildings. Methods of calculating energy impacts from infiltration tests. Validation with measured energy consumption data.
- Focus group testing of consumer acceptance of LED sources for bathroom vanity lights, kitchen lighting, and down lights. Product development and evaluation project. These are the sockets with the most energy use in residences
- Development of a test method for flicker and application to dimming LEDs, dimming fluorescent and dimming HID.
- Mechanical ventilation of homes: impact of various implementations of ASHRAE 62.2 methodology depressurization versus pressurization of homes, continuous ventilation versus "smart ventilation" strategies on pollutant levels and energy

consumption. Trade-offs of energy and indoor air quality for various filtration levels.

- Revisit drain-down solar systems with improved electronically actuated valves and method of rating electronically actuated valves for longevity.
- Field study of air sealing to 3 ACH 50 and lower. Methods of speeding up test and methods of increasing the efficiency of sealing teams. Development of construction details and field guide.
- High slope cool roofs. Selective reflectance tile glazings - standard color space with increased solar reflectivity. Increased solar reflectance of asphalt tiles while maintaining a wide range of color space.
- Insulating roof decks as a retrofit opportunity in hot climates. Evaluate the energy impact, longevity, application issues and costs of different methods or insulating roof decks with and without re-roofing. Evaluate the feasibility as a standard retrofit opportunity for programs and energy codes.
- Technical evaluation and field tests of super-insulated continuous insulation applied to exterior of buildings. Current codes limited by feasibility of adding more than 1 inch of exterior insulation to walls - more would be cost-effective in hot climate zones.
- Technical evaluation and field study of adding mass to homes. Simulation study and physical test of adding mass to residential homes. Impact of using 5/8" drywall and 2 layer 5/8" drywall instead of 1/2" drywall.
- High speed, low cost, high efficiency whole home upgrades and ratings. Bringing process efficiency to efficiency upgrades.

3.14. Expand ZNE Market Transformation Programs

As described in the introduction there isn't a better time to make the transition to a zero net energy economy. Interest rates are low so it costs less to invest in technologies that make recurring payments over the long term. New construction activity has been the lowest it has been in 70 years with only 45,000 dwelling units built last year and 36,000 units built the year before as compared to the 1998 to 2007 average construction rate of 148,000 units/yr. Thus this is a prime time to transform the market; an aggressive ZNE program now, over the next three years would cost approximately $325 Million.[45] A similar program with similar market penetration under average market conditions would cost $1.1 Billion. Currently in the middle of this recession, there is an oversupply of photovoltaic production capacity and a concerted effort could convert this opportunity to propel the experience further. Efforts now could transform the residential construction market for a lower cost than any time in recent history, help stimulate the housing industry with a clearly superior product (ZNE residences), increase construction employment and place California on the road to a more sustainable economy.

[45] Assuming 40% participation and a $6,000/dwelling unit program cost

So what would such a market transformation program look like?

- Program entry would be streamlined so participation cost is low
- Include utility marketing and branding of ZNE and include the California Whole-House Home Energy Rating so that builders would want to participate not only for the money but also for the marketing benefit.
- Focus groups would collect customer preferences that could be used to develop information on potential marketing approaches.
- Advance notice would be given to builders that participating new subdivisions over a certain size would have to have "solar oriented" street layouts
- Design expertise would be provided on a broad range of topics.
- Data would be collected on a wide range of factors (technology, financing, permitting issues, codes, interconnection etc.)
- Barriers to projects would be tracked and the resources of the program brought to bear on commonly experienced barriers.
- Key technologies identified and efforts to bring down technology cost investigated (mass procurement etc.)

3.15. Backwards Looking Research

This research looks backwards at ZNE or near ZNE buildings and learns from the experiences to date.

- What technologies are and building design practices are typically used to achieve ZNE? What are the current costs and what area the cost trajectories?
- What can we learn from other advanced building systems (i.e. passive house)?
- What financial vehicles are used to sell ZNE? Is a ZNE house an all-around premium product of does the builder try to t offset the added cost of energy features by removing other features? Are energy efficient mortgages or other special financing pursued?
- What are we finding in regards to how people use their energy in ZNE homes? Do they use more or less as compared to a person in a convention house?
- Are systems working the way we predict? As we get close to zero do the standard modeling tools work well? What is the level of error in the tools?
- Are there gaps in current design tools that render design of these homes more difficult than they need to be?

- Are energy codes and utility interconnection rules creating any barriers for solar installations?

3.16. Legislation and Roadblocks to ZNE

In addition to positive requirements for ZNE homes, it is also important to identify and remove obstacles to renewables and energy efficiency. This includes covenants against clothes lines, solar collectors on roofs or even light colored roofs. Identify permitting and regulatory barriers to use of renewables. One such barrier that has been identified by CBIA is the lack of consistent fire code regulations on the amount of access that is required around photovoltaic systems on the roof. Having a single requirement statewide could simplify the design process for large builders that are building in multiple jurisdictions.

Methods of streamlining the permitting and fees associated with photovoltaic systems should be evaluated. In some jurisdictions the fees are proportional to the cost of the installation. Given that PV systems are relatively expensive this also renders the cost of permitting fees high for some jurisdictions. A cap on these fees is warranted, especially if the system is processed as part of an expedited permit process.

Considerations should be given to an expedited permit process that can be adopted on a statewide basis.[46] This expedited process is intended for standard small systems less than 15 kW. The purpose of this process is to, "simplify the structural and electrical review of a small PV system project and minimize the need for detailed engineering studies and unnecessary delays." The building standards commission should review this proposal, and modify it so it is compatible with the California Electrical Code and compatible with California structural and seismic code requirements.

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[46] Solar America Board for Codes & Standards. **Expedited Permit Process Report** http://www.solarabcs.org/about/publications/reports/expedited-permit/

3.17. Impact of ZNE on the Energy Delivery System

Identify and quantify the total impact of ZNE on the energy delivery system including licensing and relicensing of power plants, effect on T&D system capacity requirements and how this interacts with likely trends (smart metering, real time rates, smart grid, growth of electric vehicle loads, etc.)

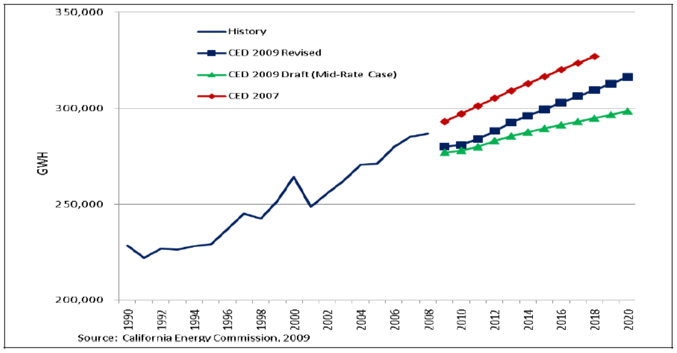

Figure 30: Forecast of Electricity Consumption (CEC 2009b)

At first glance, one might be under the impression that the ZNE policy would in the near term reduce the utilization of the power grid and decrease the revenues to the utility companies. Surely this strategy would reduce the growth of the energy supply system and that reduction in growth is one of the financial benefits to the state. Ultimately increasing the growth in the energy supply system is something that has to be paid for with increased outlays (admittedly from a larger population).

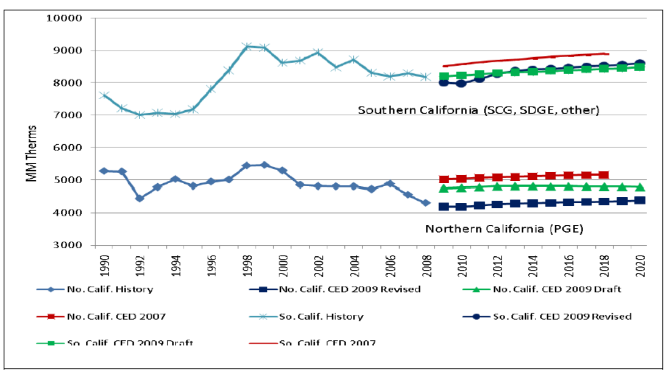

Figure 31: Forecast of Natural Gas Consumption (CEC2009b)

The average annual growth rate for electrical consumption over the time period between 2010 and 2018 is predicted by the CEC to be 0.74%. Similarly for the time period between 2010 and 2018, the annual average growth rate for natural gas consumption is 0.4%. With a little more than 1%/yr of the residential building stock being upgraded to ZNE after 2020, this is not going to bring the financing of the electrical or natural gas systems to their knees. What should be noted is that these estimates include the recurring savings from appliance and building energy efficiency codes and the energy efficiency programs operated by the IOUs through 2012. In addition this estimate predicts that statewide consumption of electricity for electric vehicles will be 4,400 GWH hours by 2020 based upon 1.5 Million plug-in hybrids in use by 2020 (approximately 5% of the 25-30 Million cars in service by 2020.

In addition to predicted growth of energy consumption, significant investments in the electricity supply system will be occurring over the next 15 years. The Zero Net Energy Strategy if applied to both new and existing homes could result in deferred or fully obviated investments for power plants that will be exceeding their design life. The timing of the energy efficiency and renewable generation goals are also synergistic with the California State Water Control Board Resolution No. 2010-0020 (CSWRCB 2010) which would phase out once through cooling at the 19 coastal power plant complexes with a total 21 GW of capacity (ICF Jones et al. 2008) over the 2010 to 2029 time period. The cost of upgrading the power plant cooling system from once through cooling to wet cooling (cooling towers) range between \$2.5 Million to \$108 Million per site. In some cases it may be cheaper to upgrade transmission to out of state generators. However this is also expensive and as shown in Figure 32, would require upgrading of transmission systems across the state to replace power plants on the coast. On-site generation along with demand response may be the cheapest and mostly timely method of replacing lost capacity. Some of this cost can be avoided if a combination of energy conservation and distributed renewables result in a decrease in load and a plant can be mothballed rather than retrofitted.

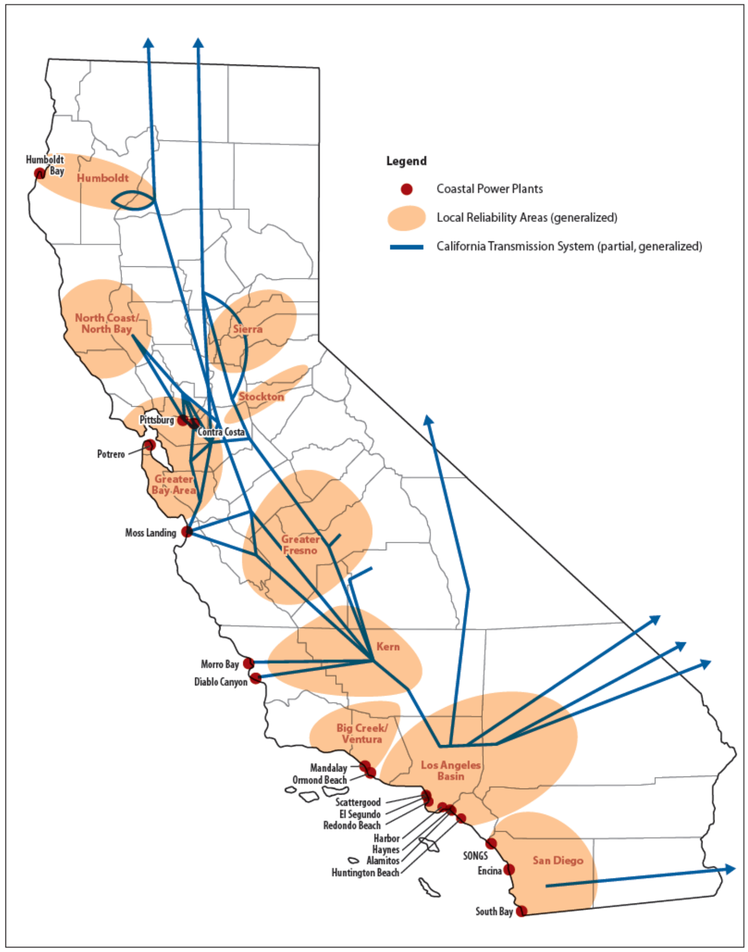

Figure 32: Power plants with once through cooling targeted for cooling system replacement

Nonetheless, understanding how this ZNE policy will impact the costs of the energy generation and delivery systems will be important so that California captures the synergies between the incumbent technologies and the new technologies that are being integrated into the energy system.

4. Summary of Interviews

4.1. Sample Frame of Interviewees

Since our sample of interviewees was relatively small (22) we tried to get a broad cross-section of opinions by having a stratified sample of people who would represent different stakeholder groups. These groups included staff at California government state agencies, green rating organizations, California utility staff who are working on developing zero net energy pilot programs, a DOE program person, ZNE home builders, consultants who worked for the DOE Building America program, other low energy building designers, staff at photovoltaic equipment and installation companies, a realtor, and a building industry representative.

Most of the interviewees did not complete the entire interview as the interview was fairly long. In addition, for many of the interviewees, they either did not have the expertise or they otherwise did not have an opinion about some of the questions. Thus the responses here capture the range of thoughts on different topics and in a few cases capture where there was consensus.

4.2. How broad to define the circle?

This question concerned itself with the question of how broadly should one consider the site for "on-site renewable generation." The renewable energy that offsets site consumption, how far away from the home could it be? Does the renewable energy system have to be on the individual house site, on the same development, the same city or the entire state? Most of the respondents indicated that having renewable generation in the same development was the appropriate balance between flexibility, cost, and proximity. A few thought a broader approach should be allowed, such as the entire state or the regional area similar to the regions defined in SB 375. One respondent felt that requiring on-site renewables would be racist as it would be penalizing folks who live in multi-family housing in the city.

4.3. Added value of site generated electricity

The interviewees felt that one of the main benefits was one of "conspicuous conservation." Other positive benefits were the marketing advantage for the home and that local communities might be more supportive of a new development if it had solar on it and was "green." A number of interviewees also indicated that site generated electricity would increase grid stability and reduce the amount of transmission lines and transmission losses. Some thought that building integrated photovoltaics (PV) would reduce the land impacts of centralized power generation.

Negative attributes of site generated electricity were primarily concerning the relatively high cost of PV and some thought that small scale PV would have an overall higher cost that larger centralized photovoltaic systems. Other concerns were that solar system on roofs might be shaded or have maintenance or safety problems.

There was relatively broad agreement that institutional barriers to community level generation and especially for centralizing PV installations for multifamily systems are a problem. There was broad agreement that large systems in multi-family occupancies should be able to be virtually metered so that these systems could be placed over common areas or on carports and still be used to reduce utility bills for multiple tenants and be considered as an offset to the energy consumption of multiple dwelling units in the ZNE definition.

Most people thought that site generated PV was OK after all cost-effective efficiency measures were adopted first. Most people believed that in most cases that energy efficiency would be pursued first before adding photovoltaics. The overall consensus was that it was important that high levels of efficiency were implemented before investing in renewables.

There was no consensus on whether the installation of a renewable energy system would impact energy consumption behavior. However a number of people thought that if energy monitoring was included with the renewable energy systems that an energy display would impact how people use energy including turning off equipment with high standby loads.

With PV systems covering the some of the surface area of the roof, interviewees were asked the question if the presence of PV's had an appreciable impacts on the rest of the house. Most respondents though that the impacts on other aspects of the house were negligible. Only a few respondents thought that the presence of PV panels would have any significant impact on thermal loads or the longevity of the roof. It was noted that most PV systems were installed with stand-offs, and were not building integrated PV (BIPV) and as a result there was no reduction in roofing materials and roofing would cost the same.

Most of the interviewees thought the presence of PV on homes had little impact on its perceived aesthetics. Some thought that over time PV will only become even more aesthetically acceptable as more PV systems are installed.

Of the interviewees that responded most thought the presence of a PV system increased the value of the home. The few dissenters were unsure and thought there should be some research on whether the presence of a renewable energy system does increase the resale value of a home.

4.4. Trade-offs between PV and EE in codes

Most of the respondents were opposed to allowing trade-offs between energy efficiency and renewables in the energy code. Their position was that energy efficiency is more cost-effective and should be fully pursued in advance of adding renewables. Thus it would not make sense to allow renewables to displace energy efficiency.

This author actually disagrees with the position of the majority. There are some times where aesthetics or feasibility would provide a compelling argument to allow renewables for limited trade-offs. One example might be to allow greater window area (for view) in return for installing more efficiency measures or a renewable energy system.

4.5. Building Technology Paths

In summary the technologies described are higher levels of efficiency and make up the rest of the energy consumption with photovoltaic systems. Experiences with the Building America program indicated that common designs reduced energy consumption by 50% - 60% with energy efficiency and then added PV systems. The added efficiency measures required included:

- Ground source heat pumps
- Eliminating HVAC ducts or placing them in conditioned space
- Demand response and other smart controls to control HVAC, lighting and plugs
- Improved windows
- Heat recovery ventilators
- Night ventilation
- Improved design and orientation
- Home energy management controls with energy use display
- High efficacy lighting
- Cool roofs (high reflectivity and high emissivity)
- Increased insulation for walls and attic (often requires at least 6” walls and exterior insulation)
- Air sealing as validated by blower door
- High efficiency HVAC and domestic hot water
- Compact piping design with low volume piping (manifold piping system)

4.6. Design and Construction Techniques

Responses to this question brought in about as many different replies as there were respondents. However many of the respondents mentioned good site orientation. One respondent said that site orientation was important but that with high performing windows (low U-factor and low SHGC) orientation becomes less important. The use of or need for good design software was also mentioned. Attention to details was also mentioned. A couple of respondents thought that a good way to pay closer attention to details was to consider alternatives to site built homes (i.e. pre-manufactured housing). One designer talked about how it was hard to find small enough heating and cooling equipment for low load buildings. The consensus was that the energy efficiency measures were already available but that it required a different mind-set that treated energy as it were important.

One of the key barriers to greater efficiency in homes and ZNE homes was a way to clearly differentiate these homes from the rest of the homes in the market. Some felt that common design practice was resistant to change as change could result in liability in a market place that really does not value energy efficiency or ZNE. One respondent summarized the effort as follows: *"The challenge is getting ZNE homes into use in the marketplace, developing consumer demand, demonstrating the non-energy benefits. It's more of a social acceptance issue than a technology issue."*

Looking towards the future, systematic problems in the housing industry is due to lack of education of designers, contractors and the consumer. Thus ZNE education is required in architecture schools, contractor training programs, realtor training and finally marketing to the consumer.

4.7. Transportation

As described in the Section of the report on Embodied Energy and Transportation Energy, at least 2/3's of energy costs are dedicated to transportation. Given that transport has such a large impact on energy use and energy cost, it begs the question whether a Zero Net Energy Home should include the impact that the location of a home has on the energy consumption of its occupants.

The overwhelming response from most of the respondents was that the definition of ZNE should NOT include embedded energy whether it is embedded energy in water, construction materials or transportation. The rationale was that as an initial goal, the ZNE definition should be kept simple and applies only to the energy consumption of the home and its inhabitants (i.e. energy for heating, cooling, water heating, cooking and appliances.)

However a significant fraction thought there should be credits given for location near mass-transit for planning approvals. It should be noted that these questions were developed before we had developed the policy proposal that "All homes should be Zero

Net Energy or equivalent by 2020." Clearly there was desire to keep the ZNE concept simple but many respondents recognized how important transportation is to California's overall energy consumption.

4.8. Density (Multifamily vs. Single Family)

In its simplest form ZNE is often thought of as a very energy efficient single family house with a solar system on the roof to generate the remaining amount of energy needed. If one applies this concept to multi-family housing, energy consumption per units is decreased due to smaller floor area and lower ratio of exterior wall area to floor area. However as multifamily buildings get taller there is less roof area to support a large enough solar system to provide all of the energy needed of the inhabitants below. Yet more compact housing not only reduces the occupants' energy footprint it conserves land area and increases location efficiency. Given the clear societal benefits of high density housing we raised the question of whether there should be some credit for or dispensation for high rise multi-family housing in terms of what is considered ZNE.

Responses to this question were split. Some felt that yes there should be some relaxed definition of ZNE for high rise multifamily such as renewable generation providing only 25% of remaining energy consumption after energy efficiency measures are applied. As shown in Figure 33, some felt the ZNE concept was inherently flawed as it was a suburban-centric view of zero energy footprint.

However about half of the respondents felt that an exception or a reduction in what zero is should not be applied to multifamily buildings. If such a credit or relaxing of the renewable generation requirements were applied these respondents though that this would be diluting the message of what ZNE is. However these more hard core respondents also thought that current net metering requirements were unnecessarily burdensome. At the time of the survey, net metering was only allowed if the photovoltaic system was separately metered for each dwelling unit. This results in the technically unnecessary cost of multiple inverters, balance of system (inverters, protective devices etc.) and meters for a system that could be metered as a single system and the credits allocated mathematically to each dwelling unit. Since this time the CPUC has made the finding that multi-family affordable housing can have a single meter for the solar system and the benefits allocated to each dwelling unit. However this solution is currently not available for market rate multifamily housing.

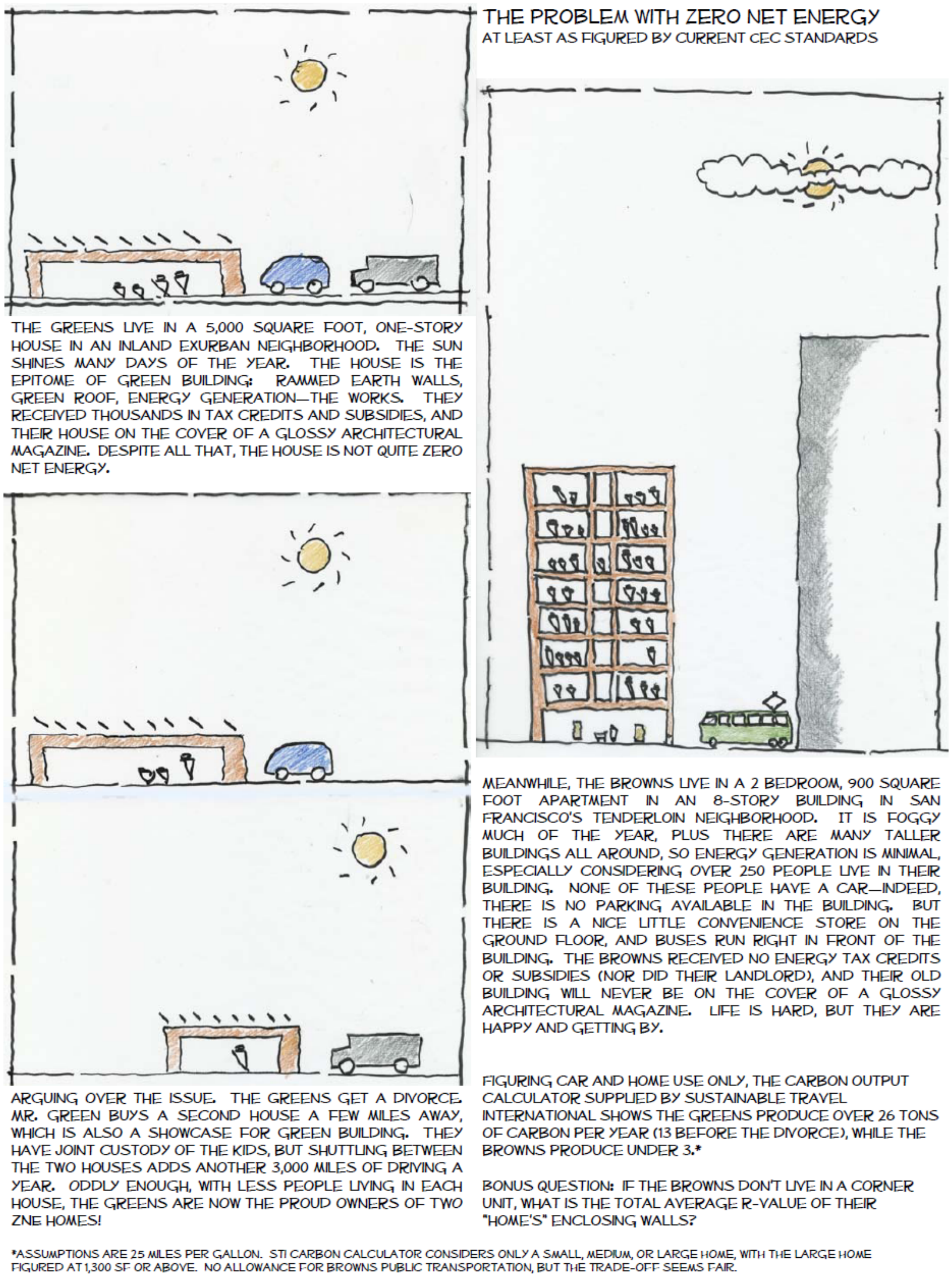

Figure 33: Cartoon "Browns vs. Greens" (Larry Mayers)

4.9. Economics, financing and appraisal

A couple of the participants indicated that ZNE homes cost approximately 20% as compared to a standard home. Many people will not be living in their home long enough to fully amortize the added cost of the efficiency and renewable energy additions. When they are ready to move, it is not clear that the house will be appraised at a high enough value so the first cost is recouped. As one respondent commented, *"Appraisers are running around like scared rabbits. They're afraid of their own shadow because of the whole foreclosure debacle. They're in fear of the liability they're going to incur if they give the wrong number. In order for the retrofit and new construction business to be successful, if you're going to install energy efficiency, there needs to be recognition that it has increased the value of the house."*

However others described progress on the appraisal front, with efforts on a third party underwriting methodology for high efficiency homes. Also another mentioned an internal Fannie Mae study that indicated that EnergyStar homes had an 11% lower default rates than other houses in the zip codes. Ultimately this lower risk could eventually be reflected in lower interest rates or higher qualifying amounts for the same income. Several respondents had hopes for PACE (Property Assessed Clean Energy) financing. The PACE financing model [new regulations that allow PV purchases to be funded through loans paid back via property taxes] has a lot of promise for existing homes and something comparable could be developed for new homes. Right now it's hard to get home owners to invest in something with a 10-20 year return on investment when their planning horizon is 3 to 5 years but PACE model could help with that.

In summary the key recommendations for improving financing of ZNE homes included:

- Documentation of the economic case for ZNE (first cost, reduced energy costs, maintenance costs, and resale value)
- HERS ratings of ZNE homes and comparison to bill impacts
- Training of real estate and financial industry to the financial considerations for ZNE homes.
- Special financing that accounts for reduced utility bills. Also PACE or other financing mechanisms that provide low cost financing of energy efficiency and renewable energy features.

4.10. Consumer demand, value of net zero

The primary reasons listed for consumers wanting to buy ZNE or green homes included:

- Lower to no utility bills
- Stable utility bills especially for retired people
- Reduced environmental impact.
- Improved comfort and quality of the home

One respondent suggested we look at the opinion reports published by the Sheldon Group on green homes. Some of their findings included:

- 2/3s of consumers would pay a 10% increment in cost for homes with green features and 9% would pay 30% more for a home with green features.
- The green feature most recognized is the most expensive – photovoltaics.
- A significant number of people are purchasing green products – not to save the planet but to protect their family from toxics or to save money. These people are called "accidental environmentalists."
- 40% of people are interested in buying a certified green home

4.11. Institutional Barriers

Title 24 Energy code. A few respondents thought that Title 24 was too inflexible in that it did not allow trade-offs between energy efficiency and renewables. However this is somewhat at odds with most respondents saying earlier in the survey that energy efficiency should be maximized and only after energy efficiency was maximized that solar should be used.

Planning Commissions. Subdivisions no longer planned for grid layout, as a result less solar access than in the past. Some planning commissions want complex roof lines with gables etc. which makes installing solar more difficult and more likely that solar is shaded. Simpler roof profiles are better for solar access.

Utility or Rate Barriers. Currently one cannot be a net generator. This CPUC policy is in conflict with the CPUC goal of Zero Net Energy (as compared to a Grid Neutral goal). Even if one is not a net generator, if one is getting close to grid neutral – they are getting paid at the low energy tier rates. Related to this is no real time rate for renewable energy exported to the grid. Group net metering not allowed for market rate apartment buildings where single large solar system is placed on top of carports or common areas.

Other barriers. Non-uniform implementation of Zero Net Energy. One-upmanship by municipalities chases people out of municipalities with harder to achieve definitions of ZNE.

HUD policy is based on first cost and not life cycle cost. They will pay for AC but not sunshades that would obviate the AC.

No trained and educated workforce to install HVAC right, no path to training these workers.

Consumers don't want to pay for ZNE and State doesn't have the money to pay for it.

4.12. Three Code Cycles to ZNE

Because of the length of the interview about half of the respondents did not answer what they thought the Title 24 path to ZNE might look like. The following table captures that the remaining respondents though the path to zero might look like in Title 24.

Table 2: Survey Responses – Path to ZNE in three Title 24 code cycles

2013	High AC baseline, streamline code for less trade-offs	Voluntary standards so industry can see what ZNE would look like	Energy Efficient Envelope	Cap based on 2500 sf home max x kBtu and allow PV trade-offs	Three codes is realistic only if the market has recovered.	Incentivizing energy efficiency more	plug loads, efficiency,
2016	Compressorless cooling, evap cooling, passive design and orientation, better windows	Identify which things worked and were cost-effective	Site zero emissions	Net zero electricity		more reduction of peak loads, more renewable onsite production	water conservation
2019	No traditional forced air systems		Carbon neutrality	Net zero energy			Efficiency measures that guarantee cheap bills, including peak load

5. Conclusions

CPUC/CEC should define ZNE and ZNE policy ASAP

The CPUC ZNE definitions focus group identified the choices but was not able to reach consensus on a majority opinion definition and redefinition of the residential big bold strategy. However a decision has to be made so that there is clarity about the direction of ZNE programs, ZNE marketing and ultimately a ZNE action plan. With only 8 years before the 2020 goal, waiting another 3 years to define ZNE would not show clarity of purpose.

CEC should address SMUD's issues on Societal Cost (TDV)

Time Dependent Valuation is the basis of the performance approach in Title 24, the basis of the California Whole-House Home Energy Rating and, if the proposed definition is accepted, the basis of ZNE. The Sacramento Municipal Utility District (SMUD) has one of the most robust ZNE home programs. Because program staff have concerns that TDV values for climate zone 12 (Sacramento region) does not adequately reflect SMUD's peaks demand, SMUD is not using TDV or the California Whole-House Home Energy Rating as the basis of their definition of ZNE home. Thus program marketing material and guidelines are not consistent across the state and the California Whole-House Home Energy Rating is not being fully exercised on ZNE projects.

State Policy: ZNE = California Home Energy Rating ≤0

This policy implies a number of things:

- State agencies and ZNE stakeholders work together on a consistent policy and branding of ZNE = California Home Energy Rating ≤ 0
- California Whole-House Home Energy Rating is improved on a number of fronts:
    - Marketing organization hired to review the basis of marketing the concept for what the rating means and what how it should be marketed.[47]
    - The software program must be easy to use with an intuitive interface and return relatively accurate results (i.e. the program defaults must be compared across a wide range of residential buildings and calibrated to average annual energy consumption).
    - Ratings should be relative to a fixed baseline that does not change over time (in contrast to older ratings where 100 was the energy code baseline for the year the rating was performed).

[47] Are the additional words in the title "Whole House" really add to the concept and make it easier to promote?

    - Rating software should be incorporated into standard performance method software so data is entered once for both a home rating and for energy code compliance.

- A California home energy rating is part of all ZNE programs
- A California home energy rating is part of the CALGreen voluntary reach standard

HCD and CEC coordinate so that ZNE is one of the Tiers for CALGreen

CALGreen, the California Green Building Standard (Title 24, part 11) currently has two "voluntary" beyond code tiers that local governments can adopt as part of their Greenhouse Action Plans. The advantage of adopting the advanced tiers is that the effort of writing the code language and developing training materials is already done as part of the CALGreen process. By having a ZNE tier, other entities could also make use of the compliance materials and definitions to support marketing efforts and incentive programs. The creation of a ZNE tier also provides advance notice to the market of the type of documentation that would be required in 2020. A ZNE tier would help the CEC and local governments develop the administrative tools for enforcing a ZNE based code while just a few builders are building ZNE homes for the marketing benefits. This smaller "dry-run" is desirable for ironing out administrative issues in advance of a statewide roll-out of the ZNE requirement in 2020.

Research on ZNE equivalence policy should start now

One of the outcomes of the ZNE definitions group that did not seem very controversial was that CPUC big bold policy for new residences should be that "All new residential construction in California will be zero net energy <u>or equivalent to zero net energy</u> by 2020." The equivalency issue is a big deal as a lot is at stake. Make qualifying for the use of equivalency too easy and the goal is undermined. However there will be situations where ZNE is not possible but comparable total societal benefits are possible. Likely research topics are location efficiency, embedded energy in construction materials, embedded energy in water consumption and disposal, what other renewable projects will provide similar societal benefits as on site generation, pros and cons of RECs. In particular, any offsets that occur outside of California would be highly controversial. Proposing rule sets for these alternatives will take time and will need a full public process. This process can be less controversial if more information is available about the likely outcomes of the various equivalency rules.

Provide funding for energy efficiency and renewables research

Reducing the cost of ZNE relies on innovation, the development of new technologies, new design methods and construction practices and an improved understanding of how people and energy consuming technologies interact. There is a need for short term research on a number of residential energy efficiency and renewable technologies and there is a medium term need to evaluate and demonstrate these technologies and methods. Unless action is taken by the legislature within the next year, PIER (Public Interest Energy Research) will have run out of funds for new research proposals. Thus developing the interest in restoring funding for research in the short and medium term must be addressed.

Quantify the full costs and benefits of a ZNE policy

A careful evaluation of the total long term costs of a ZNE future relative to a status quo future is warranted. This scope would include a sensitivity study of: likely load growth scenarios (including electric vehicles), energy escalation rates, costs of maintaining or replacing generation, costs of CO_2, cost of air pollutants, air quality health related costs, renewable energy costs associated with various experience curve coefficients and projected installations and state population/economic growth..

Develop a societal cost and CO2 abatement supply curve.

Similar to the carbon abatement supply curve in Figure 4, develop a residential carbon abatement and societal cost reduction curve based on different residential building technologies and on-site renewable technologies. To this add other methods of complying with the AB32 Greenhouse Action plan. Even the very cheapest Cap and Trade offset outside of the state will have a positive net life cycle cost. All cost-effective efficiency measures will have negative net life cycle costs. This can create a very powerful graphic for explaining why it is important to build up energy capital in our buildings and infrastructure – they reduce net costs and as a result generate wealth.

Develop an actionable mandate and public support

The Warren-Alquist Act calls for energy codes that reduce energy consumption and that are cost-effective in their entirety. However this does not result in the Title 24 energy code adopting all cost-effective and feasible measures. Presumably there is not full political support for adopting all cost-effective efficiency measures. With the results of the benefit/cost evaluation advocates for ZNE or near ZNE should ask for a legislative or administrative mandate. How far is the legislature willing to go in reducing air pollution, reducing greenhouse gas emissions and reducing a recurring stream of payments?

The administrative approach to this mandate is to identify what portion of the AB32 action plan applies to the residential buildings. If the assumption is for the action plan that all new homes will be net zero by 2020, ask for an administrative finding that this is how the state will implement this portion of AB 32 which has already been legislatively approved. The CO2 abatement supply curve can help make the argument for the level of priority associated with more stringent efficiency standards and requirements for renewables.

CPUC and IOUs reorient energy efficiency spending priorities

Statewide IOU Codes and Standards budgets are less than 1% of the Statewide Energy Efficiency program budgets, yet the long term savings are larger than any another program. (CPUC 2010) The amount of effort required to modify appliance regulations and building efficiency regulations and to support streamlined and automated compliance tools as we get closer to ZNE will become proportionately larger.

Since codes and standards are the least cost method of avoided energy costs, a rational approach for the CPUC would be to develop a "loading order" for energy efficiency that seeks to reduce the cost of energy efficiency by expanding the role of Codes and Standards in State appliance and building efficiency regulations, Federal appliance regulations and the national building codes (IECC for residential and ASHRAE 90.1 for nonresidential standards) and the implementation of all California energy codes. The amount of resources allocated to these efforts could easily be triple the current expenditure levels or around $90 Million (3%) over a 3 year time period out of a $3 Billion EE program.

In addition, if the ZNE goals are indeed the reorganizing principles for the energy efficiency strategic plan more resources need to be directed at strategic mass marketed technologies and whole building approaches. Both mass market programs and whole building approaches need to be re-invented so their technology trajectory is focused on whether they would fit in or are they needed for a ZNE home. He implication of such bleeding edge interventions is that in the short term these technologies may have an TRC (total resource cost) ratio less than one (not cost effective as compared to wholesale rates) in advance of the experience curve and commoditization effects that drive the costs down. These effects may not fully occur until the back end of the market transformation life cycle that includes code adoption.

The time for this transition is now. Interest rates are low so it costs less to invest in technologies that make recurring payments over the long term. New construction activity has been the lowest it has been in 70 years with only 45,000 dwelling units built last year and 36,000 units built the year before as compared to the 1998 to 2007 average construction rate of 148,000 units/yr. Thus this is a prime time to transform the market; an aggressive ZNE program now, over the next three years would cost approximately $630 Million.[48] This is around 3/4 the cost of current residential energy efficiency program costs, including residential third party and residential local utility programs and 10 times as much budget as the ZNE pilots planned for the 2010 to 2012 time frame.[49]

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[48] Assuming 20,000 multifamily dwelling units and 25,000 single family homes per year, 40% participation and a $5,000/dwelling unit and $10,000/single family home incentive cost and 50% overhead. This is a ballpark estimate to be updated by results from the IOU pilot programs.

[49] Statewide residential program costs for 2010 - 2012 were around $800 Million; ZNE pilots were around $45 Million. Decision Approving 2010 to 2012 Energy Efficiency Portfolios And Budgets http://docs.cpuc.ca.gov/word_pdf/AGENDA_DECISION/107378.doc

Ideally the pilots in place currently will assist the California IOUs in setting a course for a rapid expansion of ZNE residential programs over the next 2 program cycles

CPUC must decide if tariffs will support ZNE

Currently CPUC policy calls for mandating Zero Net Energy homes by 2020. If the mandate is zero net energy homes, this implies that for homes that use natural gas, more electricity is exported to the grid than that imported so that exported electricity offsets both electricity and natural gas imports. This mandate is hard to justify if home owners are unable to receive payment for the additional electricity that they export. Resolving this disconnect between the policy goal and current tariffs so that consumers have a rational financial motivation to install PV systems that are net exporters of electricity while keeping the utilities solvent is a high priority.

Executive and legislative coordination on removing barriers to ZNE

As described earlier, federal preemption hamstrings state energy standards from requiring cost-effective, higher levels of efficiency for their state. The federal government has an appropriate role for setting the national floor for minimum equipment efficiency but not the ceiling on the efficiency in state energy standards. To date, all states who have applied to DOE for a waiver from preemption have been unsuccessful. Energizing the California delegation to coordinate with other states to remove some of the limitations of preemption would be extremely helpful for developing more cost-effective energy codes and remove a barrier to code requirements that get closer to the ZNE goal.

In addition, a statewide uniform approach to renewable energy systems would reduce costs and regulatory uncertainty and streamline the permit application process. Some of the issues include fire department roof access path widths, zoning and CC&Rs that prohibit or hinder deployment of renewable energy systems.

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Appendix A: Bibliography with summaries

AB32 2006. California Environmental Protection Agency. Website: **Assembly Bill 32: Global Warming Solutions Act** http://www.arb.ca.gov/cc/ab32/ab32.htm

This website provides an overview of AB 32 and has links to the text of the Global Warming Solutions Act and what activities are taking place to implement the act, including the AB32 scoping plan, and details about the cap and trade program.

AB 2112, 2008. Assembly Bill No. 2112 Saldana/Lieu. Introduced February 20, 2008. AMENDED IN ASSEMBLY MARCH 24, 2008 http://www.leginfo.ca.gov/pub/07-08/bill/asm/ab_2101-2150/ab_2112_bill_20080324_amended_asm_v98.pdf

Note this bill did not pass, but did pass the Assembly Natural Resources Committee.. Died in Senate Housing and Transportation Committee. Requires the California Energy Commission (CEC) to adopt standards requiring that all new residential construction be "zero net energy" buildings by 2020

Architectural Energy Corporation (AEC 2009). Rethinking Percent Savings The Problem with Percent Savings and the New Scale for a Zero Net-Energy Future July 31, 2009 http://www.archenergy.com/assets/files/News/Rethinking_Percent_Savings.pdf

This paper made the case for a rating scale from 0 for zero net energy and 100 which represented the average new home at the turn of the millennium. The idea is that if 100 on the scale keeps changing then the metric is not stable.

Athena 2006. Athena Institute & Morrison Hershfield. S*ervice Life Considerations in Relation to Green Building Systems*. April 2006 http://www.athenasmi.org/publications/docs/Service_Life_Expl_Study_Report.pdf

This report describes the issues associated with evaluating durability as part of rating a green building. More durable builds require less maintenance but also use less materials and their associated embedded energy. Just as important this study recognizes that adaptability is also a key element in the longevity of buildings.

Brown Richard, William Rittelman, Danny Parker, and Gregory Homan. 2007. "Appliances, Lighting, Electronics, and Miscellaneous Equipment Electricity Use in New Homes." Lawrence Berkeley National Laboratory. http://enduse.lbl.gov/info/LBNL-62440.pdf

This paper attempts to condense information on the 'other' energy use in houses, not used by heating and air conditioning but instead is used by appliances and electronics. The percentage of energy used by these other end uses has increased over the years and now reaches 40-48% of total home energy use.

CARB 2008. **Climate Change Scoping Plan: a framework for change.** Prepared by the California Air Resources Board Pursuant to AB 32 California Global Warming Solutions Act of 2006. December 2008
http://www.arb.ca.gov/cc/scopingplan/document/adopted_scoping_plan.pdf

This Action plan discusses the methods for achieving the target of reducing greenhouse gases in 2020 to 1990 levels. The action includes recommendations including:

- Expanding existing energy efficiency programs and building and appliance standards;
- Statewide renewables energy mix (RPS) of 33 percent;
- A California cap-and-trade program linked with Western Climate Initiative partner programs to create a regional market system;
- Setting targets for transportation-related greenhouse gas emissions and pursuing policies and incentives to achieve those targets;

CARB 2011. California Environmental Protection Agency Air Resources Board Staff Report: *Initial Statement Of Reasons Advanced Clean Cars 2012 Proposed Amendments To The California Zero Emission Vehicle Program Regulations.* December 7, 2011.
http://www.arb.ca.gov/regact/2012/zev2012/zevisor.pdf

CBIA 2011. California New Housing Starts 1954 – 2010. Data from CIRB.
http://www.cbia.org/go/cbia/?LinkServID=FE5ED931-F09E-44C7-96836630388F21F7&showMeta=0

New construction activity posted as a bar chart with both single family and multi-family dwelling units separately listed.

CEC 2001. Prepared by Endecon Engineering & Regional Economic Research for California Energy Commission. *A Guide to Photovoltaic (PV) System Design And Installation.* June 2001 CEC Pub No. 500-01-020
http://www.energy.ca.gov/reports/2001-09-04_500-01-020.PDF

This is an early version of the photovoltaic design guide. For this report what was useful is that it had an estimate of the labor hours required to install a 2 kWh photovoltaic

system. *"Installation effort is very sensitive to specific house layouts and roofing type. An experienced crew can install a 2 kW non-battery PV system in two-to-four person-days. Systems with large solar arrays are relatively less effort per watt of power and kWh of energy than smaller systems because the installation of the inverter and other hardware required by all PV systems is spread over more solar modules. Systems with battery backup are more labor intensive than non-battery systems because of the additional wiring required for wiring the critical load subpanel. A battery system can add 50-100% to the time required for the installation."*

CEC 2005a. Trask, Matt. *Water-Energy Relationship* Staff report in support of the 2005 Integrated Energy Policy Report. June 2005 Report Number: CEC-700-2005-011 http://www.energy.ca.gov/2005publications/CEC-700-2005-011/CEC-700-2005-011.PDF

This report summarizes California's embodied energy in water linkage.

CEC 2005b. Klein, Gary. *California's Water – Energy Relationship* Prepared in Support of the 2005 Integrated Energy Policy Report Proceeding (04-IEPR-01E) November 2005 Report Number:CEC-700-2005-011-SF. http://www.energy.ca.gov/2005publications/CEC-700-2005-011/CEC-700-2005-011-SF.PDF

This report summarizes California's embodied energy in water linkage.

CEC 2007. TIAX LLC prepared for the California Energy Commission. **Full Fuel Cycle Assessment: Well-To-Wheels Energy Inputs, Emissions, and Water Impacts State Plan to Increase the Use of Non-Petroleum Transportation Fuels**. *Assembly Bill 1007 (Pavley) Alternative Transportation Fuels Plan Proceeding* Revised 8/1/2007 Report No. CEC-600-2007-004-REV. http://www.energy.ca.gov/2007publications/CEC-600-2007-004/CEC-600-2007-004-REV.PDF

CEC 2008. California Energy Commission **Home Energy Rating System (HERS) Technical Manual**. December 2008 Report Number: CEC-400-2008-012-CMF. http://www.energy.ca.gov/2008publications/CEC-400-2008-012/CEC-400-2008-012-CMF.PDF

This contains the rule sets for the software developers of HERS@ software.

CEC 2009a. California Energy Commission **Home Energy Rating System (HERS) Regulations**. August 2009 Report Number: CEC-400-2008-011-CMF http://www.energy.ca.gov/2008publications/CEC-400-2008-011/CEC-400-2008-011-CMF.PDF

This manual provides the rules for the HERS raters that are going to be providing the HERS ratings.

CEC 2009b California Energy Commission. **California Energy Demand 2010-2020 Adopted Forecast.** December 2009 CEC-200-2009-012-CMF http://www.energy.ca.gov/2009publications/CEC-200-2009-012/CEC-200-2009-012-CMF.PDF

This report contains the updated energy consumption forecast. This report has updated the forecast based on latest estimates of economic growth..

CEC 2011. California Energy Commission, 2011. 2011 **Integrated Energy Policy Report (IEPR)**. Publication Number: CEC‐100‐2011‐001‐CMF. http://www.energy.ca.gov/2011publications/CEC-100-2011-001/CEC-100-2011-001-CMF.pdf

From the abstract to the report: *"The 2011 Integrated Energy Policy Report provides a summary of priority energy issues currently facing California. The report provides strategies and recommendations to further the state's goal of ensuring reliable, affordable, and environmentally responsible energy sources. Energy topics covered in the report include progress toward statewide renewable energy targets and issues facing future renewable development; efforts to increase energy efficiency in existing and new buildings; progress by utilities in achieving energy efficiency targets and potential; improving coordination among the state's energy agencies; streamlining power plant licensing processes; results of preliminary forecasts of electricity, natural gas, and transportation fuel supply and demand; future energy infrastructure needs; the need for research and development efforts to support statewide energy policies; and issues facing California's nuclear power plants."*

This report clearly indicates that ZNE goals are a key part of California's energy efficiency and renewables policy.

CPUC 2008. California Public Utilities Commission. **Long Term Energy Efficiency Strategic Plan** September 2008. http://www.cpuc.ca.gov/NR/rdonlyres/D4321448-208C-48F9-9F62-1BBB14A8D717/0/EEStrategicPlan.pdf

This is the energy efficiency strategic plan that documented the 4 Big Bold Energy Efficiency Strategies (BBEES) which included the 2020 goal for all new homes being ZNE and that by 2030 all new commercial buildings would be ZNE. The other two strategies that the HVAC industry would be transformed to optimize performance for

California hot, dry climate and that by 2020, all low income customers would have the opportunity to participate in an energy efficiency program.

CPUC/CEC 2008. California Public Utilities Commission and California Energy Commission. **Energy Action Plan 2008 Update** . February 2008. http://www.cpuc.ca.gov/NR/rdonlyres/58ADCD6A-7FE6-4B32-8C70-7C85CB31EBE7/0/2008_EAP_UPDATE.PDF

California Public Utilities Commission (CPUC) 2010. Fact Sheet Energy Efficiency Statewide Codes and Standards Program (2010-2012) July 2010. http://www.cpuc.ca.gov/NR/rdonlyres/FAA129C6-55D8-42CC-8B1C-3F4FBAD8FE5B/0/EE14CodesandStandardsPrograms0710.pdf

This fact sheet describes the features of the California Statewide Codes & Standards program operated by the investor owned utilities (IOUs). "*The Statewide Codes and Standards Program saves energy by: 1) Influencing standards and code-setting bodies (such as the California Energy Commission) to strengthen energy efficiency regulations, 2) Improving compliance with existing codes and standards; and, 3) Assisting local governments to develop ordinances that exceed statewide minimum requirements.*" This document indicates that the budget over 3 years is $30 Million and that it is projected to save 837 GWh/yr and 1.5 Million therms.

California Public Utilities Commission (CPUC) 2011. **California Energy Efficiency Strategic Plan:** January 2011 Update. http://www.cpuc.ca.gov/NR/rdonlyres/A54B59C2-D571-440D-9477-3363726F573A/0/CAEnergyEfficiencyStrategicPlan_Jan2011.pdf

Energy and Environmental Economics (E3) 2011. Time Dependent Valuation of Energy for Developing Building Efficiency Standards 2013 Time Dependent Valuation (TDV) Data Sources and Inputs. http://www.energy.ca.gov/title24/2013standards/prerulemaking/documents/general_cec_documents/Title24_2013_TDV_Methodology_Report_23Feb2011.pdf

ECEEE 2011. European Council for an Energy Efficient Economy. *Steering through the maze #2: Nearly zero energy buildings: achieving the EU 2020 target*. Updated 8 February 2011 http://www.eceee.org/buildings/Steering-2-zerobldgs.pdf

Update on the European Union's directive for "nearly zero energy buildings," required of all new building built after 2020 and required for all government buildings after 2018.

EIA 2011. Energy Information Agency. **Annual Energy Outlook 2011 with Projections to 2035** DOE/EIA-0383(2011) April 2011 http://www.eia.gov/forecasts/aeo/pdf/0383(2011).pdf

ERG, Hannon & Stein 1976. Energy Research Group, Center for Advanced Computation, University of Illinois at Urbana-Champaign (Bruce Hannon) & Richard Stein & Associates Architects. (1976) **Energy Use for Building Construction.** Prepared for US Energy Research and Development Administration., New York USDOE 1976

Classic research report on embodied energy in building construction. Values are still quoted today in preservation and green building community.

European Union Press Release April 23, 2009. EU 2009) "All new buildings to be zero energy from 2019 say MEPs" http://www.europarl.europa.eu/sides/getDoc.do?language=en&type=IM-PRESS&reference=20090422IPR54163

"All buildings built after 31 December 2018 will have to produce as much energy as they consume on-site, says the European Parliament, amending the 2002 Energy Performance of Buildings Directive. MEPs also call for more public investments in energy-efficient buildings." ….MEPs define zero-energy buildings as buildings "where, as a result of the very high level of energy efficiency of the building, the overall annual primary energy consumption is equal to or less than the energy production from renewable energy sources on site".

Fanney, Hunter. 2009. "Measurement Science Workshop for Net Zero Energy Buildings." Building and Fire Research Laboratory. National Institute of Standards and Technology.

This presentation serves to provide perspective on the challenges, trends, ad forces behind Zero-Net energy. It also serves to identify critical technologies necessary to achieve net zero energy buildings. Specifically it addresses the measurement science that enables the realization of technologies required for zero net energy, in the areas of building envelope, energy production, and overall efficiency and performance.

Greens/EFA 2011. Greens/Europe Free Alliance Group in the European Parliament. The Vision Scenario for the European Union 2011 Update for the EU-27 Berlin, January 2011. http://www.greens-efa.eu/cms/topics/dokbin/368/368667.the_vision_scenario_for_the_european_uni@en.pdf

Holtzclaw, John; Clear, Robert; Dittmar, Hank; Goldstein, David & Peter Haas (2002) *Location Efficiency: Neighborhood and Socio-Economic Characteristics Determine Auto Ownership and Use – Studies in Chicago, Los Angeles and San Francisco*. Transportation Planning and Technology Volume 25, Issue 1, 2002

This paper develops a quantitative model for the likelihood of personal vehicle ownership and vehicle miles traveled per household based on variables associated with the neighborhood: mass transit accessibility, housing density, proximity to employment centers (city centers), local shopping and pedestrian friendliness. Fraction of car ownership is accessible though US Census records and odometer readings collected during vehicle emission inspections. The resulting metric of neighborhood characteristic to vehicle miles traveled per household is called location efficiency. Given that high vehicle miles traveled incurs huge personal and societal costs, location efficiency could be used to create a Location Efficient Mortgage similar to the Energy Efficient Mortgage and help create the financial incentive to design neighborhoods with location efficiency in mind.

[ICF Jones et al.] ICF Jones & Stokes, Global Energy Decisions and Matt Trask. 2008. *Electric Grid Reliability Impacts from Regulation of Once-Through Cooling in California.* April 2008. http://www.swrcb.ca.gov/water_issues/programs/ocean/cwa316/docs/reliability_study.pdf

Jackson, Mike. 2005. *Embodied Energy and Historic Renovation*. APT Bulletin: Journal of Preservation Technology. **36:4**, 2005.

http://www.areforum.org/up/Materials%20and%20Methods/EmbodHP.pdf

This article summarizes some of the findings in “Energy Use for Building Construction” and makes the argument for building re-use as the embodied energy in building construction is approximately 30+ of the potential energy savings associated with demolishing the building and starting over with a highly efficient new building. Typical single family embodied energy is estimated to be 702,000 Btu/sf, 2-4 family multifamily around 625,000 Btu/sf.

Jonathan Rose Companies 2011. *Location Efficiency and Housing Type Boiling it Down to BTUs.* Updated March 2011. http://www.epa.gov/smartgrowth/pdf/location_efficiency_BTU.pdf

LaFrance, Marc and Therese Stovall. 2009. "Emerging and Future Technologies to Achieve Zero Energy Buildings." U.S. Department of Energy. http://sites.energetics.com/buildingenvelope/pdfs/LaFrance_Construct_Presentation_June_17_2009.pdf

This presentation provides an overview of the USDOE Building Technologies program strategies for reducing building energy consumption and their vision of how to approach ZNE. The lead technologies identified included ground source heat pumps, LED and OLED lighting, R-5 window procurement etc.

LBNL 2005. Arasteh, D., Goudey, H., et al. (LBNL). *Performance Criteria for Residential Zero Energy Windows.* Berkeley, CA, Lawrence Berkeley National Laboratory: 2005. Report Number LBNL-59190. http://gaia.lbl.gov/btech/papers/59190.pdf

This paper shows that the energy requirements for today's typical efficient window products (i.e. ENERGY STAR™ products) are significant when compared to the needs of Zero Energy Homes (ZEHs). Through the use of whole house energy modeling, typical efficient products are evaluated in five US climates and compared against the requirements for ZEHs. Products which meet these needs are defined as a function of climate. In heating dominated climates, windows with U-factors of 0.10 Btu/hr-ft2-F (0.57 W/m2-K) will become energy neutral. In mixed heating/cooling climates a low U-factor is not as significant as the ability to modulate from high SHGCs (heating season) to low SHGCs (cooling season).

LBNL 2009. Wiser, Ryan; Galen, Barbose; Peterman, Carla; and Darghouth, Naim. 2009. "Tracking the Sun II: The Installed Cost of Photovoltaics in the U.S from 1998-2008." Lawrence Berkeley National Laboratory. http://eetd.lbl.gov/ea/emp/reports/lbnl-2674e.pdf

This report summarizes the trends of grid-connected PV systems between the years 1998 and 2008. The report finds that installed costs have fallen an average 3.6% a year, with room for improvement and further cost cuts as evidenced by international applications. Costs also vary significantly between states, especially considering widely varying incentives between states.

LBNL 2011. Barbose, Galen, Naïm Darghouth, Ryan Wiser & Joachim Seel. Tracking the Sun IV: A Historical Summary of the Installed Cost of Photovoltaics in the United States from 1998 to 2010. LBNL-5047E. September 2011. http://eetd.lbl.gov/ea/ems/reports/lbnl-5047e.pdf

This report updates the finding that photovoltaic costs keep declining also incentives are declining. This report contains a wealth of information on installed system costs, components of costs, the relative costs of owner financed versus third party financed systems etc.

NRDC 2010. Henry, Jennifer & Goldstein, David. *Reducing Foreclosures and Environmental Impacts through Location-Efficient Neighborhood Design*. January 2010. http://www.nrdc.org/energy/files/LocationEfficiency4pgr.pdf

This brief describes the financial impacts of "location efficiency" of neighborhoods and their financial impacts on occupants. Location efficiency refers to the walkability of neighborhoods, the proximity of commercial stores and the availability of public transit. Areas with high location efficiency of course reduce vehicle miles traveled. As a result a significant cost is reduced. After controlling for other variables, mortgage defaults are less for homes in areas with high location efficiency.

NIST 2008 . "Federal Research and Development Agenda for Net Zero Energy High Performance Green Buildings." 2008. National Science and Technology Committee on Technology. http://www.bfrl.nist.gov/buildingtechnology/documents/FederalRDAgendaforNetZeroEnergyHighPerformanceGreenBuildings.pdf

This document makes the judgment that change in building construction and design presents itself as one of the best opportunities to economically reduce energy consumption and greenhouse gas admissions. New technologies in Zero Net Energy and High Performance building and construction methods are key in approaching these challenges. Federal Research and Development in conjunction with private Research and Development will play a critical role in achieving these goals and a basic outline of the steps necessary is provided.

NREL 2006a. Torcellini, P, Pless, S., Deru, M., and D. Crawley. 2006. "Zero Energy Buildings: A Critical Look at the Definition." National Renewable Energy Library. http://www.nrel.gov/docs/fy06osti/39833.pdf

This document serves to describe how the way net zero is describe affects both designers and strategies for obtaining this goal. There are four well-documented definitions—net-zero site energy, net-zero source energy, net-zero energy costs, and net-zero energy emissions—are studied; pluses and minuses of each are discussed. These definitions are applied to a set of low-energy buildings for which extensive energy data are available. This study shows the design impacts of the definition used for ZEB and the large difference between definitions. It also looks at sample utility rate structures and their impact on the zero energy scenarios.

NREL 2006b. Christensen, C., Norton, P. 2006. "A Cold-Climate Case Study for Affordable Zero Energy Homes". National Renewable Energy Library. http://www.nrel.gov/docs/fy06osti/39678.pdf

This project, supported by the U.S. Department of Energy's Building America Program, is a case study in reaching zero energy within the affordable housing sector in cold climates. The design of the 1200 square foot, 3-bedroom Denver zero energy home carefully combines envelope efficiency, efficient equipment, appliances and lighting, and passive and active solar features to reach the zero energy goal.

NREL 2006c. Farhar, B.C, T.C. Coburn. 2006. "A New Market Paradigm for Zero-Energy Homes: The Comparative San Diego Case Study." National Renewable Energy Library. http://www.nrel.gov/docs/fy07osti/38304-01.pdf

This report provides a case study on the SheaHomes Scripps Highlands development in San Diego where many of the homes were built with P.V installed, solar water heating as well as various efficiency measures. This development was also compared with another community, built to title 24 energy standards, but with no extra solar features offered. Surveys from the residents reveal homeowners living in houses with PV were more satisfied with their purchase, and those who did not upgrade did so mainly out of cost.

NREL 2006d. Anderson, R. C. Christensen, and S. Horowitz. 2006. "Analysis of Residential System Strategies Targeting Least-Cost Solutions Leading to Net Zero Energy Homes." National Renewable Energy Library. http://www.nrel.gov/buildings/pdfs/38170.pdf

This report describes the analysis approach used by the program to determine the most cost-effective pathways to achieve whole-house energy-savings goals. This report also provides an overview of design/technology strategies leading to net zero energy buildings as the basis for analysis of future residential system performance.

NREL 2007. Anderson R, and Roberts, D. 2008. "Maximizing Residential Energy Savings: Net Zero Energy Home Technology Pathways." National Renewable Energy Laboratory. http://www.nrel.gov/buildings/pdfs/44547.pdf

This report serves to provide a range of technology options to fulfill the residential efficiency gap that will allow residential homes to meet DOE standards. This report selects and focuses on the current research projects that are most likely to provide cost effective results with minor risks to builders. These include High R wall systems, cold climate DOW systems, cold climate R10 window assembly, high performance AC systems and reduction to miscellaneous electricity use.

NREL 2008a. Horowitz, S., Christensen, C., and Anderson, R. Searching for the Optimal Mix of Solar and Efficiency in Zero Net Energy Buildings National Renewable Energy Laboratory Presented at Solar 2008 San Diego, California May 3–8, 2008. National Renewable Energy Library. http://www.nrel.gov/buildings/pdfs/42956.pdf

This paper describes the use of Beopt simulation and life cycle cost-optimization software to develop cost-optimal paths to ZNE for various climates. Comparing the different cases shows optimal building design characteristics, percent energy savings and cash flows at key points along the path, including the point at which investments shift from building improvements to purchasing PV, and PV array sizes required to achieve ZNE.

NREL 2008b. Barley, C.D. Haley, C., Pratsch, L. and Anderson. R. 2008. "Building America System Research Plan for Reduction of Miscellaneous Electrical Loads in Zero Energy Homes." National Renewable Energy Library. http://www.nrel.gov/docs/fy09osti/43718.pdf

This research plan describes the overall scope of system research that is needed to reduce miscellaneous electrical loads (MEL) in future net zero energy homes. The MEL category includes all the loads that remain after accounting for heating, cooling, ventilation, domestic hot water (DHW), lighting, and large appliance loads. MELs are more difficult to address from a systems engineering standpoint because many are not under the control of the builder. As a result, energy savings in MELs has lagged behind energy savings in other residential end uses in BA homes. The present focus of this research effort is on builder-implementable whole-house energy management systems. As these strategies have the potential to also reduce non-MEL energy usage, cost-benefit analyses will include the overall impact on whole house energy usage.

NREL 2009. Crawley, Drury B, Pless, Shanti and Torcellini, Paul. "Getting to Zero Net Energy in Commercial Buildings: Key Measurements to Support R&D." National Renewable Energy Laboratory. NREL/JA-550-46382 http://www.nrel.gov/docs/fy09osti/46382.pdf

This presentation provides the Department of Energy's goals insofar that it is desirable to pursue energy efficient and high technology buildings that are better for owners, occupants and the economy as a whole. The presentation provides 6 examples that show these technologies in use that serve as a base point for expanding these principles to broader implementation.

NREL 2009. Torcellini, Paul A. 2009. "Twenty-first Century Building Design: Getting to Net-Zero Energy?" National Renewable Energy Library.

This presentation explores the problem of the large impact of buildings and energy use and how the problem can be rectified through changes in architecture, design, standards and PV. Efficiency and cost effective measures are key as are clear standards and goals that keep progression moving and gains measurable.

NREL 2011. Goodrich, Alan C. Woodhouse, M. & James, T. Solar PV Manufacturing Cost Model Group: Installed Solar PV System Prices. SEGIS-ADEPT Power Electronics in Photovoltaic Systems Workshop Arlington, Virginia February 8, 2011 NREL/PR-6A20-50955. http://www.nrel.gov/docs/fy11osti/50955.pdf

This presentation provides a breakdown of installed costs of photovoltaics systems. This cost breakdown is useful for identifying what components of installed PV system cost have the greatest opportunity for further cost reductions.

OECD/IEA, 2008. Laustsen, Jens. **Energy Efficiency Requirements in Building Codes, Energy Efficiency Policies For New Buildings** IEA Information paper in Support of the G8 Plan of Action**.** International Energy Agency OECD/IEA, March 2008 http://www.iea.org/g8/2008/Building_Codes.pdf

This paper compares building codes in various counties with the aim of disseminating best practices. This paper also illustrates how energy efficiency can be improved through such initiatives as efficiency labeling or certification, very best practice buildings with extremely low- or no-energy consumption and other policies to raise buildings' energy efficiency beyond minimum requirements.

Parker, Danny. 2009. "Zero Energy Homes: Measurement Science to Meet Expanding Research & Performance Goals". Building America: U.S Department of Energy.

This presentation serves to provide perspective on what technologies to implement first via cost effectiveness and where more research needs to be done on existing technologies and their cost effectiveness. The consensus is the efficiency should be pursued first and should move beyond the envelope to look at HVAC units and plug loads.

Penrith, Sean. 2010. Comment on U.S. Department of Energy's EnergySmart Home Scale (E ‐ Scale) Label Earth Advantage Institute May 28, 2010 http://www.ci.portland.me.us/energy/earthadvantageinstitutecommentstoresnetonesle.pdf

This letter discusses a simpler rating tool and also makes the argument for a rating that is based on energy consumption of a home not in units of energy per square foot but just absolute energy units so home size is not normalized out.

Pollock, Edward. 2009. “Builders Challenge: Recognizing Energy Leadership in Homebuilding.” Building America: U.S. Department of Energy.

This presentation breaks down Building Americas research goals by region and the overall strategies needed to pursue net zero energy homes. This includes a clear way to measure, verify and convey home energy use, a transparent process for builders, abundant technical and marketing resources, consumer outreach and strong partnerships with other organizations working on similar projects.

Pratsch, Lew. 2003. “Zero Energy Buildings” U.S. Department of Energy. San Diego.

This presentation serves to provide an overview of the national objectives regarding zero net energy which is to eventually provide affordable residential and commercial zero energy buildings in the near future. The presentation looks at zero energy homes in developments already in existence highlighting potential savings for consumers and the need for a zero energy rating system.

RMIT 2001. *Greening the Building Life Cycle: Life Cycle Assessment Tools in Building and Construction*. http://buildlca.rmit.edu.au/

This project was completed in 2001, it was commissioned by Environment Australia. The project consortium was led by the Centre for Design at RMIT and the project was to assess the status of life cycle assessment (LCA) tools in the building and construction sector and to develop strategies to improve the uptake and use of these tools. This project aimed to improve of the environmental performance of the building and construction sector, by promoting LCA as a tool to assess the environmental impacts of building materials and building systems in Australia.

This web page has the results of embodied energy case studies for 8 residential buildings. The findings are that the embodied energy in the case study residences varies between 10 to 15 GJ/m^2 [880,000 Btu/ft^2 to 1.3 Million Btu/ft^2].

[SWRCB] State Water Resources Control Board. 2010. *Resolution No. 2010-0020 Adopt A Proposed “Water Quality Control Policy on the Use of Coastal and Estuarine Waters for Power Plant Cooling” and Associated Certified Regulatory Program Environmental Analysis.* May 4, 2010.

http://www.waterboards.ca.gov/board_decisions/adopted_orders/resolutions/2010/rs2010_0020.pdf

USDOE 2004. "Moving toward Zero Energy Homes: Zero Energy Home Powers Up in North Texas." 2004. Building America: U.S Department of Energy. http://www.nrel.gov/docs/fy05osti/36944.pdf

This document is a brief look at the construction and design of a zero energy home in North Texas. It concerns itself with aspects of energy efficiency, indoor environment quality, durability, water efficiency and occupant comfort, which in all areas this model exceeds standards set by standard homes.

USDOE 2005. Building America: U.S. Department of Energy. "Building America Research Is Leading the Way to Zero Energy Homes: Energy efficiency and solar energy technologies can result in zero net energy consumption from nonrenewable sources." Produced for the U.S. Department of Energy (DOE) by the National Renewable Energy Laboratory, a DOE national laboratory. May 2005. DOE/GO-102005-2064. http://www.nrel.gov/docs/fy05osti/37547.pdf

This pamphlet is a report on two homes built in Florida in 1998, one control house and another designed to reduce energy loads to an absolute minimum. The result was a home that used 90% less energy than the control home with the areas and mode of savings broke down to reveal what methods and technologies are most efficient and cost effective.

USDOE 2007. Love, Pat, & Bacheler, Michael. 2007. "High-Performance Home Technologies: Solar Thermal & Photovoltaic Systems." Building America Best Practice Series.Vol.6. Building America U.S Department of Energy. http://apps1.eere.energy.gov/buildings/publications/pdfs/building_america/41085.pdf

This report presents information useful for enhancing energy efficient practices in all U.S climate zones. It provides evaluations of DOE research which is identifying system engineering issues that must be resolved so zero net energy homes are cost effective, marketable. Inside are 9 chapters complete with case studies that cover, a technology overview, marketing solar systems, solar thermal and PV technologies, site planning and orientation, mounting systems, safety and how homes can be solar ready.

USDOE “Residential Buildings, New Construction, Existing Buildings, Buildings Integrating On-Site Power, Residential Codes Research.” Building America: U.S. Department of Energy. http://www.ncfap.org/documents/BuildingAmericaTrifold.pdf

This brochure provides information on what building America is doing to advance U.S energy and building goals. These actions include building test homes, reducing energy consumption in existing homes, integrating on site power and conducting research into renewable technologies as well as conducting to research into energy codes.

Van Dijk, Dick 2008. Numerical indicator for the energy performance based on primary energy use and CO2 emissions Procedures according to CEN standard EN 15603. TNO Built Environment and Geosciences The Netherlands Paper 150. 18-12-2008. http://www.buildup.eu/system/files/P150_EN_CEN_Num_Indicator_p3354.pdf

This paper describes how to calculate energy consumption or carbon footprint based on national primary energy factors. This is used for calculating Primary energy rating. CO2 emissions rating and a national “policy energy rating” based primarily on cost. An example is calculated based on the Dutch energy factors for an example reference building. In this example natural gas has a primary energy factor of 1 whereas imported and consumed electricity has a primary energy factor of 2.56 and exported renewably produced electricity has a primary energy factor of 2.

Zirngibl, Johann 2010 How to integrate the CEN-EPBD standards in national building regulations? The use of EN 15603 as starting point for coordination of Member States regulations. Energy Performance of Buildings. CENSE P87. 02-02-2009 http://www.iee-cense.eu/upload/sites/iee-cense/wp6/6.6/p087_en_cense_en_15603_integration.pdf

This presentation describes an overview of how the many related standards coordinate into national energy codes in the European Union. These codes have a series of regulations that describe how to calculate building loads, how to simulate distribution losses and equipment performance and then finally how to calculate primary energy impacts which is used for determining overall building compliance.

Christian, Jeff, Pratsch, Lew. & Blasing, T. J 2007. “Zero Peak Communities Electric Utility Benefits.” ASHRAE. http://climatechangescience.ornl.gov/system/files/publications/zero_peak_communities_electric_utility_benefits_chrisitan_2007.pdf

This paper proposes utility incentives that could provide the stepping stone to zero peak demand housing with positive cash flow between mortgage and utility bills. The key incentive that could enable zero cost in climates similar to those in Lenoir City are to offer homeowners a premium price for all the renewable power produced at their home site. The utility sells this green power to the customer base willing to pay a premium to have electricity generated by renewable sources. This second tier for the buying of renewable power would only be available to those homeowners willing to invest in 50% energy saving houses and install at least 2 kW of peak solar power generation.

Appendix B: Survey tool – sample interview

Definitions of zero net energy?

1. How do you define a "net zero" building? Based on source energy, site energy, energy cost, carbon footprint, electricity only, other?
2. How should water use be included?
3. Should embedded energy be included?
4. How should transport energy be included?
5. Should peak demand be included?
6. How important is net zero as a concept for guiding building efficiency policy?
7. How broadly should net zero be considered? Building level, development level, community levels state level?
8. How should sites be addressed that are shaded or have limited space?
9. Any special considerations for addressing multifamily

Added value of site generated electricity

1. What are benefits of having renewable generation on site?
2. Increases value of energy?
3. Increases the amount of efficiency options considered?
4. Psychological impact on how people use energy?
5. Impact on transmission and distribution grid?
6. Benefits of PV to the home? Less roof cost? Less thermal load? Back-up power?
7. Societal benefits on the home – less transmission, less land dedicated to energy, mounting platform for PV?
8. Marketing for energy efficient homes?
9. Allows an alternative path for restrictive efficiency standards?

Transportation

1. Should transportation energy consumption be considered part of net zero homes?
2. Should the home energy budget include electricity for plug-in hybrid?
3. Should credit be given for proximity to mass transit?

Density (Multifamily versus Single Family)

1. How does this extend past the transportation questions asked above?
2. When we have high rise dwellings, should the concept of net zero be redefined? Does this just need to redefine the site for energy production or are there other issues?

Appliances

1. What are the main issues associated with appliances that have to be addressed for net zero homes?
2. What are the big appliance efficiency issues for getting to net zero?
3. How much of appliance energy consumption can be addressed through energy codes?

Case studies, Example Projects

Describe net zero home projects,

- Name
- Location
- Locale (city, suburban, rural)
- Builder
- Type (Multi-family, single family, townhouse)
- Market (Development, customer, affordable, high end etc.)
- Any report or marketing materials?

Key technologies

- Envelope
- HVAC
- Lighting
- Water Heating
- Hardwired Appliances

specific features (technology, financing, marketing) that are noteworthy?

Energy rating

- What are incremental costs?
- What are incremental kWh/yr savings

- HERS rating for building only – fraction of code compliant energy use
- Total rating including PC – how close to zero?

Success what made it work

What problems uncovered

General Net Zero Building Technology Paths

1. What technology paths are required for a net zero energy home?
2. Are these technologies different if the homes are single family versus multi-family?
3. Which of these technologies are cost-effective today?
4. Which of these technologies are likely to be cost-effective in 10 years?
5. What technological or market barriers have to be overcome for technologies that are not cost-effective?
6. Are there other benefits besides saving energy to these technologies?
7. Are there other feasibility or technical issues that have to be addressed?

Design and Construction Techniques

1. What design techniques are required to design net zero homes
2. What design techniques are required to optimize net zero homes?
3. What barriers exist to the application of these techniques?
4. What changes are needed to construction techniques or common practices to achieve net zero homes?
5. What aspects of the construction industry are compatible with net zero homes?
6. What is a good outcome for the building industry in regards to net zero homes?

Economics, financing and appraisal

What financial issues have to be resolved before net zero is more broadly adopted?

How important is cost-effectiveness for acceptance of net zero?

Ideas on financing options that would increase use of net zero (longer mortgage times, EE mortgage rate etc.)

What is needed so that net zero features are valued (new sale and home resale)?

Consumer demand, value of net zero

What do consumers want for net zero?

Do current rating methods provide assurance of performance?

Who do consumers trust?

Are there other non-energy benefits from net zero?

Should net zero be linked to other home attributes for greater uptake?

What are your thoughts about the usefulness of energy use feedback (displays of energy usage and PV generation) what are your thoughts about having the display in the house?

What does success mean to you?

What outcome around net zero homes or home efficiency results in a successful outcome for your industry?

Barriers

Is there anything in the energy code which creates an obstacle to ZNE?

Any of the other codes create barriers?

Any planning commission policy that creates barriers?

Anything in rates or utility incentives that creates a barrier for ZNE?

Any legal barriers (covenants etc.) to ZNE.

Other barriers?

Path to Zero

If you had three code cycles (steps) to get to zero

What would be your three steps?

1.

2.

3.

Other key thought leaders?

1. In your field
2. In the field of net zero homes?

Appendix C: Federal Preemption

USC Title 42 § 6297. Effect on other law[50]

United States Code Title 42

TITLE 42 > CHAPTER 77 > SUBCHAPTER III > Part A > § 6297 § 6297. Effect on other law

(f) Exception for certain building code requirements

(1) A regulation or other requirement enacted or prescribed before January 8, 1987, that is contained in a State or local building code for new construction concerning the energy efficiency or energy use of a covered product is not superseded by this part until the effective date of the energy conservation standard established in or prescribed under section 6295 of this title for such covered product.

(2) A regulation or other requirement, or revision thereof, enacted or prescribed on or after January 8, 1987, that is contained in a State or local building code for new construction concerning the energy efficiency or energy use of a covered product is not superseded by this part until the effective date of the energy conservation standard established in or prescribed under section 6295 of this title for such covered product if the code does not require that the energy efficiency of such covered product

exceed-

(A) the applicable minimum efficiency requirement in a national voluntary consensus standard; or

(B) the minimum energy efficiency level in a regulation or other requirement of the State meeting the requirements of subsection (b)(1) or (b)(5) of this section, whichever is higher.

(3) Effective on the effective date of an energy conservation standard for a covered product established in or prescribed under section 6295 of this title, a regulation or other requirement contained in a State or local building code for new construction concerning the energy efficiency or energy use of such covered product is not superseded by this part if the code complies with all of the following requirements:

(A) The code permits a builder to meet an energy consumption or conservation objective for a building by selecting items whose combined energy efficiencies meet the objective.

(B) The code does not require that the covered product have an energy efficiency exceeding the applicable energy conservation standard established in or prescribed under

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[50] http://www.law.cornell.edu/uscode/html/uscode42/usc_sec_42_00006297----000-.html

section 6295 of this title, except that the required efficiency may exceed such standard up to the level required by a regulation of that State for which the Secretary has issued a rule granting a waiver under subsection (d) of this section.

(C) The credit to the energy consumption or conservation objective allowed by the code for installing covered products having energy efficiencies exceeding such energy conservation standard established in or prescribed under section 6295 of this title or the efficiency level required in a State regulation referred to in subparagraph (B) is on a one-for-one equivalent energy use or equivalent cost basis.

(D) If the code uses one or more baseline building designs against which all submitted building designs are to be evaluated and such baseline building designs contain a covered product subject to an energy conservation standard established in or prescribed under section 6295 of this title, the baseline building designs are based on the efficiency level for such covered product which meets but does not exceed such standard or the efficiency level required by a regulation of that State for which the Secretary has issued a rule granting a waiver under subsection (d) of this section.

(E) If the code sets forth one or more optional combinations of items which meet the energy consumption or conservation objective, for every combination which includes a covered product the efficiency of which exceeds either standard or level referred to in subparagraph (D) , there also shall be at least one combination which includes such covered product the efficiency of which does not exceed such standard or level by more than 5 percent, except that at least one combination shall include such covered product the efficiency of which meets but does not exceed such standard.

(F) The energy consumption or conservation objective is specified in terms of an estimated total consumption of energy (which may be calculated from energy loss- or gain-based codes) utilizing an equivalent amount of energy (which may be specified in units of energy or its equivalent cost).

(G) The estimated energy use of any covered product permitted or required in the code, or used in calculating the objective, is determined using the applicable test procedures prescribed under section 6293 of this title, except that the State may permit the estimated energy use calculation to be adjusted to reflect the conditions of the areas where the code is being applied if such adjustment is based on the use of the applicable test procedures prescribed under section 6293 of this title or other technically accurate documented procedure.

(4)

(A) Subject to subparagraph (B), a State or local government is not required to submit a petition to the Secretary in order to enforce or apply its building code or to establish that the code meets the conditions set forth in this subsection.

(B) If a building code requires the installation of covered products with efficiencies exceeding both the applicable Federal standard established in or prescribed under section

6295 of this title and the applicable standard of such State, if any, that has been granted a waiver under subsection (d) of this section, such requirement of the building code shall not be applicable unless the Secretary has granted a waiver for such requirement under subsection (d) of this section.

USC Title 42 § 6316 Administration, penalties, enforcement, and preemption[51]

TITLE 42 > CHAPTER 77 > SUBCHAPTER III > Part A-1 > § 6316 § 6316.

Administration, penalties, enforcement, and preemption

(b)

(1) The provisions of section 6295 (p)(5) [2] of this title, section 6296 (a), (b), and (d) of this title, section 6297 (a) of this title, and sections 6298 through 6306 of this title shall apply with respect to the equipment specified in subparagraphs (B) through (G) of section 6311 (1) of this title to the same extent and in the same manner as they apply in part A.[3] In applying such provisions for the purposes of such equipment, paragraphs (1), (2), (3), and (4) of subsection (a) of this section shall apply.

(2)

(A) A standard prescribed or established under section 6313 (a) of this title shall, beginning on the effective date of such standard, supersede any State or local regulation concerning the energy efficiency or energy use of a product for which a standard is prescribed or established pursuant to such section.

(B) Notwithstanding subparagraph (A), a standard prescribed or established under section 6313 (a) of this title shall not supersede a standard for such a product contained in a State or local building code for new construction

if-

(i) the standard in the building code does not require that the energy efficiency of such product exceed the applicable minimum energy efficiency requirement in amended ASHRAE/IES Standard 90.1; and

(ii) the standard in the building code does not take effect prior to the effective date of the applicable minimum energy efficiency requirement in amended ASHRAE/IES Standard 90.1.

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[51] http://www.law.cornell.edu/uscode/html/uscode42/usc_sec_42_00006316----000-.html

Appendix D: Non-Consensus ZNE Definition

Disclaimer

The following document was developed over several months of effort. Some major break thoughts were made on the definition of Zero Net Energy buildings (the primary one being that the 2020 directive should be recast that all residential buildings be zero net energy or zero net energy equivalent). This is a non-consensus document in that several of the participants felt strongly that their concerns were not resolved.

Some participants felt that the definition should be based on site energy. Other participants felt that ZNE should be based on source energy rather than societal cost so that the definition would be more aligned with the ZNE definition used by the USDOE Building America program. Some of the participants felt that embedded energy and transportation energy should be included in the definition of ZNE. Even though there was not complete consensus some of these concepts below are useful regardless if one wishes to use societal cost, site energy or source energy for evaluating trade-offs or one wishes to include embedded energy.

A Zero Net Energy Definition for Residential and Commercial Buildings

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ZNE Definitions Team: Gregg Ander, SCE; Jamy Bacchus, NRDC; Martha Brook, CEC; Pat Eilert, PG&E; Charles Eley, Charles Eley & Assoc.; Steve Galanter, SCE; Dave Hewitt, NBI; Jon McHugh, Jon McHugh & Assoc.; Max Perelman, Building Wise; Dana Papke, ARB; Rob Raymer, CBIA; Devin Rauss, SCE**;** Pat Saxton, CEC; Peter Turnbull, PG&E; Diane Vrkic, Waypoint Building

Draft: June 6, 2011

Introduction

In 2008, the California Public Utilities Commission (CPUC) developed a Long Term Energy Efficiency Plan with four “Big Bold Energy Efficiency Strategies” that envisioned major new initiatives for promoting building energy efficiency. [52] These strategies are intended to be a basis for organizing California energy efficiency efforts including Investor Owned Utility (IOU) efficiency programs, energy code development and future energy legislation. Two of these key strategies involve the concept of “Zero Net Energy”:

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[52] Section 1, Page 6. (CPUC 2008)

1. All new residential construction in California will be zero net energy by 2020;

2. All new commercial construction in California will be zero net energy by 2030;

In this document, Zero Net Energy (ZNE) was defined as follows:

- *The amount of energy provided by on-site renewable energy sources is equal to the amount of energy used by the building.*
- *A ZNE building may also consider embodied energy – the quantity of energy required to manufacture and supply to the point of use, the materials utilized for its building.*

This policy and associated concept required some clarification so implementation could be effectively pursued. As a result, this group was formed to develop definitions of ZNE, for consideration by the responsible California agencies. Questions that were identified include:

- How is energy valued for trade-offs between different sources (natural gas, propane and electricity) and trade-offs with on-site renewable generation? Example energy metrics include: site, source, TDV, embedded, transportation energy etc.
- What is on-site renewable energy (PV, hydro, fuel cells, biomass, landfill gas)?
- What is on-site? Building site, development site, utility grid etc.?
- How does definition or policy address sites that do not have access to renewable energy?

The concept of Zero Net Energy is a powerful one. It has reset expectations of what is possible from small incremental improvements in efficiency to targets that exceed 50% savings from energy efficiency and with the addition of renewables, net energy autonomy. There are hundreds of examples of zero (or near zero) net energy buildings and homes. Griffith, et al., (2007) have estimated that "Based on a ZEB definition that uses net site energy use of zero or less, the results show that 47% of commercial floor area and 62% of buildings could reach ZEB by using known technologies and practices with projected performance levels for 2025." An even greater fraction of buildings would comply with a source energy or societal cost based definition of ZNE. A desirable outcome is that this definition of zero net energy be technically achievable as a policy, enforceable when adopted into building codes, and be meaningful as metric of exemplary building design.

Policy Goals

There are many California policies, such as California AB 32, that are supported by a ZNE strategy to increase building energy efficiency in a cost-effective manner, together with the use of demand response and an expanded use of on-site renewable energy sources.[53] The policy goals for the CPUC Energy Efficiency Strategic Plan ZNE are:

Original (2008 EE Strategic Plan) Zero Net Energy Goals

1. All new residential construction in California will be zero net energy by 2020;
2. All new commercial construction in California will be zero net energy by 2030;

A strict requirement that every building be zero net energy is not currently feasible and may never be feasible when considering site limitations, high rise buildings, high energy intensity buildings, etc. We are offering an alternative definition to the CPUC and other key stakeholders to consider. This definition would be recasting the bold energy efficiency strategies that keeps the policy goal intact while keeping a strong central concept of ZNE that is easy to understand and easy to market for those buildings that are able to meet the unadulterated ZNE principles. This revised definition is as follows:

Revised Zero Net Energy Goals

1. All new residential construction in California will be zero net energy *or equivalent to zero net energy* by 2020;
2. All new commercial construction in California will be zero net energy *or equivalent to zero net energy* by 2030;

This modified definition is a major step forward by recognizing that not all buildings have to be ZNE but for code purposes could be ZNE "equivalent." This definition builds on the performance approach that we have in Title 24 Part 6 while preserving the common sense intent of what is a ZNE building. This is also in line with Long Term Energy Efficiency Plan's subsidiary goal for existing commercial buildings: [54] *"50 percent of existing buildings will be equivalent to zero net energy buildings by 2030 through achievement of deep levels of energy efficiency and clean distributed generation."*(emphasis added).

Audience

The primary audiences for the ZNE definition are California policy makers and policy implementers. We expect that some effort will go into developing user-friendly

[53] California Public Utilities Code Section 454.5(b)(9)(C)

[54] Section 3 – Page 31, (CPUC 2008)

definitions that will be useful to the general public, code officials, design professionals, building owners, builders and the building industry in general. A secondary audience is other states, federal agencies, and other countries that can help transform the market for building products and building practices.

Proposed Definition of Zero Net Energy

> The *societal value of energy* consumed by the building over the course of a typical year is less than or equal to the societal value of the *on-site renewable energy* generated.[55]

Definitions of Terms

1. *Societal value of energy*

Societal value of energy is the long-term projected cost of energy including the cost of serving peak demand and varies from hour-to-hour to account for peak demand and other fluctuating costs including projected costs for carbon emissions.[56]

2. *Building*

The property "receiving development entitlements and building code permits."[57], e.g., a single building, or set of buildings on one site, such as a housing development, multifamily building, campus, etc.

3. *On-site*

On-site is defined for new construction as located on the property for the "project receiving development entitlements and building code permits."[58] For existing buildings we define on-site as "located on the property receiving development entitlements and building code permits."

4. *Renewable energy*

Photovoltaic-generated electricity, solar-thermal generated electricity, micro-hydro generated electricity and wind-generated electricity.

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[55] For a home or low-rise dwelling unit, ZNE is achieved by demonstrating a California Whole-House Home Energy Rating of zero or less.

[56] In Title 24, part 6 this is called Time Dependent Valuation of Energy of TDV energy. See Title 24, part 6 Section 102

[57] Section 2 – Page 13. (CPUC 2008).

[58] ibid

5. *Zero net energy equivalent*

A property that achieves the societal value of energy (TDV energy) equivalent of ZNE with consideration of off-site renewable resources, or other factors to be determined by California policy makers such as the CEC and CPUC.[59]

Notes

1. Policy Goal. The primary ZNE goal is to support the AB 32 carbon reductions. This definition primarily defines the desired outcome (ZNE buildings) and does not directly address the loading order (efficiency and demand response before renewables). However these priorities are captured in Title 24 Part 6 rule sets for renewables and energy efficiency that are under development, as well as in the California Public Utilities Code.[60]

A major step forward was the recognition that not all buildings had to be ZNE, but for code purposes could be “ZNE equivalent.” This definition builds on the performance approach that we currently have in Title 24 Part 6, while preserving the popular understanding of a ZNE building or community.

ZNE buildings also provide other substantial benefits that are compatible and synergistic with policy goals than AB 32. For example, reductions in energy consumption and definitions of on-site renewable energy that do not involve local emissions help address California’s serious ground level ozone problems.

We also anticipate that policy makers will need to address additional energy costs such as the energy use of transportation to the building site, the embodied costs of energy in the building materials, the energy costs of water use at the building, and other factors that reflect the larger societal energy costs of the building, but we are not currently including these concepts in the definition of ZNE. State policymakers can add these concepts at the appropriate time. We note them here because we believe they are important considerations and want to contribute to the discussion of their implementation (see also the notes under “societal value of energy” below).

2. Proposed Audience. The purpose of this exercise is to refine the definitions of ZNE for policymakers so progress can be made on a number of fronts. However we recognize that ZNE is a powerful concept that has sparked the imaginations of people all over the world and that there are a growing number of builders and designers who are

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[59] See note 8 in the Notes section

[60] California PUC §454.5(b)(9)(C): “The electrical corporation will first meet its unmet resource needs through all available energy efficiency and demand reduction resources that are cost effective, reliable, and feasible”

marketing ZNE buildings. The language in the proposed definition was considered to be "standard" English, with the idea that the technical definitions of specific terms would be supplied in the accompanying notes.

3. Societal Value of Energy. Societal value of energy is the long-term projected cost of energy, including the cost of serving peak demand. It varies from hour-to-hour to account for peak demand and other fluctuating costs, including projected costs for carbon emissions. It varies from utility rates in that rates are meant to be simple and thus though they track the short term average cost, they do not yet include real time costs nor do they capture the long term estimates of relative energy costs.

California uses a metric known as "TDV" (time dependent valuation) to address and evaluate the societal value of energy. TDV addresses peak demand and has embedded within it a number of previous California policy decisions. TDV is the basis for the energy calculations in Title 24 Part 6, the California Home Energy Rating System Program, and the evaluation of utility programs.[61] TDV is the only one of the metrics considered that differentiates between natural gas and propane as their long term costs are significantly different. TDV provides policy signals that would be missing with a flat (non-time dependent) evaluation of energy that does not include a value for peak demand. TDV could be considered more complex because the relative value of different sources changes on an hour-by-hour basis. However TDV occurs "under the hood" of the performance method calculations and the California Whole-House Home Energy Rating calculations, and what the consumer sees is a "percent better than Title 24" or a HERS score. As the concept of TDV can be difficult to convey and understand, for the purposes of the general definition, we refer to it as the "societal value of energy."

Source energy is also considered as a metric for this definition, as many other entities are using source energy for evaluating trade-offs between fuels and for defining ZNE buildings. However different regions can use different source energy multipliers, and they do not account for the value of peak electrical demand, thus one could consider TDV an improved version of source energy. The basis of these source energy multipliers can also be very complex if an accurate source multiplier is developed that includes the average heat rate of generation and the mix of sources providing electricity for a given area.

Site energy was also considered as it is clearly defined. However, electricity and natural gas are sold in different energy units and these energy sources have different source

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[61] TDV represents the societal costs borne by all Californians for energy. TDV includes the avoided wholesale costs of energy including energy, T&D, capacity costs and carbon costs, TDV also includes the "retail rate adder" which includes utility fixed costs and overhead and profit. For evaluation of the cost-effectiveness of utility programs, the CPUC uses the E3 Calculator to calculate the avoided wholesale costs of energy in essentially the same manner that is used by TDV; however the retail rate adder is not included. It should also be noted that the CPUC sets energy savings targets for the IOUs that are in terms of site energy, but these targets do not allow for trade-offs between different energy sources. See reference 12.

energy content, environmental impacts and costs. The thermodynamic quality of electricity is higher than natural gas, unit for unit electricity can heat more, (including combustion losses) light more, and create more motive power. A ZNE definition based on site energy sets the bar significantly higher for homes with gas heating and water heating (90% of our building stock). For a home that was able to reduce Title 24 Part 6 loads by 15% each code cycle, the costs of a photovoltaic (PV) system sized on-site energy definition of ZNE would be 60% greater than a PV system sized to meet a source or TDV energy definition of ZNE. This comparison is shown in Figure 7.

There have been calls to set the bar higher for ZNE homes where it is based on a site energy definition or inclusion of other indirect forms of energy consumption associated with buildings. ZNE is a transformative concept that is not quite captured by "near ZNE." These higher standards for ZNE run the risk of the goal being unattainable and the goal becomes "aspirational" or "advisory" i.e. with no teeth and no hard policy milestones. If the state of California wants to hit the 2020 target for homes we should start with ZNE being based on the societal value of the energy consumed by use of the home (HVAC, water heating and appliances). Once we have clearly hit this target then it is reasonable to start considering the additional energy consumption due to 1) embodied energy, 2) the energy costs of water, 3) transportation, and 4) other services. However even in the short term, these important other forms of energy consumption may be addressed in venues other than ZNE definitions, such as product life cycle assessment and enhanced water conservation in CALGreen,[62] and transportation planning in CEQA.[63] See note 8 for how other forms of energy (embedded, transportation etc.) might be accounted as credits in ZNE equivalent

4. Building. The question was raised of how code could address multiple buildings. The current definition allows for multiple buildings as part of the same development, or under the same building permit. Another solution would be to differentiate "ZNE Building" from "ZNE Community," as has been proposed by others.

5. Asset vs. Operational Ratings. Asset ratings are based on a computer model of energy consumption of buildings. Operational ratings are based on the actual energy consumption of buildings (typically a billing analysis). For new buildings an "asset" is really the only practical rating method as part of a certificate of occupancy. Existing buildings can be rated using either operational or asset ratings. Energy Star is actually a hybrid of asset and operational ratings — it is based on actual usage, but includes normalization for weather, operating schedules, vintage, etc. such that it isn't simply just an asset or an operational rating. The details of these ratings are developed through a public process and reflect trade-offs of accuracy, comparability, simplicity and

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[62] *California Green Building Standard (CALGreen)* California Code of Regulations Title 24 Part 11. http://www.bsc.ca.gov/CALGreen/default.htm

[63] As required by SB 375 Steinberg. Statutes of 2008, "Transportation planning:" http://www.leginfo.ca.gov/pub/07-08/bill/sen/sb_0351-0400/sb_375_bill_20080930_chaptered.pdf

repeatability. As we approach zero energy, plug loads become increasingly important. Addressing this in asset rating methods will require careful consideration. See COMNET.org for one method of how plug loads are addressed.

6. On-Site. The question was raised whether it was acceptable if an owner could purchase Renewable Energy Credits (RECs). The consensus was that this would not be allowable, but that other more dependable offsets would be available (see "equivalency" below). Additional debate is whether it makes sense for some building types, e.g., hospitals, high rises, some locations, e.g., downtown, and specific geographic regions, e.g., coastal fog belt, are appropriate candidates at this time for on-site generation. The concept of equivalence may resolve all of these issues.

7. Renewable Resources. This definition does not include "geothermal" (in the sense of a geothermal heat pump as opposed to electricity generation from geothermal steam) or solar thermal domestic water heating as a renewable resource. Geothermal heat pumps, solar domestic water heating, solar driven absorption cooling etc. all reduce energy consumption on-site and reduce needed imports of energy from off-site. But currently, these sources cannot usefully export energy off-site and are treated as energy efficiency measures.

A ZNE building must export as much societal value of on-site renewable energy as was imported. At this time, the only form of on-site renewable energy we can envision being exported is electricity. And thus on-site renewable energy exports would be in the form of photovoltaic-generated electricity, solar-thermal generated electricity, micro-hydro generated electricity or wind-generated electricity injected back into the grid. Biofuels, fuel cells and landfill gas would not be included as an on-site renewable resource; as this results in local emissions and is not renewable in the sense of the useful energy transformation of local solar and wind energy.

8. Equivalency. Redefining the 2020 and 2030 goals in terms of "ZNE or equivalent" helps address all of the concerns about exceptions to the ZNE rule. Not every building can be ZNE, but every building can be ZNE equivalent. However, a "ZNE equivalent" building should not have the bragging rights of being called ZNE, as that would weaken the brand and value of ZNE for all the people who are making buildings that are truly ZNE.

Our initial thought on equivalency is that it would take the form of paying for the installation of a new renewable energy system on another California building.[64] By making sure the residual energy consumption is served by systems on a building site, we help assure that one of the other objectives of the BBEES is accomplished, i.e., the volume of on-site installed renewables systems are large enough to maintain the economies of scale that are driving down system costs.

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[64] TDV allows for accounting of equivalency at any location in California; however, there are likely to be policy reasons for restricting the location of the alternative renewable energy system.

Many issues would have to be carefully considered as the state gets closer to the development and adoption of the 2019 Title 24, part 6 standards. For example, conditions that would allow equivalency via off-site renewables, details around geographical location and the timing of construction for qualifying off-site renewables systems. We expect that implementation of many of the intermediate steps towards the realization of ZNE goals will help inform the rules on ZNE equivalency.

Equivalency may also include concepts such as providing credits for equivalent reductions in transportation energy, embedded energy and other considerations.

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8. Rajkovich, Nicholas B., Rick Diamond, and Bill Burke, 2010. "Zero Net Energy Myths and Modes of Thought," Proceedings of the 2010 ACEEE Summer Study on Energy Efficiency in Buildings. LBNL-3974E

9. Torcellini, Paul, S. Pless, M. Deru, D. Crawley, 2006. “Zero Energy Buildings: A Critical Look at the Definition,” in: ACEEE Summer Study, Pacific Grove, California, USA.

10. U.S EPA 2011. Energy Star Performance Ratings Methodology for Incorporating Source Energy Use. www.energystar.gov/ia/business/...performance/site_source.pdf

11. White and Klein, 2006. “The Water-Energy Connection in California,” ACEEE Summer Study 2006.

12. Time-Dependent Valuation (TDV) (from 2005 Title 24 Part 6 archive) http://www.energy.ca.gov/title24/2005standards/archive/rulemaking/documents/tdv/index.html

Appendix E: Societal Energy Cost (Time Dependent Valuation of Energy or TDV)

Prior to the 2005 version of Title 24, efficiency trade-offs in the energy performance (whole building energy simulation) used the concept of source energy. One unit of electricity was equivalent to 3 units of natural gas (i.e. 1 kWh = 3 x 3,413 Btu/kWh= 10,239 Btu of natural gas). This "source multiplier of 3 for electricity" roughly approximated the efficiency of thermal plants and losses associated with transmission and distribution. However, since electricity is not easily stored and given the widely fluctuating loads over the course of the day and course of the year, a significant amount of physical infrastructure and investment is required to serve the top hundred peak hours per year. Thus a new "dollar based" metric was developed to evaluate trade-offs between efficiency measures in the Title 24 building energy efficiency standards. As compared to the previous source energy metric, which attributed the same energy value to a kWh or electricity or a therm of natural gas, this new metric varied the values of electricity and natural gas by time of day and day of year, thus the name time dependent valuation (TDV).

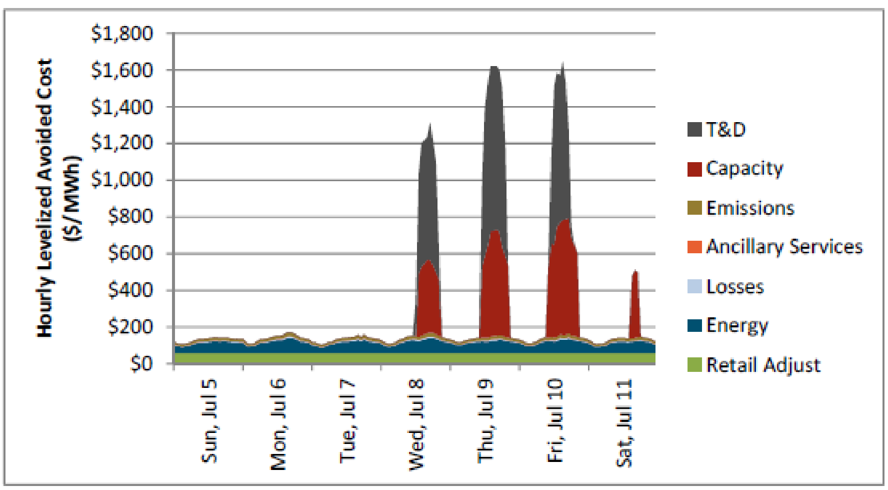

Figure 34: One week snapshot of energy values (Climate Zone 2)[65]

Figure 34 shows just how widely energy costs fluctuate on a hot summer afternoon, most hours of the year the T&D and capacity costs are close to zero. However this plot also shows that there is a regular diurnal cycle associated with costs. These costs are based on a production model of electricity generation that is serving a load profile which in turn is significantly affected by outdoor temperature (air conditioning) , time of day and day of week (patterns of commerce).

[65] P. 16 (E3, 2011)

During the development of the TDV's the question arose, "If TDVs are cost based why not just use utility rates as the basis of this new trade-off?" The answer was that the choices made in the design of buildings would last for 30 to 50 years and the short term energy rate would not capture the total energy cost impacts of the decisions made at time of design and construction. Thus the TDV are developed based on long term projections of the cost of energy – 30 years for residential TDV and 15 years for nonresidential trade-offs. (It should be noted that a 30 year TDV is used to evaluation the cost-effectiveness of nonresidential envelope measures).

Table 3: Residential Load Weighted Average Present Valued 2013 T-24 TDV's[66]

30 Year Res TDV Annual Wtg Average Present Value of Electricity (PV $/kWh)								
Climate Zone	Energy	Losses	Ancillary Services	Capacity	T&D	CO2 Emissions	Retail Adjust-ment	Total Levelized Value
CZ1	$1.1916	$0.0879	$0.0119	$0.3246	$0.1737	$0.4079	$1.4485	$3.6461
CZ2	$1.1916	$0.0879	$0.0119	$0.3246	$0.1740	$0.4079	$1.4481	$3.6461
CZ3	$1.1916	$0.0879	$0.0119	$0.3246	$0.1740	$0.4079	$1.4481	$3.6461
CZ4	$1.1916	$0.0879	$0.0119	$0.3246	$0.1741	$0.4079	$1.4480	$3.6461
CZ5	$1.1916	$0.0879	$0.0119	$0.3246	$0.1744	$0.4079	$1.4477	$3.6461
CZ6	$1.2081	$0.0916	$0.0121	$0.3992	$0.1896	$0.4151	$1.3304	$3.6461
CZ7	$1.1972	$0.0885	$0.0120	$0.3050	$0.1681	$0.4111	$1.4643	$3.6461
CZ8	$1.2081	$0.0916	$0.0121	$0.3992	$0.1853	$0.4151	$1.3347	$3.6461
CZ9	$1.2081	$0.0916	$0.0121	$0.3992	$0.2110	$0.4151	$1.3090	$3.6461
CZ10	$1.2081	$0.0916	$0.0121	$0.3992	$0.2125	$0.4151	$1.3075	$3.6461
CZ11	$1.1916	$0.0879	$0.0119	$0.3246	$0.1744	$0.4079	$1.4478	$3.6461
CZ12	$1.1916	$0.0879	$0.0119	$0.3246	$0.1744	$0.4079	$1.4477	$3.6461
CZ13	$1.1916	$0.0879	$0.0119	$0.3246	$0.1740	$0.4079	$1.4481	$3.6461
CZ14	$1.2081	$0.0916	$0.0121	$0.3992	$0.2144	$0.4151	$1.3056	$3.6461
CZ15	$1.2081	$0.0916	$0.0121	$0.3992	$0.2111	$0.4151	$1.3089	$3.6461
CZ16	$1.2081	$0.0916	$0.0121	$0.3992	$0.2199	$0.4151	$1.3001	$3.6461
Average Res TDV	**$1.1992**	**$0.0895**	**$0.0120**	**$0.3560**	**$0.1878**	**$0.4113**	**$1.3903**	**$3.6461**
Average Levelized	**$0.0612**	**$0.0046**	**$0.0006**	**$0.0182**	**$0.0096**	**$0.0210**	**$0.0709**	**$0.1860**
Average %	32.9%	2.5%	0.3%	9.8%	5.2%	11.3%	38.1%	100.0%

66 My thanks to Snuller Price of E2, for providing guidance on how to calculate the weighted average costs from the TDV methodology spreadsheet available on the California Energy Commission website. http://www.energy.ca.gov/title24/2013standards/prerulemaking/documents/general_cec_documents/TDV_2011DRMeth_v1-4.xlsm

Utility rates do not directly reflect costs as rates are simplified for ease of customer understanding of their bill and for other objectives such as encouraging conservation (inverted block rates). Thus the time dependent valuation procedure involved developing an estimation of the hourly avoided costs associated with each hour, an estimate of carbon costs that ultimately may be levied on generators and then finally a "retail rate adder" that trues up the difference in avoided energy costs and the total revenues that are collected by the utility. The retail rate adder is required for the energy code evaluations as the energy codes are developed with cost-effectiveness to the customer in mind.

Table 4: Average TDV Natural Gas Values

Climate Zone	TDV kBtu/ therm	PV $/therm	1 year $/therm
CTZ 1	159.51	27.62	1.41
CTZ 2	159.51	27.62	1.41
CTZ 3	159.51	27.62	1.41
CTZ 4	159.51	27.62	1.41
CTZ 5	159.51	27.62	1.41
CTZ 6	160.45	27.79	1.42
CTZ 7	157.62	27.30	1.39
CTZ 8	160.45	27.79	1.42
CTZ 9	160.45	27.79	1.42
CTZ 10	160.45	27.79	1.42
CTZ 11	159.51	27.62	1.41
CTZ 12	159.51	27.62	1.41
CTZ 13	159.51	27.62	1.41
CTZ 14	160.45	27.79	1.42
CTZ 15	160.45	27.79	1.42
CTZ 16	160.45	27.79	1.42
Average	159.80	27.68	1.41

Though we are calling these values "societal" costs since they do include some costs associated with what is estimated as a market price of CO_2, but as shown in Table 3, the value associated with CO2 emissions is only 11% of the total cost of electricity. This cost does not externalize all impacts of emissions but rather the expected costs of CO_2 mitigation that may occur through a cap and trade program.

The weighted average residential electricity levelized (1 year) costs were multiplied by the present worth multiplier for 30 years at a 3% real discount rate (scalar of 19.6) to yield the present value of 30 years of energy consumption in Table 3. In the evaluation of the trade-offs associated with the different definitions of ZNE (site, source, and societal basis) these present valued TDV values are multiplied by the electricity consumption for each scenario. Since the natural costs do not fluctuate as much we used the simple average of the natural gas TDV factors (shown in the levelized and present valued form).

Societal Value of Roof Mounted Photovoltaic Production

Table 5 contains the results of multiple simulations of a standard non-tracking, non-concentrating photovoltaic system similar to what one might find on the roof a residence that has participated in the New Solar Home Partnership of the California Solar Initiative. All simulations were conducted using the CECPV version 2.4 photovoltaic system simulation program with the panels tilted 20° from horizontal (4:12 roof pitch). The left half of the table describes the annual kWh/yr generated by each nominal peak kilowatt (kWp) capacity of the photovoltaic system. This production value varies by climate zone and by the compass heading (azimuth) that the panel is facing as measured in plan degrees clockwise from due North. This photovoltaic system production model does not account for shading by nearby trees or other obstructions. Thus this can be thought of as a best case scenario. The right half of the table summarizes the societal value of the energy produced by the photovoltaic system. The societal value is calculated by multiplying the hourly production in kWh by the time dependent valuation hourly values over the course of the year and summing these products.

Table 5: Full load hours (kWh/kWp) and Societal Value (PV$/kWp) from Photovoltaic System at Different Azimuths

	Full Load Hours Production (kWh/kWp)					30 Year Residential Societal Value (PV$/kWp)				
Climate Zone	AZ 90 (E)	AZ 135	AZ180 (S)	AZ 225	AZ 270 (W)	AZ 90 (E)	AZ 135	AZ180 (S)	AZ 225	AZ 270 (W)
CZ1	1,120	1,264	1,340	1,305	1,178	$4,853	$5,562	$6,125	$6,218	$5,776
CZ2	1,338	1,499	1,575	1,523	1,371	$5,464	$6,244	$6,866	$6,973	$6,492
CZ3	1,341	1,508	1,592	1,546	1,395	$5,641	$6,440	$7,073	$7,168	$6,671
CZ4	1,383	1,551	1,629	1,572	1,411	$5,631	$6,432	$7,070	$7,173	$6,669
CZ5	1,419	1,608	1,710	1,664	1,497	$6,011	$6,886	$7,557	$7,621	$7,036
CZ6	1,344	1,504	1,589	1,549	1,407	$5,482	$6,223	$6,795	$6,864	$6,385
CZ7	1,391	1,567	1,666	1,630	1,478	$5,649	$6,459	$7,115	$7,232	$6,728
CZ8	1,346	1,506	1,593	1,557	1,418	$5,376	$6,103	$6,684	$6,775	$6,322
CZ9	1,409	1,573	1,649	1,593	1,437	$5,498	$6,252	$6,844	$6,930	$6,452
CZ10	1,397	1,563	1,645	1,596	1,443	$5,504	$6,248	$6,842	$6,941	$6,479
CZ11	1,364	1,538	1,600	1,523	1,343	$5,385	$6,205	$6,807	$6,861	$6,311
CZ12	1,375	1,521	1,572	1,503	1,349	$5,359	$6,066	$6,597	$6,662	$6,202
CZ13	1,369	1,503	1,549	1,485	1,343	$5,375	$6,027	$6,531	$6,606	$6,188
CZ14	1,551	1,752	1,834	1,754	1,551	$5,788	$6,647	$7,313	$7,418	$6,861
CZ15	1,433	1,599	1,673	1,619	1,459	$5,314	$6,013	$6,578	$6,714	$6,294
CZ16	1,473	1,678	1,745	1,644	1,426	$5,707	$6,657	$7,322	$7,329	$6,661
Average	1,378	1,546	1,623	1,566	1,407	$5,502	$6,279	$6,882	$6,968	$6,470

As illustrated in *Section 3.7 On-site Renewable Energy Policy & Timeline*, two patterns can be observed:

1. The Societal (TDV) Value of photovoltaic production is weighted towards orienting the panels to the south or to the west as the value of energy is higher in the afternoon. Ideally photovoltaic systems are oriented between SSE (135° from north) and due west (270°).
2. For photovoltaic systems oriented close to South with few obstructions, these panels are barely cost-effective today in California if incentives and tax credits are not included. However, if the value of the incentives is included, the systems are cost-effective from a societal cost perspective. In Germany, which has a 5 times greater installed capacity than the United States and has removed institutional barriers, the installed cost of small size (3-5 kW) residential photovoltaic systems without subsidies is less than the California societal value of the energy production.

Appendix F: CALGreen Proposal – ZNE Tier

The following proposal submitted to the Department of Housing and Community Development (HCD) is an attempt to start the process of having an official definition of Zero Net Energy homes adopted into the voluntary portion of CALGreen, otherwise known as the California Green Building Standard (Title 24, part 11). This would result in a clear definition of ZNE that could be adopted by utility incentive programs, labeling programs, marketing materials etc. It would also set into motion mechanisms for the longer term goal of developing code compliance documentation of ZNE homes.

Monday, April 09, 2012

Stoyan Bumbalov
Division of Codes and Standards
Department of Housing and Community Development
sbumbalov@hcd.ca.gov

Re: 2013 CALGreen Proposed Express Terms Comments

To Stoyan Bumbalov and Developers of the 2013 update to CALGreen (Title 24, part 11);

These comments are in response to the California Energy Commission's proposed voluntary energy requirements in the 2013 update to CALGreen as presented at the November 14, 2011 HCD focus group meeting. My recommendations are summarized as follows, with the remainder of this letter describing in more detail these recommendations including proposed revisions to the code language:

- Overall we support the CEC proposal
- A Zero Net Energy (ZNE) tier should be added to the two other voluntary tiers for showing advanced energy performance
- The "all high efficiency lighting" prerequisite should allow an exception for low efficiency lighting when at least as many rated watts of photovoltaics are installed as the wattage of low efficacy lighting.
- Vacancy sensor requirements beyond those in Title 24 part 6 should be carefully considered as some of these spaces do not have many permanently installed luminaires or the luminaires are not on very many hours. .

Background

At the November 14th focus group meeting, Martha Brook of the California Energy Commission presented a proposal for CALGreen that can be summarized as follows:

- Energy measures are in the voluntary portion of CALGreen (Appendix A4)
- Prerequisites required for both tiers include:
    - Home Energy Rating System (HERS) Design Rating
    - Quality Insulation Inspection (QII)
    - All permanently installed lighting shall be high efficacy and have vacancy sensor controls
    - All permanently installed lighting mounted to the building shall be high efficacy and have photocontrol or time clock controls
    - All appliances provided by the builder shall be ENERGY STAR labeled if an ENERGY STAR specification is applicable
- Tier 1 performance standard
    - Energy Budget that is 85 percent or less than the Title 24, Part 6 Energy Budget
    - Maximum modeled imported electricity consumption no greater than 10,000 kWh per year
- Tier 2 performance standard
    - Energy Budget that is 70 percent or less than the Title 24, Part 6 Energy Budget
    - Maximum modeled imported electricity consumption no greater than 8,500 kWh per year

Overall we support the CEC proposal as it makes progress towards the goals in the CPUC Energy Efficiency Strategic Plan[67], namely that, "All new residential construction in California will be zero net energy by 2020." To achieve this goal, the California building codes must increasingly promote high levels of energy efficiency with on-site renewable energy systems. Though the tiers are nominally voluntary, the tiers provide a model code that cities can adopt as a standard or various beyond code incentive programs can adopt as a program criteria. Ideally the tiers act as a market signal that prepares the market for the increased levels of efficiency that will be required as California approaches its Zero Net Energy (ZNE) goal.

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[67] California Public Utilities Commission, California Long Term Energy Efficiency Strategic, September 2008. (CPUC 2008)

If we consider that California has two more standards cycles (2016 and 2019) in advance of the 2020 ZNE goal, then it is desirable that we have a CALGreen tier that is representative of the 2016 T-24 energy code that has adopted all cost effective efficiency measures and 2019 T-24 energy code that is Zero Net Energy for all new homes. Thus it is desirable to have CALGreen tiers that reflect this trajectory to zero net energy as shown in Figure 35.

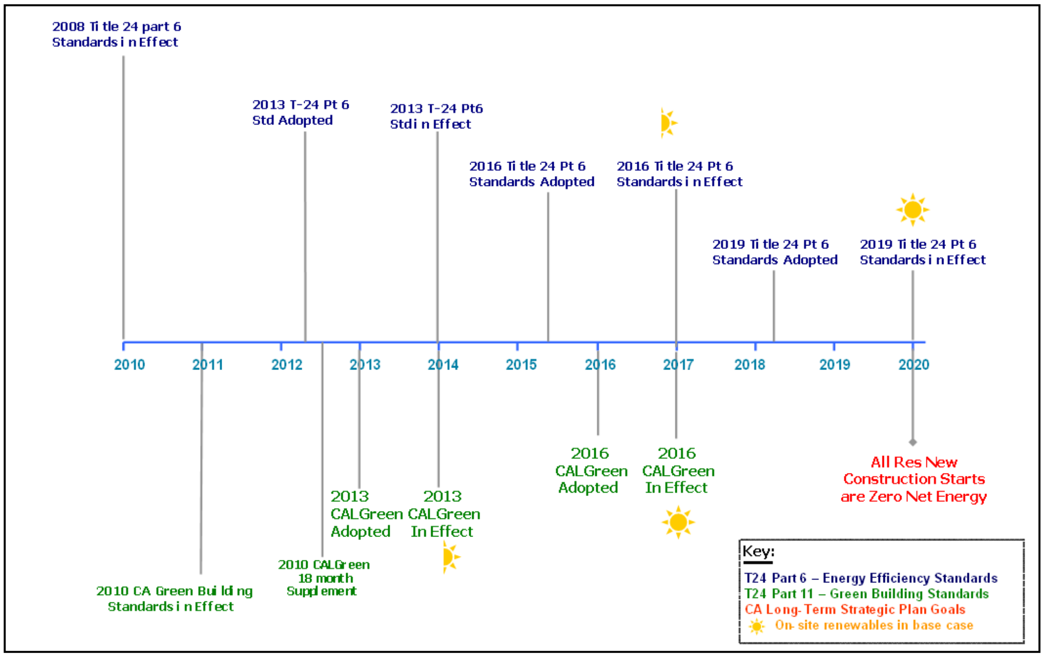

Figure 35: Building Standards Timeline to Net Zero Homes

For utility efficiency programs a reduction in energy consumption of at least 15% is considered the minimum threshold for receiving utility rebates. Thus the tier 1 levels of efficiency of 15% beyond code coordinates well with the IOU programs in terms of defining a minimum beyond code threshold.

During the Title 24 workshops, CEC staff presented an analysis of potential alternatives for the prescriptive envelope measures that would comprise “Package A” in the 2013 Title 24 part 6 standard. The package of envelope measures that would save the most energy and still be cost-effective would save 45% of energy simulated in the performance approach, however the CEC staff selected a package of measures that did not exceed a first cost threshold – this package as proposed would save around 30% of energy simulated in the performance approach. Thus considering just considering envelope measures that are cost-effective in 2011, the opportunity as compared to the 2013 standard is 0.55 / 0.70 = 79% or 21% beyond code before considering putting ducts inside conditioned spaces, and other measures that consider HVAC or water heating improvements. Thus Tier 2 is potentially a reasonable proxy for what the 2016 energy code might approach.

What is missing is a proxy for what might be required two code cycles out. What is needed is a "ZNE Tier" that describes what the state of California considers a ZNE home and what might be the requirements of the energy code two code cycles out in 2019. This ZNE tier would provide guidance and marketing support to cutting edge developers that want to differentiate their homes from other homes on the market (half of which were built before there was any energy code). A ZNE tier would differentiate ZNE homes from inefficient homes have solar panels. This ZNE tier provides the policy signals to the market and as a voluntary standard helps works out the mechanics of such a rating well in advance of mandatory energy code requirement.

Space	Avg h/yr
Kitchen	1,241
Master Bathroom	730
Secondary Bathroom	730
Powder room	730
Closets	511
Master Bedrooms	511
Secondary Bedrooms	511
Utility Rooms	949
Hallways	438
Living Rooms	949
Dining Rooms	1,241

Figure 36: Lighting hours per year by room, grayed spaces required to have a vacancy sensor under 2013 T-24, Pt. 6[68]

Thus we support the addition of a ZNE tier that includes all of the requirements of tier 2 plus zero net energy requirements.

We also recommend the following modifications to the CEC proposal:

- For the all high efficiency lighting prerequisite, allow low efficacy lighting if it is offset on a watt per watt basis with on-site renewable generation (photovoltaics). In most situations, the full load hours of PV generation (between 1,200 – 1,400 kWh/kW) will exceed the full load hours of energy consumption by low efficacy lighting (see Figure 36). This trade-off is simple and provides the flexibility to a tiny percentage of the market not satisfied with the broad range of high efficiency lighting products and results in a net energy savings. This simplicity meets all of the efficacy of the energy code without all of the exceptions and is likely a model for a future (and more simple) energy code.
- The proposed T-24 energy code would require occupancy sensors in garages, laundry rooms and utility rooms and all lighting in these spaces must be high efficacy. It also requires that bathrooms have an occupancy sensor or have all high efficiency lighting. All other lighting must be high efficacy or have an occupancy sensor or a dimmer. Thus we recommend dropping the requirements for vacancy sensors for most spaces not already required by Title 24 part 6. These other spaces include kitchens, bedrooms, hallways, living rooms and dining rooms. Kitchens have projections like cabinets that would thwart a simple

[68] Residential Lighting 2013 T-24 CASE (Codes and Standards Enhancement) report. http://www.energy.ca.gov/title24/2013standards/prerulemaking/documents/2011-04-04_workshop/review/Residential_Lighting.pdf

passive infrared wall box sensor. Bedrooms are typically illuminated by electric light only 1.4 hours per day, thus the savings opportunity is small. Lights are typically on in hallways a little over an hour per day. Dining rooms and living rooms are occupied longer, savings are subject to how much lighting is permanently installed and how often lights are left on when unoccupied. The energy savings benefit of the occupancy sensor is reduced if the lighting is all high efficacy and there is less wattage to control. Thus removing added controls language keeps this proposed green code simple.

Proposed Changes

The following are friendly amendments to the CEC staff proposal with stricken language with ~~strikeouts~~ and added language underlined.

APPENDIX A4 – RESIDENTIAL VOLUNTARY MEASURES

DIVISION A4.2 ENERGY EFFFICIENCY

Newly constructed low-rise residential buildings shall meet Sections 1 and 2:

1. **Prerequisites.** Each of the following efficiency measures is required:

   A. **Home Energy Rating System (HERS) Design Rating.** A HERS design rating shall be computed by Compliance Software certified by the Commission for the Proposed Design Building and this rating shall be included in the Certificate of Compliance documentation;

   B. **Quality Insulation Inspection (QII).** The QII procedures specified in Title 24, Part 6 shall be completed;

   C. **High efficacy indoor lighting.** All permanently installed lighting shall be high efficacy as defined in Title 24, Part 6.

   Exception: Low efficacy lighting shall be allowed when it is offset by an equal or more watts of on-site photovoltaic generation installed between 110 and 270 degrees as measured clockwise from due north when viewed in plan and installed with no significant shading obstruction. Significant shading obstructions include vent, chimney, architectural feature, roof mounted equipment that are closer than two times the height of the obstruction above the lowest part of the photovoltaic panels and south of any part of the photovoltaic panels.

   ~~And shall have vacancy sensor controls. Vacancy sensors in garages shall use ultrasonic, dual technology, or other methods for occupant detection which do not rely solely on line of sight. Permanently installed lighting shall be installed in kitchens, bathrooms, utility rooms, and garages at a minimum. Every room which does not have permanently installed lighting shall have at least one switched receptacle installed. Each ceiling fan provided by the builder shall be installed with an ENERGY STAR light kit;~~

   D. **High efficacy exterior lighting.** All permanently installed lighting mounted to the building shall be high efficacy as defined in Title 24, Part 6 and shall have photocontrol or time clock controls; and

   E. **Appliance rating.** Each appliance provided by the builder shall be ENERGY STAR labeled if an ENERGY STAR specification is applicable for the appliance.

2. **Performance Standard.** One of the following advanced efficiency levels shall be met:

A. **Tier I:** Buildings complying with the first level of advanced energy efficiency shall have an Energy Budget that is 85 percent or less than the Title 24, Part 6 Energy Budget for the Proposed Design Building as calculated by Compliance Software certified by the Energy Commission. ~~There shall be a limit on calculated t~~Total net building electricity consumption ~~placed on~~ of the Proposed Design Building as calculated by ~~within~~ the Compliance Software ~~that is equivalent to~~ shall be no greater than 10,000 kWh per year. A Proposed Design Building calculated by the Compliance Software to consume more than this amount of grid supplied electricity shall use additional energy efficiency measures or an on-site solar electric system to reduce the Proposed Design Building calculated total net building electricity consumption to a level that is at or below 10,000 kWh per year; or

B. **Tier II:** Buildings complying with the second level of advanced energy efficiency shall have an Energy Budget that is 70 percent or less than the Title 24, Part 6 Energy Budget for the Proposed Design Building as calculated by Compliance Software certified by the Energy Commission. ~~There shall be a limit on calculated t~~Total net building electricity consumption ~~placed on~~ of the Proposed Design Building as calculated by ~~within~~ the Compliance Software ~~that is equivalent to~~ shall be no greater than 8,500 kWh per year. A Proposed Design Building calculated by the Compliance Software to consume more than this amount of grid supplied electricity shall use additional energy efficiency measures or an on-site solar electric system to reduce the Proposed Design Building calculated total net building electricity consumption to a level that is at or below 8,500 kWh per year.

C. **Zero Net Energy:**. Zero Net Energy buildings shall comply with all of the tier II requirements and shall have a Home Energy Rating System (HERS) Design Rating of 0 or less.

Additions and alterations to low-rise residential buildings shall meet Sections 3 and 4:

3. **Prerequisites.** Each of the following efficiency measures is required if applicable to the addition or alteration building project:

A. **Quality Insulation Inspection (QII).** The QII procedures specified in Title 24, Part 6 shall be completed;

C. **High efficacy indoor lighting.** All permanently installed lighting shall be high efficacy as defined in Title 24, Part 6 and shall have vacancy sensor controls.

Exception: Low efficacy lighting shall be allowed when it is offset by an equal or more watts of on-site photovoltaic generation installed between 110 and 270 degrees as measured clockwise from due north when viewed in plan and installed with no significant shading obstruction. Significant shading obstructions include vent, chimney, architectural feature, roof mounted equipment that are closer than two times the height of the obstruction above the lowest part of the photovoltaic panels and south of any part of the photovoltaic panels. ~~Vacancy sensors in garages shall use ultrasonic, dual technology, or other methods for occupant detection which do not rely solely on line of sight. Permanently installed lighting shall be installed in kitchens, bathrooms, utility rooms, and garages at a minimum. Every room which does not have permanently installed lighting shall have at least one switched receptacle installed. Each ceiling fan provided by the builder shall be installed with an ENERGY STAR light kit; and~~

D. **High efficacy exterior lighting.** All permanently installed lighting mounted to the building shall be high efficacy as defined in Title 24, Part 6 and shall have photocontrol or time clock controls.

4. **Performance Standard.** One of the following advanced efficiency levels shall be met:

A. **Tier I:** Buildings complying with the first level of advanced energy efficiency shall have an Energy Budget that is 95 percent or less than the Title 24, Part 6 Energy Budget for the Proposed Design Building as calculated by Compliance Software certified by the Energy Commission for each mechanical system altered. Mechanical systems include heating, space cooling, and water heating systems. If the addition or alteration changes the envelope with no change to mechanical systems, then no additional efficiency measures above Part 6 are required; or

B. **Tier II:** Buildings complying with the second level of advanced energy efficiency shall have an Energy Budget that is 90 percent or less than the Title 24, Part 6 Energy Budget for the Proposed Design Building as calculated by Compliance Software certified by the Energy Commission for each mechanical system altered. Mechanical systems include heating, space cooling, and water heating systems. If the addition or alteration changes the envelope with no change to mechanical systems, then no additional efficiency measures above Part 6 are required.

C. **Zero Net Energy:**. Zero Net Energy buildings shall comply with all of the tier II requirements and shall have a Home Energy Rating System (HERS) Design Rating of 0 or less.

Appendix G: Text from AB 2112 (Saldana/Lieu) ZNE Homes

As downloaded from: http://www.leginfo.ca.gov/pub/07-08/bill/asm/ab_2101-2150/ab_2112_bill_20080324_amended_asm_v98.pdf

AMENDED IN ASSEMBLY MARCH 24, 2008

California legislature—2007–08 regular session

ASSEMBLY BILL **No. 2112**

Introduced by Assembly Members Saldana and Lieu

February 20, 2008

An act to amend Section 25402 of the Public Resources Code, relating to energy.

LEGISLATIVE COUNSEL'S DIGEST

AB 2112, as amended, Saldana. Energy: building standards.

The Warren-Alquist State Energy Resources Conservation and Development Act requires the State Energy Resources Conservation and Development Commission to adopt building design and construction standards, and energy and water conservation standards to reduce the wasteful, uneconomic, inefficient, or unnecessary consumption of energy, including energy associated with the use of water.

This bill would require the commission to adopt, in collaboration with specified parties, building design and construction standards, and energy and water conservation standards to require new residential constructions commenced on or after January 1, 2020, ~~and new nonresidential constructions commenced on or after January 1, 2030~~, to be zero net energy buildings.

This bill would define the term "zero net energy building."

This bill would also make a technical change by deleting an obsolete statutory cross-reference.

Vote: majority. Appropriation: no. Fiscal committee: yes.

State-mandated local program: no.

The people of the State of California do enact as follows:

SECTION 1. Section 25402 of the Public Resources Code is amended to read:

25402. The commission shall, after one or more public hearings, do all of the following, in order to reduce the wasteful, uneconomic, inefficient, or unnecessary consumption of energy, including the energy associated with the use of water:

(a) (1) Prescribe, by regulation, lighting, insulation climate control system, and other building design and construction standards that increase the efficiency in the use of energy and water for new residential and new nonresidential buildings. The commission shall periodically update the standards and adopt any revision that, in its judgment, it deems necessary. Six months after the commission certifies an energy conservation manual pursuant to subdivision (c) of Section 25402.1, a city, county, or state agency shall not issue a permit for a building unless the building satisfies the standards prescribed by the commission pursuant to this subdivision or subdivision (b) that are in effect on the date an application for a building permit is filed. Water efficiency standards adopted pursuant to this subdivision shall be demonstrated by the commission to be necessary to save energy.

(2) Prior to adopting a water efficiency standard for residential buildings, the Department of Housing and Community Development and the commission shall issue a joint finding whether the standard (A) is equivalent or superior in performance, safety, and for the protection of life, health, and general welfare to standards in Title 24 of the California Code of Regulations and (B) does not unreasonably or unnecessarily impact the ability of Californians to purchase or rent affordable housing, as determined by taking account of the overall benefit derived from water efficiency standards. Nothing in this subdivision in any way reduces the authority of the Department of Housing and Community Development to adopt standards and regulations pursuant to Part 1.5 (commencing with Section 17910) of Division 13 of the Health and Safety Code.

(3) Water efficiency standards and water conservation design standards adopted pursuant to this subdivision and subdivision (b) shall be consistent with the legislative findings of this division to ensure and maintain a reliable supply of electrical energy and be equivalent to or superior to the performance, safety, and protection of life, health, and general welfare standards contained in Title 24 of the California Code of Regulations. The commission shall consult with the members of the coordinating council as established in Section 18926 of the Health and Safety Code in the development of these standards.

(b) (1) Prescribe, by regulation, energy and water conservation design standards for new residential and new nonresidential buildings. The standards shall be performance standards and shall be promulgated in terms of energy consumption per gross square foot of floorspace, but may also include devices, systems, and techniques required to conserve energy and water. The commission shall periodically review the standards and adopt any revision that, in its judgment, it deems necessary. A building that satisfies the standards prescribed pursuant to this subdivision need not comply with the standards prescribed pursuant to subdivision (a). Water conservation design standards adopted pursuant to this subdivision shall be demonstrated by the commission to be necessary to save energy. Prior to adopting a water conservation design standard for residential buildings, the Department of Housing and Community Development and the commission shall issue a joint finding whether the standard (A) is equivalent or superior in performance, safety, and for the protection of life, health, and general welfare to standards in the California Building Standards Code and (B) does not unreasonably or unnecessarily impact the ability of Californians to purchase or rent affordable housing, as determined by taking account of the overall benefit derived from the water conservation design standards. Nothing in this subdivision in any way reduces the authority of the Department of Housing and Community Development to adopt standards and regulations pursuant to Part 1.5 (commencing with Section 17910) of Division 13 of the Health and Safety Code.

(2) In order to increase public participation and improve the efficacy of the standards adopted pursuant to subdivisions (a) and (b) this subdivision and subdivision (a), the commission shall, prior to publication of the notice of proposed action required by Section 18935 of the Health and Safety Code, involve parties who would be subject to the proposed regulations in public meetings regarding the proposed regulations. All potential affected parties opportunity to provide written or oral comments. During these public meetings, the commission shall receive and take into consideration input from all parties concerning the parties' design recommendations, cost considerations, and other factors that would affect consumers and California businesses of the proposed standard. The commission shall take into consideration prior to the start of the notice of proposed action any input provided during these public meetings.

(3) The standards adopted or revised pursuant to ~~subdivisions (a) and (b)~~ *this subdivision and subdivision (a)* shall be cost-effective when taken in their entirety and when amortized over the economic life of the structure compared with historic practice. When determining cost-effectiveness, the commission shall consider the value of the water or energy saved, impact on product efficacy for the consumer, and the life cycle cost of complying with the standard. The commission shall consider other relevant factors, as required by Sections 18930 and 18935 of the Health and Safety Code, including, but not limited to, the impact on housing costs, the total statewide costs and benefits of the standard over its lifetime, economic impact on California businesses, and alternative approaches and their associated costs.

(c) (1) Prescribe, by regulation, standards for minimum levels of operating efficiency, based on a reasonable use pattern, and may prescribe other cost-effective measures, including incentive programs, fleet averaging, energy and water consumption labeling not preempted by federal labeling law, and consumer education programs, to promote the use of energy and water efficient appliances whose use, as determined by the commission, requires a significant amount of energy or water on a statewide basis. The minimum levels of operating efficiency shall be based on feasible and attainable efficiencies or feasible improved efficiencies that will reduce the energy or water consumption growth rates. The standards shall become effective no sooner than one year after the date of adoption or revision. A new appliance manufactured on or after the effective date of the standards shall not be sold or offered for sale in the state, unless it is certified by the manufacturer thereof to be in compliance with the standards. The standards shall be drawn so that they do not result in any added total costs for consumers over the designed life of the appliances concerned.

In order to increase public participation and improve the efficacy of the standards adopted pursuant to this subdivision, the commission shall, prior to publication of the notice of proposed action required by Section 18935 of the Health and Safety Code, involve parties who would be subject to the proposed regulations in public meetings regarding the proposed regulations. All potential affected parties shall be provided advance notice of these meetings and given an opportunity to provide written or oral comments. During these public meetings, the commission shall receive and take into consideration input from all parties concerning the parties' design recommendations, cost considerations, and other factors that would affect consumers and California businesses of the proposed standard. The commission shall take into consideration prior to the start of the notice of proposed action input provided during these public meetings.

The standards adopted or revised pursuant to this subdivision shall not result in added total costs for consumers over the designed life of the appliances concerned. When determining cost-effectiveness, the commission shall consider the value of the water or energy saved, impact on product efficacy for the consumer, and the life cycle cost to the consumer of complying with the standard. The commission shall consider other relevant factors, as required by Sections 11346.5 and 11357 of the Government Code, including, but not limited to, the impact on housing costs, the total statewide costs and benefits of the standard over its lifetime, economic impact on California businesses, and alternative approaches and their associated costs.

(2) A new appliance, except for any plumbing fitting, regulated under paragraph (1), that is manufactured on or after July 1, 1984, shall not be sold, or offered for sale, in the state, unless the date of the manufacture is permanently displayed in an accessible place

on that appliance.

(3) During the period of five years after the commission has adopted a standard for a particular appliance under paragraph (1), an increase or decrease in the minimum level of

operating efficiency required by the standard for that appliance shall not become effective, unless the commission adopts other cost-effective measures for that appliance.

(4) Neither the commission nor any other state agency shall take action to decrease a standard adopted under this subdivision on or before June 30, 1985, prescribing minimum levels of operating efficiency or other energy conservation measures for an appliance, unless the commission finds by a four-fifths vote that a decrease is of benefit to ratepayers, and that there is significant evidence of changed circumstances. Before January 1, 1986, the commission shall not take action to increase a standard prescribing minimum levels of operating efficiency for an appliance or adopt a new standard under paragraph (1). Before January 1, 1986, an appliance manufacturer doing business in this state shall provide directly, or through an appropriate trade or industry association, information, as specified by the commission after consultation with manufacturers doing business in the state and appropriate trade or industry associations on sales of appliances so that the commission may study the effects of regulations on those sales. These informational requirements shall remain in effect until the information is received. The trade or industry association may submit sales information in an aggregated form in a manner that allows the commission to carry out the purposes of the study. The commission shall treat sales information of an individual manufacturer as confidential and that information shall not be a public record. The commission shall not request information that cannot be reasonably produced in the exercise of due diligence by the manufacturer. At least one year prior to the adoption or amendment of a standard for an appliance, the commission shall notify the Legislature of its intent, and the justification to adopt or amend a standard for the appliance. Notwithstanding paragraph (3) and this paragraph, the commission may do any of the following:

(A) Increase the minimum level of operating efficiency in an existing standard up to the level of the National Voluntary Consensus Standards 90, adopted by the American Society of Heating, Refrigeration, and Air Conditioning Engineers or, for appliances not covered by that standard, up to the level established in a similar nationwide consensus standard.

(B) Change the measure or rating of efficiency of any standard, if the minimum level of operating efficiency remains substantially the same.

(C) Adjust the minimum level of operating efficiency in an existing standard in order to reflect changes in test procedures that the standards require manufacturers to use in certifying compliance, if the minimum level of operating efficiency remains substantially the same.

(D) Readopt a standard preempted, enjoined, or otherwise found legally defective by an administrative agency or a lower court, if final legal action determines that the standard is valid and if the standard that is readopted is not more stringent than the standard that was found to be defective or preempted.

(E) Adopt or amend any existing or new standard at any level of operating efficiency, if the Governor has declared an energy emergency as described in Section 8558 of the Government Code.

(5) Notwithstanding paragraph (4), the commission may adopt standards pursuant to Commission Order No. 84-0111-1, on or before June 30, 1985.

(d) Recommend minimum standards of efficiency for the operation of a new facility at a particular site that are technically and economically feasible. A site and related facility shall not be certified pursuant to Chapter 6 (commencing with Section 25500), unless the applicant certifies that standards recommended by the commission have been considered, which certification shall include a statement specifying the extent to which conformance with the recommended standards will be achieved.

(e) The commission shall do all of the following:

(1) Not later than January 1, 2004, amend any regulations in effect on January 1, 2003, pertaining to the energy efficiency standards for residential clothes washers to require that residential clothes washers manufactured on or after January 1, 2007, be at least as water efficient as commercial clothes washers.

(2) Not later than April 1, 2004, petition the federal Department of Energy for an exemption from any relevant federal regulations governing energy efficiency standards that are applicable to residential clothes washers.

(3) Not later than January 1, 2005, report to the Legislature on its progress with respect to the requirements of paragraphs (1) and (2).

(f) (1) The standards adopted by the commission pursuant to subdivision (a) or (b) shall require a new residential construction ~~commenced on or after January 1, 2020, and a new nonresidential construction commenced on or after January 1, 2030, to be a zero~~ *commenced on or after January 1, 2020, to be a zero* net energy building.

(2) For the purposes of this subdivision, the term “zero net energy building” means a building that implements a combination of building energy efficiency design features and clean onsite distributed generation that result in no net purchases from the electricity or gas grid on an annual basis.

(3) In developing the standards pursuant this subdivision, the commission shall consult with the Public Utilities Commission, the electric and gas utilities, and other interested parties.