CODES AND STANDARDS ENHANCEMENT INITIATIVE (CASE)

Solar Ready Homes and Solar Oriented Development

2013 California Building Energy Efficiency Standards

California Utilities Statewide Codes and Standards Team September 2011

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1. Purpose

The state has ambitious policy goals to significantly reduce future building energy use, increase onsite renewable energy generation, and move towards zero net energy. This report investigates the feasibility of two related solar measures for single family homes that will help realize these goals. One measure is to require “solar ready homes” that can accommodate anticipated future PV and solar water heating (SWH) installations. This measure will help ensure that future solar systems are more cost effective, have lower installation costs, realize significant statewide energy savings improvements through improved orientation, and reduce the number of homes that are not suitable for rooftop solar systems due to poor design.

The second measure examines the savings potential and opportunities for “solar oriented developments.” Solar oriented developments are developments which incorporate measures to minimize building energy use and maximize onsite renewable energy generation potential from the early planning and design stages, and include considerations such as street orientation, lot design, home placement on lots, roof configuration, etc. The way we lay out neighborhoods impacts energy use for decades and perhaps centuries. In many cases, key design decisions that impact building energy use are finalized in the planning and entitlement stage long before architects and engineers are brought on to develop specific house designs. This measure attempts to connect several rapidly converging policy spheres and develop a set of code proposals that will aid planners, developers, and others both meet various policy requirements, as well as bring significant value to the development early in the planning phase. This CASE proposes initial steps towards a more robust analytical approach to optimizing solar oriented neighborhood development.

2. Overview

a. Measure Title	Solar Ready Homes, and Solar Oriented Development
b. Description	The Solar Ready Homes measure would require single family homes to designate a “solar zone” on the roof reserved for future photovoltaic (PV) and solar water heating (SWH) systems. The solar zone would have a minimum area and orientation requirement, be kept free from vents and other protrusions and be unshaded. Furthermore, the designs shall consider piping and electrical layout, and indicate layout on the plans. Finally, adequate electrical capacity shall be provided at the electrical panel. The Solar Oriented Development proposal will strengthen existing requirements to minimize building energy use and maximize onsite solar energy generation (PV and SWH) in the planning, entitlement and design stages through street orientation, lot layout, house orientation, landscaping, building design guidelines and related factors. This measure will expand upon existing solar oriented development requirements in the reach code (CALGreen), and provide a more systematic, robust and analytical framework for documenting compliance with existing solar oriented development requirements (e.g., the California Subdivision Map Act), and connecting rapidly emerging policy issues (e.g., using solar oriented development features as a CEQA mitigation measure). General reporting and analysis requirements are proposed for the mandatory section of CALGreen, and voluntary Tier 1 and Tier 2 performance goals for solar oriented development are proposed for the voluntary measures in CALGreen.
c. Type of Change	The types of changes proposed in this CASE include: **Mandatory Measure –** A mandatory Solar Ready Home requirement is proposed for Title 24, Part 6, applicable to single family homes. **Mandatory Measure –** A mandatory Solar Development requirement is proposed for Title 24, Part 11, which requires new subdivisions to document compliance with existing solar oriented development requirements and related voluntary commitments, and use a more rigorous analytical approach to document the feasibility of solar oriented measures. This addresses a longstanding loophole in current code. **Other –** A voluntary “Tier 1” and “Tier 2” performance level for Solar Oriented Development is proposed for Title 24, Part 11.

d. Energy Benefits

The solar ready home measure will result in an increased output of 8,711 $kBTU_{TDV}$ (weighted average) for each PV system installed on a roof, and save an additional 1,116 $kBTU_{TDV}$ of natural gas for each solar water heating system due to the availability of an optimally oriented solar zone. Note: the cost effectiveness analysis accounts for the fact that not all homes will install solar. Furthermore, this measure will increase the number of new homes capable of installing a rooftop mounted solar system. Estimates vary, but anywhere from 4% to 30% of existing homes do not have suitable roof area for a solar system. These savings are not accounted for below.

	Electricity Savings (kWh/yr)	Demand Savings (kW)	Natural Gas Savings (Therms/yr)	TDV Electricity Savings	TDV Gas Savings
Per Unit Measure[1]	216	0.3	19.9	8,711	1,116
Per Prototype Building[2]	216	0.3	19.9	8,711	1,116
Savings per square foot[3]	0.08	0.000049	0.007	3.23	0.41

e. Non-Energy Benefits

The proposed solar ready homes measure is synergistic with the California Homebuyer Solar Option and Solar Offset Program (SB1, 2006), which requires production home builders to offer solar as an option on new homes. Implementing the solar ready homes proposals will ensure that solar is a viable option on all homes, reduce the cost of solar, and contribute to an increased home buyer solar adoption rate.

The solar oriented development measure connects several rapidly converging policy spheres (including land use law, environmental law, climate policy, and building energy codes) and will push planners, developers, and others involved in the early stage planning of new residential development to more rigorously consider key planning and design issues impacting building energy use. It will push planners towards a more robust analytical approach to optimizing neighborhood orientation and for documenting best practices and strategies incorporated into neighborhood design related to reducing neighborhood-wide energy use.

While this CASE focuses on solar water heating and PV, the penetration of solar space heating systems has nearly doubled from 0.7% to 1.3% from 2003 to 2009 (Figure 5), and will likely continue to grow with the push for zero net energy buildings. Solar space heating typically uses the same thermal collectors as SWH system, and has similar orientation, roof availability, and other requirements to both PV and SWH. Both the solar ready homes measure and solar oriented development measure will directly benefit future solar space heating installations as well.

f. Environmental Impact

Material Increase (I), Decrease (D), or No Change (NC): (All units are lbs/year)

	Mercury	Lead	Copper	Steel	Plastic	Others (Indentify)
Per Unit Measure[1]	NC	NC	NC	NC	NC	NC
Per Prototype Building[2]	NC	NC	NC	NC	NC	NC

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Water Consumption:

	On-Site (Not at the Powerplant) Water Savings (or Increase) (Gallons/Year)
Per Unit Measure[1]	0
Per Prototype Building[2]	0

Water Quality Impacts:

	Mineralization (calcium, boron, and salts	Algae or Bacterial Buildup	Corrosives as a Result of PH Change	Others
Impact (I, D, or NC)	NC	NC	NC	NC
Comment on reasons for your impact assessment	This measure does not result in any change in runoff, runoff characteristics, or otherwise impact water quality.	This measure does not result in any change in runoff, runoff characteristics, or otherwise impact water quality.	This measure does not result in any change in runoff, runoff characteristics, or otherwise impact water quality.	This measure does not result in any change in runoff, runoff characteristics, or otherwise impact water quality.

g. Technology Measures	The Solar Ready Homes and Solar Oriented Development measures do not require or encourage a particular technology. There are no issues associated with measure availability, useful life, persistence or maintenance.
h. Performance Verification of the Proposed Measure	The Solar Ready Homes measure proposes documentation requirements which can be used to confirm that the solar ready requirements are met during plan check. No additional performance verification is required. The solar oriented development measure similarly proposes documentation requirements which can be reviewed during entitlement, permitting and other planning phase activities and compliance activities.

i. Cost Effectiveness

The cost effectiveness for the solar ready home was calculated using both the 2014 CEC projected housing starts and the CBIA projected housing starts. There is no change in the outcome of the cost effectiveness calculation; the solar ready homes measure is cost effective calculated using either of the housing start numbers.

a	b	c		d		e		f	g	
Measure Name	Measure Life (Years)	Additional Costs[1]– Current Measure Costs (Relative to Basecase) ($)		Additional Cost– Post-Adoption Measure Costs (Relative to Basecase) ($)		PV of Additional[2] Maintenance Costs (Savings) (Relative to Basecase) (PV$)		PV of[3] Energy Cost Savings – Per Proto Building (PV$)	LCC Per Prototype Building ($)	
		Per Unit	Per Proto Building	Per Unit	Per Proto Building	Per Unit	Per Proto Building		(c+e)-f Based on Current Costs	(d+e)-f Based on Post-Adoption Costs
Solar Ready Homes (Using CEC housing start projections)	30		$182		$182		-$196	$53	-$67	-$67
Solar Ready Homes (Using CBIA housing start projections)	30		$182		$182		-196	$53	-$67	-$67

Notes:

1. Column c is the costs that every home built in 2014 will incur to make it "solar ready" as defined in section 5.1 of this report.
2. Column e is the *average* per home retrofit cost savings due to the solar ready measure. Note that the actual savings for homes that implement solar is much higher: $2,505 savings for each home that installs PV, and $1,328 per home that installs Solar Water Heating (SWH). The *average* retrofit savings are calculated by adding up the present value savings for all homes that implement PV or SWH over their 30 year life, and dividing by the total number of homes constructed in 2014.
3. The energy savings are not constant over the 30 year measure life, but depend on the number of homes that retrofit PV or SWH each year. The energy savings are calculated by first determining the total number of PV and SWH systems installed each year and each year's total PV and SWH savings, then calculating the present value for each year's energy savings (calculated consistent with the TDV methodology), summing over the 30 year measure lifetime, and then dividing y the total number of homes constructed in 2014.
4. Cost effectiveness projections shown here are based on PV and SWH market adoption meeting the California Solar Initiative Goals, and that that penetration growth continues throughout the 30 year measure life, resulting in a 7.8% PV penetration and 12% SWH penetration by 2043. Note that the cost effectiveness has been calculated for other scenarios, and the minimum PV and SWH penetration that makes this measure cost effective is 6.4% by 2043. This is well below the penetration level projected by various market surveys that account for continued drops in system prices, and various state policy goals and incentive programs.

j. Analysis Tools	The Solar Ready Homes measure is proposed as mandatory, and analysis tools are not relevant, since that measure would not be subject to whole building performance trade-offs. The Solar Oriented Development Measure proposes a mandatory requirement to use an analytic tool or process to evaluate "viability" of solar oriented development measures, and a voluntary Tier 1 and Tier 2 performance goal for demonstrating that a specific solar oriented neighborhood layout exceeds the performance of a typical design by a specified percent. There are currently a variety of tools and methods being used to analyze this type of measure. Specific tools focused only on solar oriented neighborhood analysis (e.g., the Subdivision Energy Analysis Tool) are nascent. This CASE proposes that the specific tool choice be left unspecified, or minimally specified to enable a diverse array of tools and methods coming into the market. This can be changed over time. Alternatively, a simple spreadsheet compliance tool can be developed based on data generated during this CASE to demonstrate solar oriented development effectiveness.
k. Relationship to Other Measures	This CASE proposes PV and SWH "solar ready" requirements for *single family* homes. This CASE is related to three other solar water heating measures: 1) The multifamily SWH CASE proposes solar water heating and solar ready requirements for *multifamily* homes. The cross-cutting SWH CASE developed by Energy Solutions proposes to increase the existing solar fraction requirement for single family residential buildings with electric water heating, and to add a new solar fraction requirement for restaurants with both electric and natural gas water heating above a certain square footage. The Commercial Solar Ready CASE proposes solar ready requirements for PV systems in *commercial* buildings. These CASEs were developed collaboratively, with each CASE addressing distinct areas of the code. This CASE proposal was also coordinated with other relevant CASEs, including the residential windows and compressorless comfort cooling CASEs. Specifically, the solar oriented development analysis coordinated the building energy simulation modeling with the proposed residential window CASE proposals to reflect potential future code directions. This includes the impacts of a 2% west facing glazing limitation, shading and overhang requirements, and updated glazing proposals.

3. Methodology

This section describes the methodology that was followed to assess the savings, costs, and cost effectiveness of the proposed code change. There is significant overlap in the methodology and data for the two measures considered in this CASE. The analysis described in sections 3.1 through 3.4 supports both the solar ready homes and solar oriented development measures. Specific analysis pertaining only to the solar ready homes measure is described in section 3.5, and analysis pertaining only to the solar oriented development measure in section 3.6.

This work was publicly vetted through our stakeholder outreach process, which through in-person meetings, webinars, email correspondence and phone calls, requested and received feedback on the direction of the proposed changes. The stakeholder meeting process is described at the end of the Methodology section.

3.1 Literature, Market and Regulatory Context Review

The CASE team conducted a review of literature pertaining to solar ready homes and solar oriented developments. This included a review of scholarly journals; trade publications; a review of existing federal, state and local municipal codes and regulations; and review of current market practices and voluntary best practices. The purpose of the literature review was to gather supporting data, identify best practices, lessons learned, analysis methodologies and tools used, and other relevant data to inform and guide this CASE study.

3.1.1 Future PV and SWH Market Projections

An important aspect of the market review was to establish future market projections of PV and SWH systems for the cost effectiveness analysis of the solar ready homes measure. To this end, The CASE team reviewed the literature and available data to determine the most appropriate projections. Data reviewed included the 2003 and 2009 California Statewide Residential Appliance Saturation Study[1], CSI Thermal program data[2], California Solar Initiative (CSI) program data, the New Solar Homes Partnership (NSHP) program, AB 1470 program goals, California's Global Warming Solutions Act (AB 32) Scoping Plan goals, California's Long Term Energy Efficiency Strategic Plan[3], market studies done by Navigant[4], the National Renewable Energy Laboratory[5], and CALSEIA[6], and others. Future market penetrations for a range of scenarios were projected based on the above data. The

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[1] Data available at http://websafe.kemainc.com/RASS2009/Default.aspx

[2] Project data can be downloaded from http://www.gosolarcalifornia.org/solarwater/index.php

[3] California Public Utilities Commission, September 2008

[4] Paidipati, J. et al., "Rooftop Photovoltaics Market Penetration Scenarios," Navigant Consulting, February 2008, http://www.navigantconsulting.com/downloads/Final_Report_PV_MarketsNREL_US_EG.pdf.

[5] Drury, E., Denholm, P., and Margolis, R. "Modeling the U.S. Rooftop Photovoltaics Market." Proceedings of American Solar Energy Society 2010 National Solar Conference, Phoenix, AZ, May 2010. http://www.nrel.gov/docs/fy10osti/47823.pdf

[6] The California Solar Energy Industries Association (CALSEIA), "The Value Proposition of Solar Water Heating In California", January 2009. http://www.seia.org/galleries/pdf/CALSEIA_Report_SWH_Value_Proposition.pdf

projections bracketed the worst case (lowest penetration), best case, and several intermediate scenarios. A more detailed discussion on the methodology and issues is provided in context with actual data in section 4.1.1.

3.1.2 Online Surveys

To support the market review, a series of surveys were developed to solicit stakeholder input on solar ready homes current/best practices and solar oriented development current/best practices. These were posted using a web-based survey service called 'Survey Monkey'. Stakeholder participation was solicited via direct email, as well as requests during stakeholder meetings. The online surveys were coordinated with similar surveys from the other solar CASEs. A collective email list was assembled by the CASE teams for soliciting participation. Contacts were pulled from the Database of Solar Installers, Contractors, and Retailers in California[7], from relevant trade and industry organizations, and other personnel with relevant experience. Additionally, participants in the stakeholder meetings were encouraged to participate.

Notice of the surveys was also posted on the 2013 Title 24 Codes and Standards Enhancement Solar Topics web page, http://www.h-m-g.com/t24/Solar/solar.htm.

The links to the online surveys are:

- Solar Ready Best Practices Survey: http://www.surveymonkey.com/s/7NMP89T
- Solar Oriented Development Best Practices Survey: http://www.surveymonkey.com/s/BZF9LD3

Survey questions are presented in the appendices to this report.

3.1.3 Informal Interviews

The CASE team also conducted a series of informal interviews with solar system manufacturers, installers, designers, and other relevant parties to identify significant issues related to solar ready homes/solar oriented development, to identify current and best practices, and to review and vet various aspects of the analysis. These interviews and communications were used to supplement the online surveys, and solicit feedback from people who did not participate in the online survey but were identified as having relevant information.

3.2 Analysis of "Current Practice" Solar Performance in Existing Homes and Communities

In order to characterize the current practice and performance of solar-ready homes and solar-oriented residential developments, it was necessary to collect and analyze data from a number of relevant residential developments. Housing data was collected for solar-ready, solar-oriented, and non-solar communities in California to determine the specific implementation of current practice and the potential for improvement for each residential category in both solar energy generation and building

[7] http://www.gosolarcalifornia.org/database/search-new.php

energy use. Building, roof, and solar system orientation as well as additional specific design attributes were compared amongst solar-ready, solar-oriented, and non-solar homes in order to determine the feasibility and effectiveness of plausible solar-ready and solar-oriented measures to reduce overall building energy use and maximize solar PV and solar hot water generation.

The photovoltaic performance of the communities were evaluated by completing housing surveys to identify specific attributes and orientations of each home and applying annual PV output estimates to the data. Bing Maps[8] and Google Maps[9] were used to collect data for the specific lot orientation, roof orientation, roof area, roof complexity, roof pitch, and PV and SDWH size and orientation[10].

To guide initial measure development, the PV orientation and tilt (roof pitch) were used to estimate solar energy output with the National Renewable Energy Laboratory's PV Watts V.2 performance estimator for grid-connected solar PV panels. The calculator determines the energy production and cost savings of systems at hundreds of locations in the United States using hour-by-hour performance simulations to provide annual energy generation data for the selected location. The calculator also outputs the solar radiation incident on the PV array, and calculates the DC energy generated based on the system's DC rating and an overall DC to AC derate factor of 0.77.

After attaining photovoltaic output data for each house in the development, the data was compiled to specify the average efficiency of each development as a percentage of maximum PV output. The relationship between orientation and solar output, the quantity of homes at each orientation, and the cumulative frequency of solar performance are used as analysis techniques to highlight desirable and non-desirable attributes of the neighborhood layout and home designs. Applicable regulatory measures are considered and the potential for improvement in performance is quantified.

The PV and SWH savings were updated using results from the PV parametric study and SWH parametric study using 2013 TDV data, as described in sections 3.3 and 3.4.

[8] http://maps.bing.com

[9] http://maps.google.com

[10] North = 0º, E = 90º, S = 180º, and W = 270º

3.3 Photovoltaic (PV) Parametric Analysis

Analysis of both the solar ready homes and solar oriented development measure required PV performance data for a wide range of tilts and azimuths for each climate zone. Annual solar photovoltaic performance was analyzed using the CECPV Calculator, Version 2.4[11]. The CECPV calculator is based on a 5-parameter model developed by the Solar Energy Laboratory at the University of Wisconsin [De Soto, et. al. 2006] with a MS Excel interface provided by the California Energy Commission. The tool allows the user to select specific PV modules and inverters, and generates estimated annual kWh production, with hourly power generation data available as a separate output file. The updated 2010 California Climate Zone weather files were processed for use with the tool. The hourly CECPV output data was post-processed to calculate TDV using the CEC's 2011 TDV v3.

A representative PV module and inverter configuration was used for each parametric run. The PV module used was the Suntech Power STP 180S-24/AB-1, which is a 180 W_{DC} module. The system analyzed was a 20 module system arranged in 2 parallel strings of 10 modules each. This system totals 3.6 kW_{DC}, which is approximately 3.1 kW_{AC} per the CECPV calculations. Each run used the SMA America SB4000US (240V) inverter. An example output file, documenting inputs, is shown Figure 1.

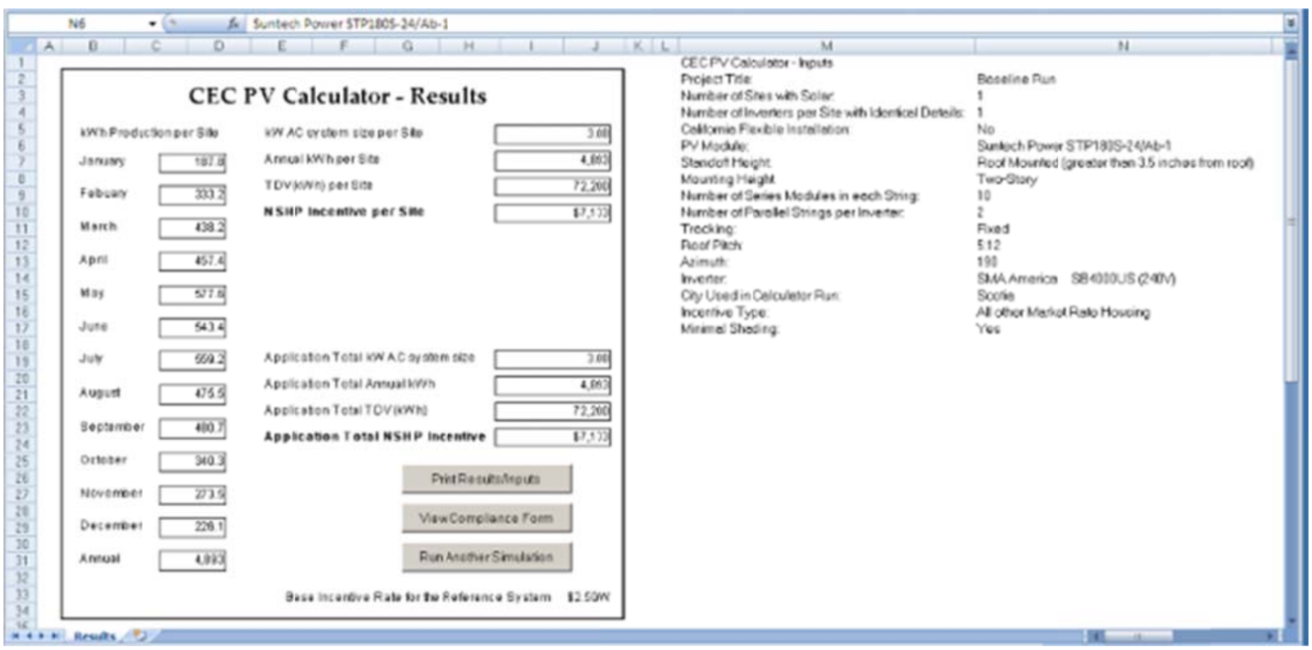

Figure 1: CECPV Calculator example results output showing key input assumptions

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[11] http://www.gosolarcalifornia.ca.gov/tools/nshpcalculator/download_calculator.php

Parametric runs were performed for each California climate zone at 0:12, 3:12, 5:12, and 8:12 roof pitches. At each roof pitch, the system was analyzed for azimuths ranging from 150 to 270 degrees at 10 degree intervals (the primary range of interest). Furthermore, an additional run was performed for 0/360 degrees.

The results of the CECPV parametric runs using the 3.6 kW_{DC} array were normalized per kW of installed nameplate capacity to explore the impacts of different sized systems. For this level of analysis, it is assumed that the array/inverter performance changes versus systems size are minimal.

The solar orientation factor (SOF) is calculated for each run. The SOF is calculated by dividing the annual PV output (in TDV) for a PV array at a given tilt and azimuth divided by the maximum output of the PV array at its optimum orientation and tilt[12]:

$$Solar\ Orientation\ Factor\ (SOF) = \frac{Annual\ TDV\ output\ of\ a\ PV\ array}{Annaul\ TDV\ output\ at\ optimal\ tilt\ and\ orientation}$$

The SOF provides an easy metric to analyze the relative performance of PV systems on different roof pitches and orientations for both the solar ready homes and solar oriented development measures. It is a unit less number ranging from 0% to 100%, with 100% representing the performance of an optimally oriented solar collector.

The CECPV Tool runs were conducted at discrete tilts and azimuths (e.g., the yellow dots in Figure 2 for a 5:12 roof pitch). The majority of runs were conducted in the 150 to 270^{o} azimuth range, to ensure that the performance range of the recommended solar orientation and most existing collectors surveyed is well defined. To facilitate analysis of PV performance on roof orientations between hourly analyses, the Solar Orientation Factor results were interpolated. A 4th order polynomial provided an excellent data fit, as shown in Figure 2: Example best fit line for interpolating the Solar Orientation Factor between discrete runs, where the yellow triangles represent SOF data from actual CECPV Tool runs, and the black line represents the 4th order best fit line. These fits were developed for all sets of parametric runs for multiple tilts and all climate zones. The best fit curve enables calculation of the PV output of any collector regardless of orientation. These performance outputs could also be used in the development of a future tool to assess solar oriented development performance without necessitating detailed hourly simulations for every conceivable system orientation.

[12] Note that maximum tilt was limited to 8:12 pitch.

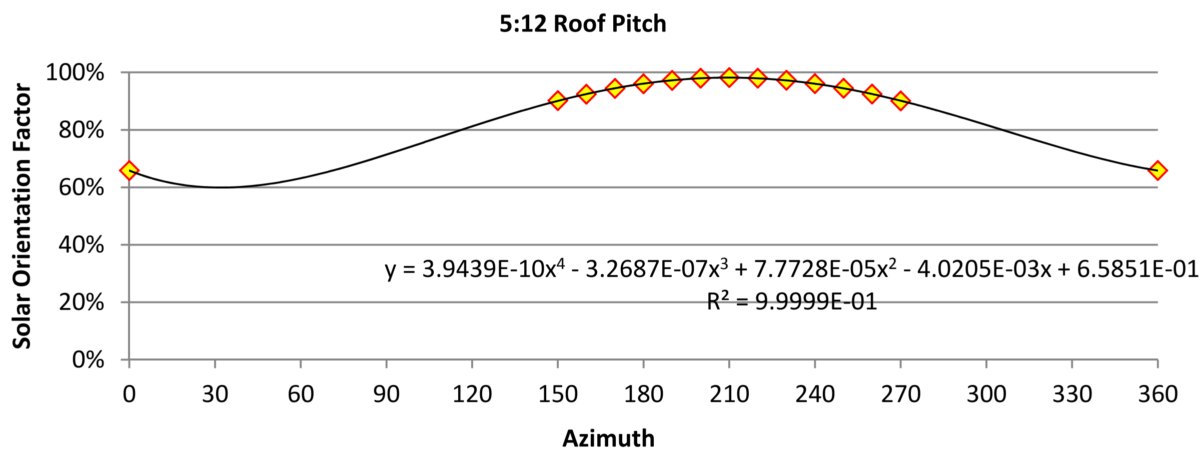

Figure 2: Example best fit line for interpolating the Solar Orientation Factor between discrete runs

3.4 Solar Water Heating (SWH) Parametric Analysis

As with PV, both the solar ready homes and solar oriented development measure require SWH performance data for a wide range of tilts and azimuths for each climate zone. Solar water heating analyses were performed using the National Renewable Energy Laboratory's Solar Domestic Hot Water Analysis Tool, developed for the Building America Program[13]. This is a detailed sub-hourly SWH simulation program designed to analyze residential SWH systems, including active flat plate systems and integral collector storage systems. It is a TRNSY based program developed by Thermal Energy System Specialists (TESS).

The updated 2010 California Climate Zone weather files were processed for use with the tool. The Solar Domestic Hot Water Analysis Tool's underlying TRNSYS.TRD input file was modified to output hourly performance data. The hourly output data was post-processed to calculate TDV using the CEC's 2011 TDV v3. The hourly water heating schedules described in the 2008 Residential Alternate Compliance Manual (RACM) Appendix E[14] were used for this analysis. Water inlet temperatures are based on the monthly ground temperatures of the revised climate zone data provided by the California Energy Commission, per Appendix E. Tank insulation, recover factor and other parameters as specified in Appendix E were used in the model.

Several prototypical SWH systems were analyzed, including:

- System 1: An active flat plate collector system with tank-type natural gas backup heater,

[13] This tool can be downloaded from the National Renewable Energy Laboratories FTP site, or TESS's website, http://www.tess-inc.com/projects/type#solardomestic

[14] Table RE-1, Hourly Water Heating Schedules

- System 2: An active flat plate collector system with a tankless natural gas water heater,
- System 3: An Integrated Collector-Storage (ICS) system with tank-type natural gas backup heater, and
- System 4: An Integrated Collector-Storage (ICS) system with a tankless natural gas water heater.

The following table summarizes key parameters for each system.

		System 1	System 2	System 3	System 4
Solar Panel(s)	Type	Flat plate, selective surface	Flat plate, selective surface	Selective surface ICS	Selective surface ICS
	Panel Area	40 ft^2	40 ft^2	24.6 ft^2 / 40 gal	24.6 ft^2 / 40 gal
	Panel Qty	2	2	1	1
	Fluid	50% glycol	50% glycol	50% glycol	50% glycol
	Flow Rate	4.10 lbm/h-ft^2	4.10 lbm/h-ft^2	Draw Pattern	Draw Pattern
	Loop Piping	¾" nominal	¾" nominal	¾" nominal	¾" nominal
	Pipe Length: Collector – HX or Mains- Aux	20 ft	20 ft	20 ft	20 ft
	Pipe Length: HX - Aux	5 ft	5 ft	N/A	N/A
Solar Tank	HX Effect.	0.50	0.50	N/A	N/A
	Tank Size	120 gal	120 gal	40 gal	40 gal
	Heat Loss Coefficient	0.0833 BTU/hr-ft^2-F	0.0833 BTU/hr-ft^2-F	Calculated by program	Calculated by program
Auxiliary Heater	Type	Gas, tank	Gas, tankless	Gas, tank	Gas, tankless
	Tank Size[15]	50 gallons	N/A	50 gallons	N/A
	Energy Factor	0.575	0.83	0.575	0.83
	Temp Setpoint	135 F	135 F	135 F	135 F
	Thermostat Deadband	9 F	9 F	9 F	9 F

Figure 3: SWH analysis parameters

3.5 Analysis of Solar Ready Home Measures

This section describes the specific analyses used to develop the solar ready homes measures. The analyses described in sections 3.1 through 3.4 supported and informed the development of the solar ready measures as well.

[15] Note: the standard design gas storage tank water heater details are used, per the 2008 Residential Alternate Compliance Manual Table R3-44, "Specifications of Standard Design Water Heater", which includes a 50 gallon tank with an EF = 0.575 and a standard distribution system with no circulation system.

3.5.1 Solar Zone Sizing and Roof Area Availability

To inform the solar zone size requirements, The CASE team analyzed the roof area availability on single family homes. This consisted of a parametric study of the different factors impacting roof area availability, and an analysis of roof area of availability on current production homes.

The parametric analysis was conducted to determine the amount of roof area available for solar zones, as a function of roof shape, house area, fire setback distances, roof tile, house rotation, and other parameters. The solar zone areas were calculated based on variable input data for key parameters. These parameters were adjusted to explore how the available roof area changed. Three primary house/roof shapes were analyzed: a rectangular home, an L-shaped home, and a T-shaped home. For each of these, the analysis was conducted for both a gabled and hip roof configuration, for a total of six different primary roof configurations, as shown in the following figure. The yellow areas indicate potential solar zone areas after fire clearances are accounted for.

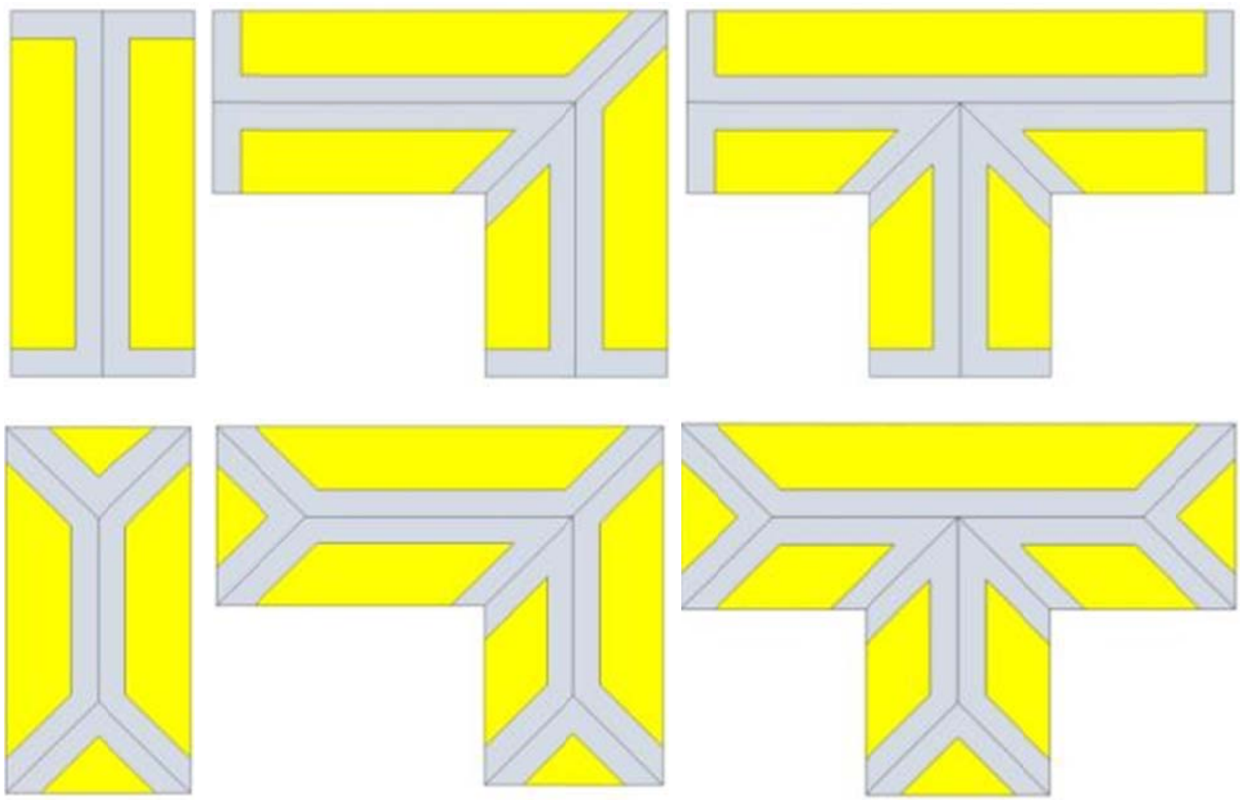

Figure 4: Primary roof shapes and configurations analyzed

Example calculations are provided for an L-shaped building with a gabled roof in Appendix 8 – Solar Zone Roof Calculations. Calculations for other roof shapes are similar.

The following key variables were used as inputs for this analysis:

A_{house} = House Area (sqft)

AR = Aspect Ratio, L'/W', where L' = length of the house (perpendicular to street), and W = width of the house (parallel to street).

S = Number of Stories

P = Roof Pitch (P:12)

F = Fire Setback for solar systems (ft)

OH = Roof Overhang (ft)

Variable length and width of the "L" and "T" projections with respect to the main house length/width

Variable placement of the "T"

In addition to the parametric study of solar zone roof availability, measurements of actual solar zone area for representative current production home designs were made, to confirm that the solar ready home's solar zone minimum area and orientation requirements are achievable. A review of current production homes currently or recently being built was performed, and selection of representative homes were analyzed. The focus was on finding representative entry-level homes in lower price brackets with two or more stories and smaller square footage.

3.5.2 Measure-level Cost and Energy Savings Analysis

To develop cost estimates, we combined data from installers, RSMeans Costworks Online Construction Cost Data (2010 Residential Cost Books)[16], and stakeholder input and feedback. Many of the solar-ready measures have a wide variance, and are not well captured in traditional cost data sources. Therefore, solar ready costs were extensively reviewed with stakeholders during stakeholder meetings. Costs were updated based on stakeholder feedback. Where appropriate, a range of costs are shown, along with the estimated percentage of homes that will incur those costs.

The solar ready homes measure level cost savings analysis assumes that all new homes built (or in some cases a fraction of all new homes built) will incur an additional initial cost at the time of construction, and that homes retrofitting solar at a future date will achieve a cost savings compared to installing solar on a non solar ready home.

In line with the California Energy Commission's 2013 cost-effectiveness method, we calculated energy savings using time-dependent valuation (TDV) assuming a 30-year measure life and residential TDV values.

[16] Note: The team did not see a significant regional variation in RS Means costs for the typical types of measures analyzed. Variation was typically less than 1%, although as high as 7% in some cases. Cost differentials (e.g., difference between a 100 Amp and 200 Amp panel) are less variable. Riverside, a fast-growing region with significant projected growth, was used as the location for the RSMeans cost estimates.

3.5.3 Cost-Effectiveness and Statewide Savings

We calculated the cost-effectiveness for the proposed measure by comparing the measure costs incurred by all new homes that must implement the "solar ready" measures, to the retrofit cost savings and incremental TDV energy savings realized through the solar ready measures verses standard practice. The analysis accounts for the fact that not every home will install solar at a future date. A range of solar system penetration scenarios were examined to understand cost effectiveness implications.

The costs for implementing the solar ready home measure assume that every home built in 2014 will incur the "solar ready" costs defined in section 5.1 of this report.

One unique feature of this "ready" measure is that not every home will realize savings from the measure, and the energy savings are not constant throughout the 30 year analysis period. i.e., some homes will retrofit solar systems in year 1 while some may not retrofit solar systems until year 29. Energy costs savings are accounted for on a yearly basis. The energy savings are calculated by first determining the total number of PV and SWH systems in operation each year (including new systems installed in that year and systems installed in previous years). The corresponding PV and SWH savings are calculated. The present value for each year's energy savings is calculated (calculated consistent with the TDV methodology), and then the present value savings is summed for the 30 year measure lifetime. These total present value savings are then dividing by the total number of homes constructed in 2014 to get the average savings per home.

The solar ready homes will also realize significant installation cost savings when a solar system is retrofitted onto a house after construction due to the "solar ready" features incorporated. The installation cost savings for installing a PV or SWH system on a solar ready verses non-solar ready home is calculated, per section 4.5.4, on a yearly basis. The present value of each year's retrofit cost savings are calculated and then summed over the 30 year measure life, and the average per home savings is calculated by dividing by the total number of homes constructed in 2014.

The cost effectiveness for the solar ready home was calculated using both the 2014 CEC projected housing starts and the CBIA projected housing starts. There is no change in the outcome of the cost effectiveness calculation; the solar ready homes measure is cost effective calculated using either of the housing start numbers. The cost effectiveness for a range of different PV and SWH penetration scenarios was calculated as well.

3.6 Analysis of Solar Oriented Development Measures

3.6.1 Building Energy Use Impacts Due to Orientation

Building energy simulations were conducted to determine the impacts of neighborhood orientation, street layout, lot layout, and building orientation impacts. Preliminary analyses were conducted using the National Renewable Energy Laboratory's Subdivision Energy Analysis Tool (SEAT). Final analyses were made using CALRES2. Building energy models were based on the residential prototype D input parameters for each case, with the one exception being that glazing distribution, glazing type, and overhangs were varied to understand the range of impacts due to orientation. Ken Nittler of Enercomp ran the final runs, in coordination with the residential windows CASE study.

3.6.2 Cost-Effectiveness and Statewide Savings

The proposed code changes affect the planning of new developments and as such are outside the scope of Title 24, part 6. The proposed solar oriented development requirements are proposed for the reach code (Title 24, Part 11).

3.7 Stakeholder Meeting Process

This work was publicly vetted through our stakeholder outreach process, which through in-person meetings, webinars, email correspondence and phone calls, requested and received feedback on the direction of the proposed changes.

All of the main approaches, assumptions and methods of analysis used in this proposal have been presented for review at one of four public Solar Stakeholder Meetings.

At each meeting, the utilities' CASE team invited feedback on the proposed language and analysis thus far, and sent out a summary of what was discussed at the meeting.

A record of the Stakeholder Meeting presentations, summaries and other supporting documents can be found at http://www.h-m-g.com/t24/Solar/solar.htm. Stakeholder meetings were held on the following dates and locations:

- First Solar Stakeholder Meeting/Webinar: January 29th, 2010, San Ramon Conference Center, San Ramon, CA.
- Second Solar Stakeholder Meeting/Webinar: November 2nd, 2010, San Ramon Conference Center, San Ramon, CA.
- Follow-Up Webinar/Teleconference to Second Solar Stakeholder Meeting: January 11th , 2010
- Third Solar Stakeholder Webinar/Teleconference: April 6th, 2011
- Fourth Solar/ Residential Topics Stakeholder Meeting: May 13th, 2011

4. Analysis and Results

The results and findings of this CASE are summarized below. Sections 4.1through 4.4 summarize analyses and background work that supported both the solar ready homes and solar oriented development measures. Specific results for each solar ready homes measure is discussed in section 4.5, and in section 4.6 for solar oriented development.

4.1 Literature, Market and Regulatory Context Review

The CASE team conducted a review of codes, standards and other literature at the federal, state, and local level to identify codes, standards and other regulatory drivers impacting solar ready homes and solar oriented development. This section summarizes the relevant code and standard context relating to solar ready homes, both to understand California-specific issues, as well as examine what other states and jurisdictions outside of California are doing.

4.1.1 Market Overview and Projections

The current market penetration and likely future market penetrations for PV and SWH are discussed below.

Current Solar Water Heating Market Penetration and Characteristics

The current market penetration for residential solar water heating systems was obtained from the 2009 California Statewide Residential Appliance Saturation Study[17]. This was the best source of market data identified. Figure 5 summarizes the number of solar water heating installations and solar space heating installations for single family homes in 2003 and 2009, based on the 2003 and 2009 RASS survey data. The penetration of solar water heating systems has remained constant at 1.4%. While this CASE focuses on solar water heating and PV, the penetration of solar space heating systems has nearly doubled from 0.7% to 1.3%, and will likely continue to grow with the push for zero net energy buildings. Solar space heating systems typically uses the same thermal collectors as SWH system, and has similar orientation, roof availability, and other requirements to both PV and SWH. Both the solar ready homes measure and solar oriented development measure will benefit and facilitate the growth of solar space heating.

Year	Building Population	Solar Water Heating	Solar Space Heating	Total Solar
2009	6,519,951	92,984	83,944	176,928
		1.43%	1.3%	2.71%
2003	5,516,455	79,275	44,497	123,772
		1.44%	0.7%	2.24%

Figure 5: Solar water heating penetration in 2003 and 2009 for single family homes

[17] Specifically, data was obtained from KEMA's http://websafe.kemainc.com/RASS2009/Default.aspx

Nearly all of these systems are believed to be retrofitted onto existing construction, verses installed during new construction. The following data points support this assumption:

- The CSI Thermal program data shows that there were 182 applications between the 10 month period of May 2010 and March 2011. Of these, 2 (1%) are for new construction, and 180 (99%) are for retrofits[18]. Extrapolating these numbers to yearly totals amounts to approximately 216 retrofit SWH systems, and ~2 new construction systems per year.
- The 2009 RASS data indicates a 1.43% solar water heating penetration rate for single family homes which has remained nearly constant since 2003. The CEC residential new construction forecast[19] shows 17,957 new single family homes built during 2010. To maintain the anticipated 1.43% solar penetration rate, 259 homes would have to install solar in 2010. The CSI thermal program indicates ~216 retrofit systems installed in 2010 (preceding bullet). Thus, retrofits from the CSI program are shown to substantially meet the expected number of new SWH installations for 2010.
- As part of the work supporting this CASE, a review of existing "solar" neighborhoods was performed, and the results of show that most newly-constructed "solar" homes/developments install PV, with minimal penetration of solar water heating. Only one neighborhood, Scripps Highlands, is known to have a large SWH penetration[20].
- The CASE author's experience working with production homebuilders to incorporate energy efficiency, renewable energy and other sustainability features into large neighborhood developments is that while solar water heating is usually recommended as a cost-effective sustainability measure, it is rarely installed; PV has much greater appeal.

Thus, based on the review of the data, it is assumed that the current market SWH penetration will stay constant at 1.44% (RASS data), and that of the newly installed systems, 1% will be installed on new construction and 99% retrofitted onto existing homes (per CSI Thermal Program data). In other words, the SWH penetration for new homes is 0.01%[21], and 1.43% for existing homes[22].

Typical SWH system characteristics, based on the CSI-Thermal Program data[23] are summarized below:

- System Type
  - Forced Circulation with Flat Plate Collectors: 79%
  - Thermosyphon: 12%

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[18] Project Data downloaded 4/6/2011 from http://www.gosolarcalifornia.org/solarwater/index.php, and filtered for residential single family installations only. "CSI-program data 2011-04-06.xlsx"

[19] Res Construction Forecast by BCZ v4.xlsx

[20] Farhar, B., Coburn, T., and Murphy, M. "Large-Production Home Builder Experience with Zero Energy Homes." ACEEE Summer Study on Energy Efficiency in Buildings. Pacific, Grove, California, 8/2004. http://www.nrel.gov/docs/fy04osti/35913.pdf

[21] 1.44% total SWH market penetration x 1% of new systems on new construction = 0.01% new construction SWH market penetration.

[22] 1.44% total SWH market penetration x 99% of new systems installed on existing homes = 1.43% existing home SWH market penetration.

[23] Based on data downloaded 4/6/2011, and filtered for residential single family systems.

    - Integral Collector Storage (ICS), Direct: 7%
    - Integral Collector Storage (ICS), Indirect: 2%
- Freeze Protection
    - Glycol: 88%
    - Drainback: 12%
- Collector Area: Ranges from 27 to 98 ft^2, with an average of 51 ± 13 ft^2.
- Solar Tank Volume: Ranges from 50 to 120 gallons, with an 80 gallons average
- Backup Heating:
    - 83% have tank-type backup heaters, and 17% have tankless heaters
    - 39% have gas backup, 61% have electric backup
    - Backup (Auxiliary) Tank Volume: ranges from 40 to 120 gallons, with a 68 gallon average
- Total Project Cost: Ranges from $3,400 to $22,300, with an average cost of $8,400 ± 2,900.
- Projected average annual energy cost savings per systems are 130 ± 26 Therms/year for gas backup systems, and 2,800 ± 360 kWh/year for electric backup systems.

Understanding the current types and sizes of SWH systems being installed is important to estimating future market penetration (see below), sizing the solar zone for the solar ready homes measure, and for selecting the SWH modeling runs described in 4.4.

Future Market Penetration for Solar Water Heating Systems

The future solar thermal market depends on many factors, including the impacts of current state policy (e.g., AB 1470, CEQA, etc. discussed in section 4.1.2), incentives, natural gas price volatility, and the outcomes of this and related CASE proposals. KEMA-XENERGY estimated that the maximum "Technical Potential" (maximum penetration technically, but not necessarily feasible) for SWH in the residential market is to displace 971,000,000 Therms/year of natural gas in single family homes.[24] Based on average system savings of 130 therms/year (see preceding summary of CSI-Thermal Program performance statistics), this would equate to approximately 7.7 million systems. This is higher than the total number of single family homes (Figure 5). The Kema-Xenergy estimate is likely based on larger system sizes, and may include solar space heating. In any case, this projection indicates nearly 100% market penetration is possible. This is not a likely, however.

A more likely scenario is that current incentive program and policy goals are met. Assembly Bill 1470 (Solar Hot Water and Efficiency Act of 2007)'s goal is to install 200,000 SWH systems throughout California by 2017 with an incentive budget of $250 million. California's Global Warming Solutions

[24] KEMA-XENERGY Inc., April 2003(b), "California Statewide Residential Sector Energy Efficiency Potential Study (Study ID #SW063): Final Report, Volume 2 of 2, Appendix G: Non-Additive Measure-Level Results – Natural Gas. http://www.calmac.org/publications/Residential_Potential_Study_Vol2.pdf

Act (AB 32) Scoping Plan includes meeting the AB 1470's goal of 200,000 SWH installations by 2020[25]. The CEC projects that there will be a total of 9,097,056 total single family homes built by 2017, and 9,435,020 homes by 2020. Assuming that the majority of SWH systems are installed on single family homes, this would result in a penetration of 2.2% by 2017, or 2.1% by 2020. A more aggressive scenario would be meeting the "big bold" goals for building energy efficiency and zero net energy buildings in the California Long Term Energy Efficiency Strategic Plan (and for which this and other CASE proposals are striving). For residential buildings, the 2020 goals include:

- All new residential construction in California be zero net energy by 2020,
- 25% of existing homes will achieve 70% decrease in purchased energy, relative to 2008 levels
- 75% of existing homes will achieve 30% decrease in purchased energy, relative to 2008 levels

Achieving the 30% decrease in purchased energy can potentially be met by energy efficiency. However, meeting the 70% decrease in purchased energy will most likely require onsite solar generation, including SWH and PV. Meeting the "big bold" goals would require a ~25% SWH penetration by 2020. This is an aggressive penetration level, given current and historical penetrations levels of ~1.43%, and the fact that the CSI Thermal program and other state policy goals would only result in a ~2% penetration. Implementing the solar ready homes and solar oriented development measures will be key to helping enable this aggressive penetration level. Based on this information, we conclude that meeting the AB 1470 (200,000 SWH systems by 2017) is a realistic scenario, backed by current incentives and policy commitments, and is used for the solar ready homes cost effectiveness analysis. It is assumed that the SWH market will continue to grow at this rate throughout the 30 year measure analysis period.

Current Market Penetration and Characteristics for PV Systems

The best market data identified for current single family PV market penetration comes from the "California Solar Initiative" (CSI), which provides rebates for existing homes, and the "New Solar Homes Partnership" (NSHP), which provides inventive for new construction. At the time of analysis (April 1, 2011), there were 48,019 residential PV systems installed under the CSI program with a combined nameplate rating of 270.927 MW, a CEC PTC rating of 232.740 MW, and a CSI Rating of 220.610 MW.[26] The average system nameplate size is 5.64 kW_{DC}, with a CSI rating of 4.59 kW. Note: this is larger than the PV systems installed on the new homes identified in section 4.2. Refer to section 4.5.1for more discussion on the solar ready solar zone sizing. Program data for the New Solar Homes Partnership (NSHP) was unable to be obtained.

The residential construction forecasts developed by the CEC[27] shows 8,372,526 total single family homes for 2010, including 97,610 new construction units[28]. Subtracting the new construction count,

[25] Measure CR-2, page C-118. http://www.arb.ca.gov/cc/scopingplan/sp_measures_implementation_timeline.pdf

[26] Project data can be downloaded here: http://www.californiasolarstatistics.ca.gov/current_data_files/

[27] Res Construction Forecast by BCZ v4.xlsx

[28] Note: this is higher than the 2009 single family counts estimated by the RASS, shown in Figure 5. The analysis presented here generally uses the CEC housing projections, except to maintain internal consistency with other data sources (e.g., the SWH penetration numbers are based entirely on RASS reported statistics).

there were ~8,274,916 existing single family homes in 2010. Dividing the CSI-reported PV system count of 48,019 PV systems on existing residential buildings by this count results in a residential PV penetration rate of 0.58%[29].

Future Market Penetration for Solar PV Systems

The National Renewable Energy Laboratory has analyzed the potential size of the future U.S. PV market given a variety of different policy and financial levers [Drury et. al. 2010]. Figure 6 shows the range or projected PV costs ($/kW). The red line shows the Energy Information Agency (EIA)'s projections used to generate the 2009 Annual Energy Outlook (AEO), the blue line is the U.S. Department of Energy (DOE) Solar Energy Technology Program (SETP)'s projections, and the black line shows the average cost projections from a DOE survey of experts. The dashed lines show the range of expert opinion where only 10% of respondents believe cost would be higher and 10% believe costs would be lower. All projections show significant continued cost reductions, potentially by a factor of two by 2015.

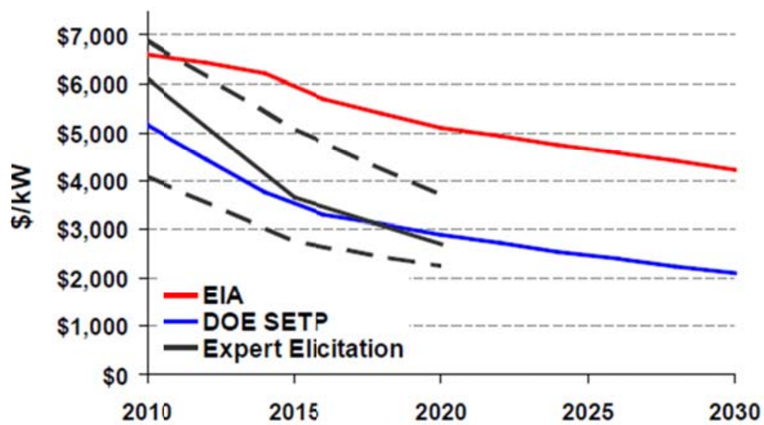

Figure 6: Projected nationwide residential PV system costs[30]

Figure 7 shows the nationwide cumulative rooftop penetration for a variety of different scenarios. The lower scenario is based on the 2009 AEO PV cost projections, does not assume net metering but that excess electricity generation is valued at natural gas costs), no carbon costs and other factors. This is not a realistic scenario for the California context. The light blue line (low PV cost) reflects the broader consensus on lower PV costs but still does not reflect net metering and other factors relevant to California. The highest (red) scenario is based on the more optimistic SETP PV cost projections, net metering, low-cost financing (e.g., PACE financing), and carbon valuation. California's growth trajectory will more likely resemble the yellow or red growth lines as the state is at the forefront of the policy, financing and incentives referenced. While it is difficult to scale these national projections to

[29] Calculation is as follows: (48,019 dwelling units with solar) / (8,274,916 single dwelling units in 2010) = 0.58% of existing dwelling units with solar.

[30] Source: National Renewable Energy Laboratory, "Modeling the US Rooftop PV Market," 09/2010

specific California numbers, the primary conclusion is clear: NREL's research suggests there is significant potential for a very large, perhaps even exponential increase in PV penetration in the residential market. This large potential increase underscores both the need and opportunity for the solar ready homes measure.

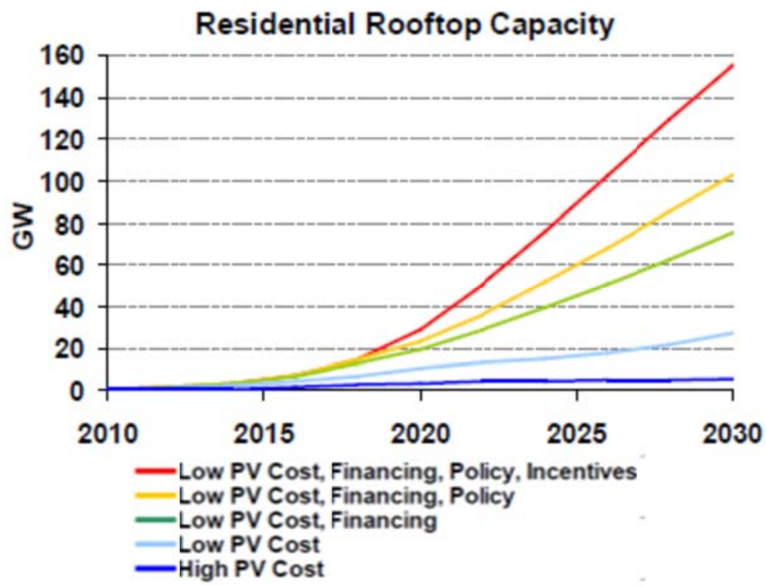

Figure 7: Projected nationwide residential rooftop PV capacity through 2030[31]

Another approach to estimating California's future PV market is to assume that California's various solar incentive programs and other policy goals are met. The CSI's program goals are to install 1,940 MW of PV by the end of 2016. To date (4/1/2011), 781 MW has been installed, leaving 1,159 MW still to be installed, or approximately 72 MW per year. Currently, 220.6 MW (28%) of the solar systems installed under the CSI program (based on the CSI kW rating) are for residential buildings, and 560.4 MW (72%) are for commercial buildings. Note that based on a review of the CSI program data, it appears that the majority of residential participants in the CSI have been single family homes. This analysis assumes a similar participation rate in the future, although this could shift. Assuming that the ratio of residential to commercial systems continues, this would leave 324.5 MW yet to be installed on residential buildings[32]. At an average residential PV size of 4.59 kW (CSI rating), this equates to approximately 70,700 additional PV installations by 2016. Furthermore, the New Solar Homes Partnership's program goals are to install 360 MW on new homes by 2016. Using the same average system size of 4.59 kW, this results in ~ 78,431 homes with PV. Thus, by 2016, there should be ~ 197,150 PV systems, or ~903 MW installed on residential roofs[33]. The residential new

[31] Source: National Renewable Energy Laboratory, "Modeling the US Rooftop PV Market," 09/2010

[32] The calculation is as follows: (1,159 MW of PV capacity remaining to be installed) x (28% installed on residential) = 324.52 MW yet to be installed on residential buildings.

[33] 48,019 PV systems installed to date + 70,700 additional systems installed under the CSI + 78,431 systems installed under the NSHP = 197,150 systems

construction forecasts developed by the CEC[34] projects 13,146,175 total dwelling units by 2016. This results in a 1.5% PV penetration, based on meeting California's rebate program goals alone. Stakeholders have raised concerns that the CEC housing projections are too optimistic. In terms of projecting the future PV market penetration by meeting State's incentive programs, using the CEC's larger housing counts results in a smaller, more conservative estimate of the total market penetration.

The overall conclusion is that based on research done by NREL, there is a strong likelihood of large PV cost reductions and a very large growth in residential PV penetration. Achieving the CSI and NSHP goals would result in approximately 903 MW installed on California residential roofs by 2016, which is consistent with NREL's projections of ~5-10 GW on residential roofs nationwide by 2016 (see Figure 7). Meeting the CSI and NSHP goals also seems feasible given current participation rates in the programs. Therefore, this scenario, achieving a 1.5% PV penetration by 2016, is selected for the solar ready cost effectiveness analysis. It is assumed that PV penetration continues to grow linearly after 2016. This is conservative, based on NREL's projections of a much faster growth rate.

4.1.2 State Regulatory Context

The solar ready homes and solar oriented development measures are at the intersection of several converging policy spheres. This includes:

- building-level regulation striving for enhanced efficiency and sustainability (e.g., Title 24 Part 6 and CAL GREEN),
- visionary greenhouse gas policy goals and initiatives to meet those goals (e.g., the California Global Warming Solutions Act, SB 375 and California's California Long Term Energy Efficiency Strategic Plan),
- California's longstanding and evolving commitment to solar and renewable energy policies (e.g., solar easements, solar access, the California Solar Initiative, the California Homebuyer Solar Option and Solar Offset Program, etc.),
- planning and development-level policy such as the Subdivision Map Act and California's Environmental Quality Act, and
- evolving fire codes impacting rooftop solar generation potential.

Details of these key policy drivers framing these proposals are discussed below.

California Building Energy Code (Title 24, Part 6)

The only "solar ready" requirement in Title 24 is §114(b)1, which requires pool or spa heating equipment allow for the future addition of solar heating equipment. There are no other direct requirements for solar ready homes or solar oriented development. The following table summarizes the current code requirements relating to solar.

[34] These housing forecasts were initially developed to support the CEC's electricity and natural gas demand forecast and have been used to support CASE development. The forecast version used is: "Res Construction Forecast by BCZ v4"

<table>
<tr><th>Subchapter</th><th>Section</th><th>Subsection</th><th>Description</th></tr>
<tr><td rowspan="5">Subchapter 2: All Occupancies—Mandatory Requirements For The Manufacture, Construction And Installation Of Systems, Equipment And Building Components</td><td rowspan="2">113: Mandatory Requirements For Service Water-Heating Systems And Equipment</td><td>113(c)4</td><td>Solar water heating tank minimum insulation requirements</td></tr>
<tr><td>113(d)6</td><td>Solar water heating required in state buildings</td></tr>
<tr><td rowspan="2">114: Mandatory Requirements For Pool And Spa Systems And Equipment</td><td>114(a)4</td><td>Exclusion 2: Electric heating permitted for ≥ 60% solar heating fraction</td></tr>
<tr><td>114(b)1</td><td>Any pool or spa heating system or equipment shall be installed with at least 36 inches of pipe installed between the filter and the heater or dedicated suction and return lines, or built-in or built-up connections shall be installed or built-in or built-up connections to allow for the future addition of solar heating equipment</td></tr>
<tr><td>118: Mandatory Requirements For Insulation And Roofing Products</td><td>118(d)2</td><td>Solar water heating tank minimum insulation requirements</td></tr>
<tr><td rowspan="3">Subchapter 5: Nonresidential, High-Rise Residential, And Hotel/Motel Occupancies—Performance And Prescriptive Compliance Approaches For Achieving Energy Efficiency</td><td rowspan="3">144: Prescriptive Requirements For Space Conditioning Systems</td><td>144(d)</td><td>Exception 3: Exception for space heating zone controls for 75% recovered energy/solar heating fraction</td></tr>
<tr><td>144(e)2a</td><td>Economizer exception for systems with 75% recovered energy/solar heating fraction</td></tr>
<tr><td>144(g)</td><td>Exception 1 permits electric resistance heating for systems with 60% recovered energy/solar heating fraction</td></tr>
<tr><td rowspan="2">Subchapter 7: Low-Rise Residential Buildings – Mandatory Features And Devices</td><td rowspan="2">150: Mandatory Features And Devices</td><td>150(j)1b</td><td>Solar water heating tank minimum insulation requirements</td></tr>
<tr><td>150(j)4</td><td>Solar water heating systems/collectors must be SRCC rated</td></tr>
<tr><td rowspan="2">Subchapter 8: Low-Rise Residential Buildings—Performance And Prescriptive Compliance Approaches</td><td rowspan="2">151: Low-Rise Residential Buildings—Performance And Prescriptive Compliance Approaches</td><td>151(f)12</td><td>Exception 1 exempts roof SRI requirements for building-integrated PV or building integrated solar heating systems</td></tr>
<tr><td>151, table 151c</td><td>Residential Component Package C: electric-resistance DHW permitted only for 25% solar heating fraction</td></tr>
</table>

Figure 8: Table of solar-related code requirements in 2008 Title 24

Another code requirement relevant to solar oriented development is the limitation on the area of west-facing windows to a maximum of 5% of the conditioned floor area, and the area of all windows to a maximum of 20% of the conditioned floor area, to reduce the energy required cool homes (added during the 2005 Title 24 update). Another relevant requirement is that the compliance model standard design requires fenestration to have a U-factor of 0.40 for all climate zones except Climate Zone 15, which requires 0.35. Both of these prescriptive requirements reduce overall solar heat gains through windows. As glazing requirements tighten, undesired solar heat gain is reduced, which makes homes less sensitive to solar orientation compared to homes that do not meet the glazing specifications.

California Green Building Standards Code (Title 24, Part 11)

The California Green Building Standards Code, or CALGreen contains several sections relevant to solar ready buildings and solar oriented development. Current relevant code requirements and opportunities for code updates are summarized below.

- Chapter 4 (Residential Mandatory Measures),
  - Division 4.1 (Planning and Design), Section 4.106 (Site Development)

    There are currently no requirements for including solar oriented development issues in the site planning phase. There is a clear opportunity to do include so.
  - Division 4.2 (Energy Efficiency), Section 4.201 (General)

    Note that this section contains no requirements; mandatory energy standards are not covered in CALGreen, but covered under Title 24, Part 6.
- Chapter 8 (Compliance Forms and Worksheets)

  There are opportunities to include documentation forms for solar oriented development practices, which would be referenced in a mandatory and/or voluntary provision(s).
- Appendix A4 (Residential Voluntary Measures)

  Appendix A4 can be adopted by a city or county.
  - Division A4.1 (Planning and Design), Section A4.106 (Site Development), A4.106.1 (Building Orientation)

    Buildings shall be oriented with the long side of the house oriented within 30^o of south to optimize the use of solar energy. Note that this CASE proposes modifications to this requirement; see section 5.2.
  - Division A4.2 (Energy Efficiency), Section A4.211 (Renewable Energy)
    - A4.211.1: Install PV systems and energy efficiency measures to meet the New Solar Homes Partnership requirements
    - A4.211.2, Install an SRCC OG300 rated solar water heating system
    - A4.211.3, Reserve 300 ft^2 of unobstructed roof area within 30^o of south for future PV or solar water heating systems. Rough in penetrations through the roof shall be provided for electrical conduit and water piping, within 24 inches of the reserved area. Note that this is very similar to the solar ready homes measure proposed in section 5.1, with the exceptions that we propose a smaller roof area and refined orientation requirements for a mandatory measure, and were unable to show cost effectiveness for the rough in penetrations.
    - A4.211.3, A minimum one inch electrical conduit shall be installed from the electrical service equipment into the attic. Note that this CASE considered requirements for this measure, but had a difficult time showing cost effectiveness and did not receive stakeholder support for this measure.

California Homebuyer Solar Option and Solar Offset Program (SB1, 2006)

California Senate Bill 1 of 2006[35] requires the California Energy Commission to implement regulations requiring sellers of production homes to either offer a solar energy system option to all prospective homebuyers, or participate in a solar offset program requires sellers to install a solar system elsewhere which is equivalent to the aggregate capacity of solar that would have been installed in an affected subdivision if 20% of the buyers had opted for the solar option. This applies to production homes constructed on land for which an application for a tentative subdivision map has been deemed complete on or after January 1, 2011. When offering the homeowner the solar option, sellers must disclose the total installed cost of the solar option, the estimated cost savings, information about California solar energy system incentives, and information about the Go Solar California website. Additional information sources are footnoted[36].

This is very synergistic to the proposed solar ready requirements. Implementing the solar ready requirements proposed here will help ensure that solar is a viable options on all homes, and that costs for the solar option are kept reasonable and not constrained by the lack of an appropriately sized and oriented solar zone, etc.

California Solar Rights Act of 1978 (AB 3250, 1978) and Subsequent Amendments (AB 1407, 2003; AB 2473, 2004; AB 2180, 2008)

The California Solar Rights Act and its amendments is a very important piece of legislation guarding the right of homeowners to install solar systems on their homes. It is synergistic to, and a pre-requisite for effective solar ready measures. An excellent synopsis of the Solar Rights Act and subsequent modifications is provided by the Database of State Incentives for Renewable Energy (DSIRE)[37]:

> *"The Solar Rights Act (CA Civil Code 714), enacted in 1978, bars restrictions by homeowners associations (HOAs) on the installation of solar-energy systems, but originally did not specifically apply to cities, counties, municipalities or other public entities. The Act was amended in September 2003 to prohibit a public entity from receiving state grant funding or loans for solar-energy programs if the entity prohibits or places unreasonable restrictions on the installation of solar-energy systems. A public entity is required to certify that it is not placing unreasonable restrictions on the procurement of solar-energy systems when applying for state-sponsored grants and loans.*
>
> *The Act was amended again in September 2004 by extending its prohibition on restrictions to all public entities. Additional key changes minimize aesthetic solar restrictions to those that cost less than $2,000 and limits building official's review of solar installations only to those*

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[35] SB1 also established the California Solar Initiative

[36] The following sources provide additional information: The CEC's Solar Offset Program rulemaking: http://www.energy.ca.gov/2010-SOPR-1/index.html; DSIRE: http://www.dsireusa.org/incentives/incentive.cfm?Incentive_Code=CA64R&re=1&ee=0, California Public Resources Code Section 25405.5, http://www.leginfo.ca.gov/cgi-bin/displaycode?section=prc&group=25001-26000&file=25400-25405.6 ; Proposed regulations for the homebuyer solar option and solar offset program, http://www.energy.ca.gov/2010-SOPR-1/documents/Text_of_Modified_Regulations_15-Day_Language.pdf

[37] http://www.dsireusa.org/incentives/incentive.cfm?Incentive_Code=CA45R&re=1&ee=1

> *items that relate to specific health and safety requirements of local, state and federal law. Assembly Bill 1892 of 2008 further amended the civil code to nullify any restrictions relating to solar energy systems contained in the governing documents of a common interest development. A common interest development includes community apartment projects, condominium projects, planned developments and stock cooperatives.*
>
> *Reasonable attorney's fees incurred during a court case between a property owner and a common interest development or HOA will be awarded to the prevailing party. AB 2180 of 2008 provided even more consumer protections under the Civil Code by providing that any homeowners' association that is not a public entity that willfully violates the Solar Rights Act must pay the solar system owner a civil penalty not to exceed $1,000. AB 2180 further provides that the approval or denial of any application submitted to authorize the installation of a system must be made in writing within 60 days. If the application is not denied within 60 days it will be deemed approved unless the delay is the result of a reasonable request for additional information.*

California Solar Shade Control Act of 1979

The Solar Shade Control Act [38] prohibits shading of solar collectors that result from tree growth occurring after a solar collector is installed. It applies to solar systems for electric generation, water heating and space heating or cooling. It states that no plant may be placed or allowed to grown such that it shades a collector more than 10% from 10 am to 2 pm. It does not apply to plants already in place or replacement of plants that die after the installation of the solar collectors, as amended by SB 1399 (2008)[39]. It does require trees already in place, but not yet shading the system, to be trimmed and maintained so that they do not impact the system.

The solar collectors are required to meet building setback requirements, or a minimum of 5 feet from the property line and 10 feet from the ground. Further setback is required if the collector is lower than 10 feet. A city or county may adopt an ordinance exempting its jurisdiction from the provisions of the act. Alternatively, some cities have passed ordinances that are more favorable to solar. In some cases, they require existing vegetation to be cleared to allow good solar access in at least some suitable place on a property. Additional information sources are footnoted[40].

California Solar Easement Laws

California's Civil Code section 801.5[41] enables neighbors to voluntary create a solar easement, which can be written up and attached to the deed of neighboring properties to legally protect one's right to

[38] California's Public Resources Code (25980), http://www.leginfo.ca.gov/cgi-bin/displaycode?section=prc&group=25001-26000&file=25980-25986

[39] California Senate Bill 1399, 2008. http://www.leginfo.ca.gov/pub/07-08/bill/sen/sb_1351-1400/sb_1399_bill_20080722_chaptered.pdf

[40] Additional background information can be found at the following sources: http://www.solardepot.com/pdf/CASolarAccessLaws.pdf, http://www.leginfo.ca.gov/cgi-bin/displaycode?section=prc&group=25001-26000&file=25980-25986, http://www.dsireusa.org/incentives/incentive.cfm?Incentive_Code=CA03R&re=1&ee=0

[41] California Civil Code § 801.5 http://www.leginfo.ca.gov/cgi-bin/displaycode?section=civ&group=00001-01000&file=801-813

receive future sunlight. Such an easement can be used to address concerns regarding neighboring structural changes.

California's Government Code section 65850.5[42] provides that subdivisions may include solar easements applicable to all plots within the subdivision in their plans. Enacting a subdivision-level solar access easement could be an important part of solar ready development.

New developments may be required to include a solar access easement (a deed restriction to protect solar access within a development). Local building codes regarding building height restrictions, building set back requirements relative to property lines and solar orientation relative to neighboring properties may reduce the need for an easement.

AB 1470: Solar Hot Water and Efficiency Act of 2007

Governor Schwarzenegger signed Assembly Bill 1470 on October 12, 2007, creating the Solar Water Heating and Efficiency Act of 2007[43, 44]. This authorized creation of the state's $250 million solar hot water incentive program. The law's goal is to install 200,000 solar water heating systems throughout California by 2017. AB 1470's goals have been incorporated into AB 32 Scoping Plans' goals.

California's Global Warming Solutions Act of 2006 (AB 32)

In September 2006, Governor Arnold Schwarzenegger signed the California Global Warming Solutions Act of 2006, also known as AB 32, into law. AB 32 commits the State to achieving 2000 GHG emission levels by 2010 (which represents an approximately 11 percent reduction from "business-as-usual") and 1990 levels by 2020 (approximately 30% percent below "business-as-usual"). Governor Schwarzenegger's Executive Order S-3-05 provides an additional long-term target of 80% below 1990 by 2050. To achieve these goals, AB 32 mandates that the California Air Resources Board (ARB) establish a quantified emissions cap, institute a schedule to meet the cap, implement regulations to reduce Statewide GHG emissions from stationary sources, and develop tracking, reporting, and enforcement mechanisms to ensure that reductions are achieved.

The California Air Resources Board's Scoping Plan lays out a comprehensive set of actions designed to reduce overall carbon emissions in California and meet AB 32's goals. The Scoping Plan includes meeting the AB 1470's goal of 200,000 SWH installations by 2020[45].

California Long Term Energy Efficiency Strategic Plan

The long Term Energy Efficiency Strategic Plan[46] lays out an aggressive plan to help meet the State's energy and climate goals. These "Big, Bold Energy Efficiency Strategies" include a strong focus on zero net energy (ZNE) buildings:

---

[42] California Government Code, §65850.5: http://www.leginfo.ca.gov/cgi-bin/displaycode?section=gov&group=65001-66000&file=65850-65863.13

[43] http://docs.cpuc.ca.gov/published/Report/66703.htm

[44] http://www.cpuc.ca.gov/PUC/energy/Solar/thermhistory.htm

[45] Measure CR-2, page C-118. http://www.arb.ca.gov/cc/scopingplan/sp_measures_implementation_timeline.pdf

- All new residential construction in California will be zero net energy by 2020
- All new commercial construction in California will be zero net energy by 2030
- Transform home improvement markets to apply whole-house energy solutions to existing homes., and by 2020:

  • 25% of existing homes will achieve 70% decrease in purchased energy, relative to 2008 levels

  • 75% of existing homes will achieve 30% decrease in purchased energy, relative to 2008 levels

  • 100% of existing multi-family homes will achieve 40% decrease in purchased energy, relative to 2008 levels.

Meeting the existing home goals will require significant penetrations of PV and solar heating. Both the solar oriented development and solar ready homes measures will play an important role in realizing these goals. California Air Resources Board's Scoping Plan also acknowledges the importance of solar water heating systems for meeting the ZNE goals: [47]

> *"Solar water heating is an enabling technology for zero net energy buildings, and successful implementation of the zero net energy targets will require significant growth and improvements in California's SWH system manufacturing and installation industry. Looking out to the [AB 32] 2050 emission reduction goals, solar water heating will be even more essential because the technology can provide carbon-free water heating. At this time, California's SWH industry is still quite small and not well established, lacking the experience and economies of scale to deliver cost-effective solar water heating for most applications. This needs to change if California is to meet its GHG reduction targets."*

Senate Bill 375 (2008)

SB 375 was designed to help California reach its AB 32 goals by promoting good planning with the goal of *more sustainable communities. Key requirements include:*[48]

- *The California Air Resources Board (ARB) must develop regional greenhouse gas emission reduction targets for passenger vehicles, and establish targets for 2020 and 2035 for each region covered by one of the State's 18 metropolitan planning organizations (MPOs).*
- *Each MPOs must prepare a "sustainable communities strategy (SCS)" that demonstrates how the region will meet its greenhouse gas reduction target through integrated land use, housing*

[46] California Public Utilities Commission, September 2008, "California Long Term Energy Efficiency Strategic Plan: Achieving Maximum Energy Savings in California for 2009 and Beyond." http://californiaenergyefficiency.com/docs/EEStrategicPlan.pdf, http://www.energy.ca.gov/ab758/documents/CA_Long_Term_EE-Plan-Summary.pdf

[47] California Air Resources Board,, AB 32 Scoping Plan , p. C-118.

[48] Excerpted from: California Air Resources Board (CARB), Senate Bill 375 – Regional Targets (webpage, updated 2/17/2011), http://www.arb.ca.gov/cc/sb375/sb375.htm.

and transportation planning. Once adopted by the MPO, the SCS will be incorporated into that region's federally enforceable regional transportation plan (RTP).

- *ARB must review each final SCS to determine whether it would, if implemented, achieve the greenhouse gas emission reduction target for its region. If the combination of measures in the SCS will not meet the region's target, the MPO must prepare a separate "alternative planning strategy (APS)" to meet the target. The APS is not a part of the RTP.*

SB 375 establishes incentives to encourage implementation of the SCS and APS. Developers can get relief from certain environmental review requirements under the California Environmental Quality Act (CEQA) if their new residential and mixed-use projects are consistent with a region's SCS (or APS) that meets the target.

California Environmental Quality Act (CEQA)

Greenhouse gas emissions and their impacts must now be considered under CEQA[49]. This significantly impacts land development. Planners and developers must now consider greenhouse gas emissions and mitigation strategies from the earliest stages of planning. In many cases, developers are voluntarily encumbering projects with building energy efficiency requirements and/or onsite renewable energy generation as mitigation measures. This presents a strong opportunity to push consideration of building energy efficiency, including solar oriented development and solar ready homes into the early design and planning phase, where many critical decisions impacting building energy use are made.

CEQA Guidelines, Appendix F: Energy Conservation[50] (effective March 2010 pursuant to SB 97) specifically identifies as an acceptable energy mitigation measure "**the potential of siting, orientation, and design to minimize energy consumption**, including transportation energy, water conservation and solid-waste reduction." This is an important connection to the solar oriented developments measure.

California Subdivision Map Act

The solar oriented development CASE extends beyond the building-scale and into larger-scale planning and development activities. The Subdivision Map Act governs the subdivision of land. The solar oriented development language should not conflict with the Subdivision Map Act.

Moreover, the California Subdivision Map Act, section 66473.1[51] contains several solar oriented development provisions, as excerpted below.

> *"The design of a subdivision for which a tentative map is required pursuant to Section 66426 shall provide, to the extent feasible, for future passive or natural heating or cooling opportunities in the subdivision. Examples of passive or natural heating opportunities in*

[49] Senate Bill 97 (2007) required the Governor's Office of Planning and Research (OPR) to develop recommended amendments to the State CEQA Guidelines for addressing greenhouse gas emissions. The Amendments became effective on March 18, 2010.

[50] CEQA Guidelines, Appendix F: Energy Conservation, http://ceres.ca.gov/ceqa/guidelines/pdf/appen_f.pdf

[51] The California Subdivision M-=pap Act, section 66473.1: http://ceres.ca.gov/planning/pzd/sub_ch4.html

> *subdivision design, include design of lot size and configuration to permit orientation of a structure in an east-west alignment for southern exposure. Examples of passive or natural cooling opportunities in subdivision design include design of lot size and configuration to permit orientation of a structure to take advantage of shade or prevailing breezes.*
>
> *In providing for future passive or natural heating or cooling opportunities in the design of a subdivision, consideration shall be given to local climate, to contour, to configuration of the parcel to be divided, and to other design and improvement requirements, and such provision shall not result in reducing allowable densities or the percentage of a lot which may be occupied by a building or structure under applicable planning and zoning in force at the time the tentative map is filed.*
>
> *The requirements of this section do not apply to condominium projects which consist of the subdivision of airspace in an existing building when no new structures are added. For the purposes of this section, "feasible" means capable of being accomplished in a successful manner within a reasonable period of time, taking into account economic, environmental, social and technological factors.*

This is another policy supporting solar oriented development. The challenge/caveat here is “to the extent feasible”. Crafting the Solar Oriented Development measure building upon this and realize synergies with CEQA is important.

Fire Access and Ventilation Issues

Fire access and ventilation has become a significant issue for solar installations. Previously, when there were relatively few installations, installers ran into relatively few constraints. However, with the increase in recent PV installations, fire marshals and others concerned about fire safety are playing a more active role, and solar installations are facing increased review and in many cases more stringent installation requirements, specifically for fire setback areas. Working through the fire marshal approval process often adds significant time to a project, and in some cases projects do not receive approval. Stakeholder feedback indicates that approximately 30% of systems that were installed in the past would not be allowed under more strict review. Currently, there is no state law governing fire setbacks, and each jurisdiction is free to set their own requirements. This is likely changing, though, as discussed below.

Firefighters have the following roof requirements when fighting fires:

- Adequate ability to access to the roof from the ground,
- Pathways to walk around on the roof to fight fires, and quick egress if needed, and
- Ability to cut holes in the roof to provide smoke ventilation.

Rooftop solar installations can potentially impede these firefighting requirements. Increased penetration of rooftop PV systems has aroused greater attention by local fire marshals, code officials and others. Local jurisdictions are generally becoming more restrictive on the placement of rooftop PV systems, although there is significant variance between jurisdictions. Some southern California jurisdictions in particular tend to be more restrictive. Many existing PV systems would not be allowed under current fire marshal requirements.

In August 2007, the California Department of Forestry and Fire Protection's (CAL FIRE) Office of the State Fire Marshal convened a task force of local fire departments and solar industry representatives to develop a guideline for rooftop solar photovoltaic systems[52]. This includes guidelines for rooftop PV placement to provide fire access and venting. The resulting document is a guideline only, and does not have the force of law unless it is specifically adopted as a local ordinance by a local enforcing agency in compliance with Health and Safety Code Section 18938(b) for Building Standards Law, Health and Safety Code Section 17950 for State Housing Law and Health and Safety Code Section 13869.7 for Fire Protection Districts. Some jurisdictions align with these guidelines[53], but some jurisdictions are more lenient and some more restrictive.

During the stakeholder review meetings, concern was expressed that these are only guidelines, and that local fire marshals are likely to require more restrictive requirements. This is particularly true for many southern California jurisdictions. There is a strong desire on behalf of the homebuilder and solar industries to have these guidelines adopted at the state level. This will make it harder for local jurisdictions to impose more restrictive requirements.

The International Code Council (ICC) has approved a revised version of the CAL FIRE guidelines for inclusion in the 2012 International Fire Code (2012 IFC), to be published in May 2011[54]. This will become the basis for 2013 California Fire Code (Title 24, Part 9) updates. It is likely that the CAL FIRE guidelines will be incorporated into the California Fire Code.

The fire access and venting requirements in the CAL FIRE Guidelines and the 2012 IFC for single and two-unit residential dwellings are summarized below, with references to both the CAL FIRE Guidelines and the 2012 IFC (note: the CAL FIRE language is quoted). The Solar America Board for Codes and Standards provides an excellent report with additional discussion and background on these requirements[55].

- **Fire Access for Hip Roof Layouts**. (CAL FIRE Guidelines 2.1.1.a ; IFC 605.11.3.2.1) *"Modules should be located in a manner that provides one (1) three-foot (3') wide clear access pathway from the eave to the ridge on each roof slope where modules are located. The access pathway should be located at a structurally strong location on the building (such as a bearing wall)."*

[52] California Department of Forestry and Fire Protection, Office of the State Fire Marshal, "Solar Photovoltaic Installation Guideline", April 22, 2008, http://osfm.fire.ca.gov/pdf/reports/solarphotovoltaicguideline.pdf.

[53] e.g., the Los Angeles City Fire Department, FPB Requirement No. 96, 2/3/09. http://lafd.org/prevention/pdfforms/solar_pwr_req.pdf

[54] International Code Council, "2012 International Fire Code", May 2011, http://www.iccsafe.org/Store/Pages/Product.aspx?id=3400X12.

[55] Bill Brooks, "Understanding the CAL Fire Solar photovoltaic Installation Guideline", March 2011. Solar America Board for Codes and Standards Report. http://www.solarabcs.org/about/publications/reports/fireguideline/pdfs/CslFire_studyreport.pdf

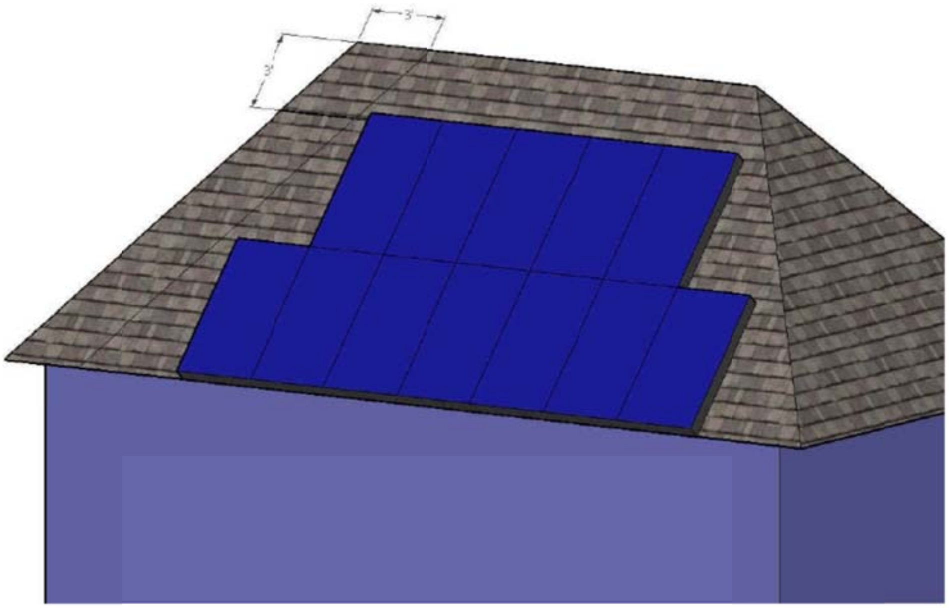

Figure 9: Hip roof fire access and venting requirements

- **Fire Access for Roofs with a Single Ridge**. (CAL FIRE Guidelines 2.1.1.B ; IFC 605.11.3.2.2) "Residential Buildings with a single ridge. Modules should be located in a manner that provides two (2) three-foot (3') wide access pathways from the eave to the ridge on each roof slope where modules are located."

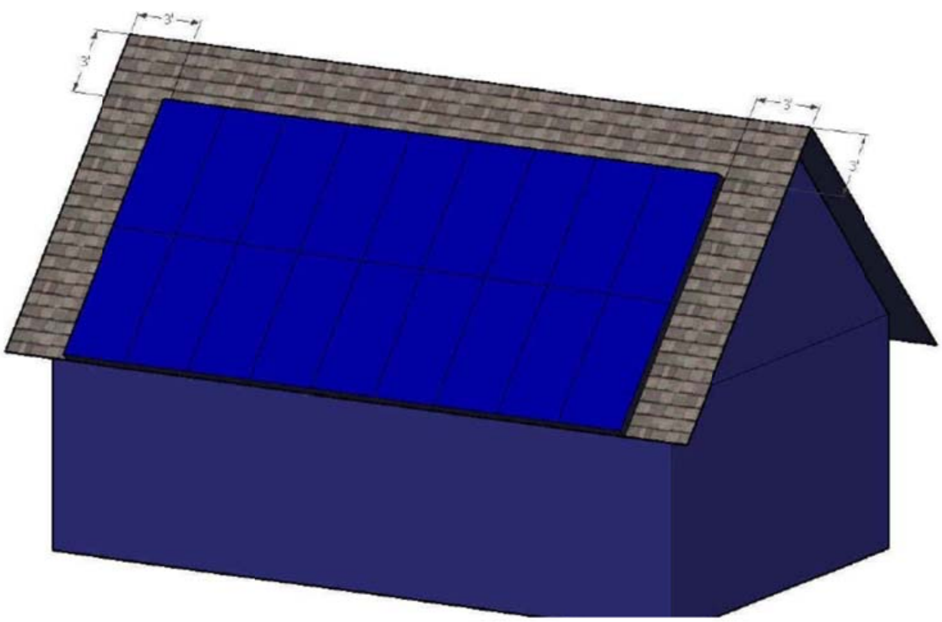

Figure 10: Gable roof fire access and venting requirements

- **Fire Access for Hips and Valleys**. (CAL FIRE Guidelines 2.1.1.C ; IFC 605.11.3.2.3) "Hips and Valleys: Modules should be located no closer than one and one half (1.5) feet to a hip or a valley if modules are to be placed on both sides of a hip or valley. If the modules are to be located on only one side of a hip or valley that is of equal length then the modules may be placed directly adjacent to the hip or valley."

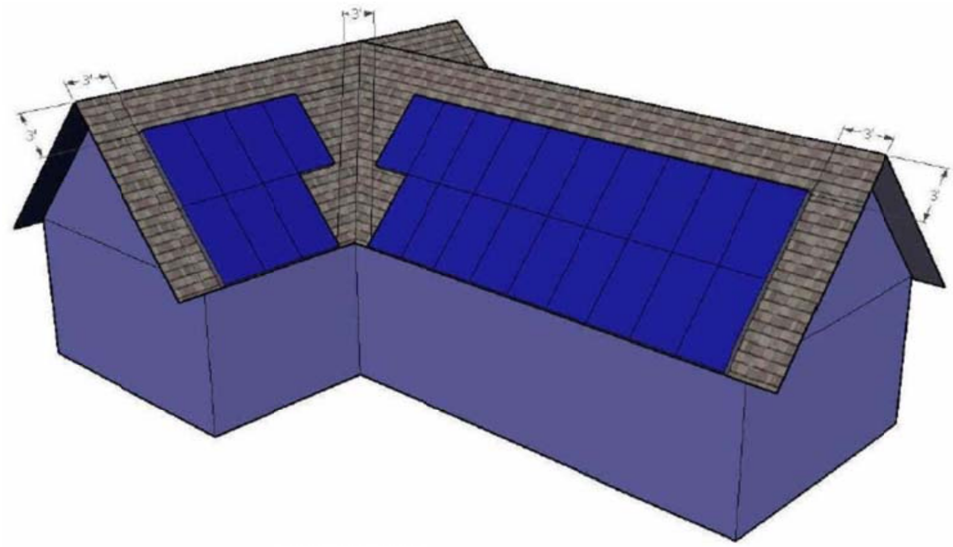

Figure 11: Hip and valley roof fire access and venting requirements

- **Ventilation**. (CAL FIRE Guidelines 2.1.1.D ; IFC 605.11.3.2.4) "Modules should be located no higher than three feet (3) below the ridge."

Roof Structural Issues

Residential roofing design load requirements are contained in Title 24, Part 2.5 (California Residential Code), Section R301.6, Roof Load, and Title 24, Part 2 (California Building Code). The CBC is based on the International Building Code, which references the American Society of Civil Engineers (ASCE)'s standard ASCE-7, "Minimum Design Loads for Buildings and Other Structures." Dead load design requirements are provided in the IBC Section 1606/ASCE-7 Chapter 3. Residential PV systems generally add less than 5, and sometimes less than 2 lbs/ft^2 of load to a roof. Current code requirements are generally sufficient to carry the dead load of PV systems.

A potential issue is wind loading, which can limit roof area available for PV in high wind areas. PV systems are generally rated for 30 lb/ft^2, but winds exceeding 110 mph can result in pressures greater than 30 lb/ft^2 at roof corners. The American Society of Civil Engineers (ASCE)'s standard ASCE-7, "Minimum Design Loads for Buildings and Other Structures," chapter provides the underlying design guidance referenced by U.S. building codes, and includes wind pressure data for various locations, wind exposure and roof location. The three foot fire setbacks discussed above generally avoid siting solar collector in these high wind load areas, and help ensure that wind loads are not an issue on residential PV systems[56].

Roof loading for solar water heating systems is more variable, given the wide range of water volume contained in different systems (e.g., flat plate vs. integral collector-storage system vs. Thermosyphon system). Generalizations about a roof's ability to carry solar water heating loads cannot be made.

Local jurisdictional requirements relating to structural issues vary significantly. The Los Angeles Department of Building and Fire Safety, for example, does not require structural design calculations for solar systems when[57]:

- The filled collector weight does not exceed two pounds per square foot, or three pounds per square foot if the collector is of a type which inhibits superimposed concentrated loadings (such as the weight of a person);
- The collector is installed with no portion thereof more than 18 inches above the roof immediately below; and
- The maximum concentrated load imposed by a collector support onto the roof structure is 40 pounds.

Substantiating plans and structural design calculations are required when the above conditions are not met, including solar systems on raised support or framed systems which impose large concentrated loads on the roof framing.

4.1.3 Relevant Codes and Standards from Other States

Standards and legislation from five states/territories including Colorado, Hawaii, New Mexico, Guam and the US Virgin Islands require some amount of solar readiness. The major focus appears to be in solar water heating. That is, all of the states other than Colorado are requiring that either solar water heating be installed for certain homes or at least that these homes be provided with piping and brackets for future addition of collectors. Two states (Colorado and Mexico) have made specific provisions for photovoltaics by requiring measures such as pre-wiring, effective roof orientation, adequate roof strength and pre-installed conduit. Refer to Appendix 3 – Summary of Relevant Codes for additional information.

4.1.4 Local and Municipal Codes for Solar Ready Homes

As summarized in Figure 12, local and municipal codes for solar-ready homes vary widely, from local restrictions on solar panel placement to strict building regulations requiring the installation of solar systems. The most common requirements are pre-plumbing for solar water heating, pre-wiring for photovoltaics, and some form of shading/obstruction prevention or mitigation. Refer to Appendix 3 – Summary of Relevant Codes for additional information.

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[56] 1. Brooks, B. "Solar America Board for Codes and Standards Report: Understanding the CAL Fire Solar photovoltaic Installation Guideline", March 2011. http://www.solarabcs.org/about/publications/reports/fireguideline/pdfs/CslFire_studyreport.pdf

[57] Los Angeles Department of Building Safety, "Guidelines for Installing Solar Devices (LAMC 91.1301, 91.2603)," Document No. P/MC 2002-001 Revised 09-26-05

	Requirement or Provision					
Municipality	**Pre-plumbing for solar water heating**	**Pre-wiring for photovoltaic**	**Obstruction/ shading mitigation**	**No additional permit or fee required for solar**	**Roof engineering for solar water heating**	**Minimum roof area requirement**
Santa Cruz, CA			X			
Los Angeles, CA			X	x		
Brentwood, CA	x				x	
Tucson, AZ	x	x				x
Oro Valley, AZ	x	x				
Vancouver, BC	x					
Total	**4**	**2**	**2**	**1**	**1**	**1**

Figure 12: Summary of local and municipal codes for solar ready homes

4.1.5 Local and Municipal Codes for Solar Oriented Developments

As seen in Figure 13, current codes enforcing solar oriented developments and designs range from broad policy goals to specific numerical standards. Ten of the 14 municipalities have a provision for orienting along a true east-west axis to allow for maximum south-facing windows. Four have included preservation of solar access for adjacent and future developments as a requirement.

With regards to the more specific solar orientation regulations, development allocation applications are generally subject to a review process in which the percentage of solar oriented houses or a point system denotes the requirement to which new home builders must adhere. Refer to Appendix 3 – Summary of Relevant Codes for additional information.

	Requirement or Provision					
Municipality	**East/West Orientation and/or solar effective aspect ratios**	**Preservation of solar access for future/ adjacent development**	**Landscape must not hinder solar access**	**Minimize visibility of and view obstruction by solar systems**	**Solar systems allowed to exceed zoning roof height**	**Potential solar easement**
Marin County, CA	x					
San Diego, CA		x				
Sacramento, CA			x		x	
San Jose, CA	x			x		
Santa Monica, CA				x		
Santa Cruz, CA	x	x				
Sebastopol, CA			x			x
Berkeley, CA	x	x				
Brentwood, CA	x					
Multnomah, OR	x					
Fort Collins, CO	x	x				
Pullman, WA	x					
Portland, OR	x					
Salt Lake City, UT	x					
Total	**10**	**4**	**2**	**2**	**1**	**1**

Figure 13: Summary of local and municipal codes for Solar Oriented Developments.

4.1.6 Voluntary Standards and Other Relevant Programs

LEED for Neighborhood Development (LEED ND) offers a credit for tree lined and shaded streets. While this is not a direct solar oriented development requirement, it is related.

4.1.7 Examples of Solar Ready Homes

The CASE team conducted a review of the literature, the web and solicited stakeholder input via an online survey and in stakeholder meetings to identify current practices and examples of solar ready homes. These are summarized below.

- **Natomas, CA: Fallen Leaf -** The 32 zero net energy (ZNE) homes at Fallen Leaf built by Treasure Homes include a 2.4kW DC photovoltaic integrated roofing system from BP Solar which, coupled with other energy efficient features, will produce almost as much electricity as it needs to power the house on an annual basis[58].
- **Rancho Cordova, CA: Premier Gardens -** The 98 single-family home community built by Premier Homes combines mechanical and passive design features with 2 kW AC solar home power systems to save residents over 60% on their utilities costs[59].
- **Watsonville, CA: Vista Montaña -** 257 single-family homes were built in 2005 by Clarum Homes to use nearly zero net energy. All homes have a 1.2 to 2.4 kW PV system and range of energy efficiency measures to reduce utility bills by up to 90%[60].
- **Pleasanton, CA: Avignon -** Centex Homes' Avignon development consists of 32 larger estate homes containing 3.5 kW PV systems designed to reduce total energy bills by 70%. They are designed to draw no more than 1 kW of electricity during peak times[61].
- **Redding, CA: Sonata -** Seastar Communities built an 84 single-family home development designed to save homebuyers up to 50% on utility costs by including in each a 2 kW solar electric home power system[62].
- **Roseville, CA: Premier Oak -** Premier Homes' second standard ZNE community, Premier Oaks, is designed to save 60% of all utilities costs using energy efficiency features including 2 kW AC solar electric home power system[63].
- **San Diego, CA: Tiempo and San Angelo -** Shea Homes built two neighborhoods in 2001 allowing homeowners to reduce their utilities costs by 30% to 50% by providing solar hot

[58] http://www.bira.ws/projects/fallen-leaf.php

[59] http://www.bira.ws/projects/premier-gardens.php

[60] http://www.bira.ws/projects/vista-montana.php

[61] http://www.bira.ws/projects/avignon.php

[62] http://www.bira.ws/projects/sonata.php

[63] http://www.bira.ws/projects/premier-oaks.php

water heaters (implemented in 293 of 306 homes) and solar electric systems (implemented in 120 homes)[64].

- **Ladera Ranch, CA: Terramor -** Over 450 of the houses at Terramor in Ladera Ranch have PV solar electric energy systems installed. The community, constructed by 10 different builders, has a variety of other sustainable features that make its houses 20% more energy and water efficient than comparable conventional homes[65].
- **Rocklin, CA: Carsten Crossings -** Built by Grupe, the 144 homes in the Carsten Crossings neighborhood are built with 2.4 kW solar roof tile electric power systems and designed to exceed Title 24 standards by 36%[66].
- **Lopez Island, WA: Common Ground -** The Lopez Community Land Trust constructed Common Ground beginning in 2007, including a mixed income development of 11 homes and 2 rental units complete with PV solar arrays and solar water heaters[67].
- **Las Vegas, NV: Maplewood Springs -** All homes in this gated community, built by Pinnacle Homes, are built solar-ready and with certified green construction[68].
- **Saskatoon, SK, Canada: Suncastle Park -** Suncatcher Solar and Sun Plans designed this solar-oriented community to include with each lot an installed, 2 kW grid-tied solar power system[69].
- **Palm Grove, India: Palm Meadows -** As an initiative towards 'green energy, Palm Meadows is equipped with a solar hybrid system with a capability to generate solar power. Up to 2 Megawatts of solar can be generated from entire community 20 kW is currently commissioned. Standard home specifications additionally include a 300 L capacity solar water heating system with a built-in electrical backup heater on the terrace[70].
- **Hyderabad, India: Aparna Palm Meadows -** The high-end villas of Aparna Palm Meadows are Andhra Pradesh’s first solar ready homes, integrated by a smart micro-grid for reduction in transmission losses[71].

4.1.8 Examples of Solar Oriented Development

Developers’ increasing focus on building green communities very often includes strategic layout designs incorporating elements of passive solar heating and cooling designs and access to sunshine.

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[64] http://www.toolbase.org/PDF/CaseStudies/ZEH_NRELfarhar2.pdf

[65] http://www.laderaranch.com/

[66] http://www.pvdatabase.org/urban_view_details.php?ID=19

[67] http://www.lopezclt.org/common-ground/

[68] http://www.pinnaclelv.com/community.php?id=2

[69] http://www.suncatchersolar.com/SuncastlePark.htm

[70] http://www.sahabitat.com/ready/palmmeadows.html#solo=solar-ready-homes

[71] http://content.magicbricks.com/aparna-palm-meadows-aps-first-solar-ready-homes

Building orientation, shading, fenestration, window distribution, and ventilation are important elements in passive solar designs that decrease the need for lighting, heating, and cooling electric power. Many communities, in addition, use building layouts to protect solar access and allow for solar power generation. Unfortunately, many of the "solar oriented development" practices go undocumented, so it is difficult to determine the extent to which communities are considering and incorporating solar oriented practices. The following list summarizes developments incorporating solar oriented features identified in the background research and stakeholder input.

- **Davis, CA: Village Homes -** In the 70-acre subdivision of Village Homes, all streets trend east-west and all lots are oriented north-south, allowing the houses with passive solar designs to efficiently utilize solar energy[72].
- **Claremont, CA: Meadowoods Subdivision -** Meadowoods is a 140 acre parcel with 92 single family homes. The neighborhood was specifically designed with a variety of solar oriented features, including east/west street orientation to provide all homes with good southern exposure, minimal windows on the east and west facing walls, clerestory windows for daylighting, and some solar water heating systems. Houses range in size from 1,400 ft^2 to 2,800 ft^2. The streets were also specifically designed with narrower widths to minimize urban heat island impacts. Other sustainability design features include low impact development stormwater design and onsite infiltration in a central park, interconnecting streets with walking and bike paths to promote walkability, and "outdoor living" features. House sizes were intermingled, and overall neighborhood densities were designed to transition into densities of neighboring developments. This neighborhood was designed by the Claremont Environmental Design Group (CEDG)[73].
- **San Diego, CA: C-Street -** The mixed-use urban development design for C-Street orients both commercial and residential units for natural lighting and cross-ventilation. Private and public green spaces are implemented for socialization and relaxation, and axes along the ground floor allow for sufficient circulation[74].
- **San Diego, CA: Quarry Falls -** Quarry Falls is a developing mixed-use, self-sustaining community designed to include a mix of low, medium, and high density homes designed and oriented to allow every building to maximize its potential use of solar energy. Currently in the construction phase, no current data or photographs are available for the development[75].
- **Wilmington, NC: Tonbo Meadow Green Sustainable Community -** In this eco-friendly community, builders make use of passive solar orientation to keep the house cooler in the summer, warmer in the winter, and reduce the need for electrical lighting[76].

[72] http://www.villagehomesdavis.org/public/about

[73] http://www.cedg-design.com

[74] http://designorigin.org/portfolio.pdf

[75] http://www.quarryfalls.com/concept.htm

[76] http://www.greenecocommunities.com/North-Carolina/Tonbo-meadow-green-community.html

- **Lopez Island, WA: Lopez Community Land Trust Sustainable Community Homes -** The non-profit, community-based organization, LCLT (developers of Common Ground, Morgantown, Innisfree, and COHO) secured 7 acres of Lopez Island for an Urban Growth Area, and are using specific sustainability measures including passive solar orientation and modeling and strategic window distribution and shading[77].
- **Pattonsburg, MO: Pattonsburg's Design Process -** A design charrett was assembled to employ a planning model for the rebuilding of the village of Pattonsburg after flooding severely damaged the buildings and architecture. The community adopted the team's sustainable design plan which included the solar orientation of all buildings[78].
- **Saskatoon, SK, Canada: Suncastle Park -** Solar home designs in Suncastle Park are provided by Suncastle Park and Sun Plans, Inc., including over 80 home plans designed to maximize passive solar energy gain and reduce the energy needed for heating[79].
- **British Columbia, Canada: Seabird Island Sustainable Community Demonstration Project -** The environmentally designed housing development on Seabird Island has garnered Canada wide attention for its low tech approach. In addition to many other innovative sustainable features, the development utilizes solar orientation and passive solar convective air flow systems. Main living areas and solariums are oriented to the south in a semi-circular pattern[80].
- **South Africa: Sustainable Design Group -** The Sustainable Design group, in collaboration with PEER South Africa, has designed and built passive solar low-cost housing and communities for the homeless throughout South Africa. Passive solar heating keeps the homes warm in winter, while shading and natural ventilation keep the homes cool during summer[81].

4.1.9 Online Survey Results

The online surveys unfortunately did not receive significant responses. This was true for similar surveys conducted by the other solar CASE proposals. Significant effort was spent developing a combined email distribution list that included personnel from the Database of Solar Installers, Contractors, and Retailers in California, key industry and trade organizations, as well as the primary stakeholder participant list used to solicit participation in the stakeholder meetings. Furthermore, survey participation was encouraged during the stakeholder meetings. All of the solar CASE studies coordinated survey development and notification to try to minimize stakeholder burden. It is possible that this proved ineffective.

[77] http://www.lopezclt.org/new-site/wp-content/uploads/HP4_green_list071.pdf

[78] http://www.smartcommunities.ncat.org/articles/Pattonsburg_design.shtml

[79] http://www.suncatchersolar.com/SuncastlePark.htm

[80] http://www.broadwayarchitects.com/sustainable-environmental-design-projects/seabird-island-sustainable-community.html

[8181] http://www.sustainabledesign.com/community_planning1.html

The Solar oriented development survey had 7 respondents. Respondent background included: equipment manufacturing or vendor (2), home builder (4), designer, and contractor/ installer/ tradesperson (1) [82].

Two respondents provided the names of project or community-level design guidelines, specifications, covenants, etc. with requirements for solar energy:

- CSU Northridge Dorms
- Del Sur neighborhood in San Diego

One respondent indicated that some cities require chimneys, which can negatively impact solar energy inclusion due to shading.

Respondents were unaware of any:

- City or local ordinances with requirements for solar energy (e.g., solar orientation, solar access, etc.).
- Planning department requirements for solar access and/or solar orientation as part of an overall climate action plan or green building strategy to reduce greenhouse gas emissions.
- Planning department requirements for solar access and/or solar orientation as specific, feasible mitigation measures for minimizing greenhouse gas emissions to a level of insignificance pursuant to CEQA guidelines?

The Solar oriented development survey had 11 respondents. Respondent background included: a developer (1), home builder (2), designer (3), contractor (3), Installer (6), tradesperson (8) and utility (1). No one was aware of solar oriented developments or best practice being implemented. The only exception was one individual who cited a 43 unit tract home development in Simi Valley. No one was aware of new home communities or homes being pre-wired for future solar PV systems or pre-plumbed for solar hot water, or other solar ready measures. One respondent recommended the inclusion of dynamic exterior solar shading over east, west, and south facing glazing (e.g., retractable solar fabric shades) as a solar ready measure. This would require blocking and wiring installed in walls during construction. This should be combined with optimal glazing specifications for each orientation that included the solar shade performance impacts.

4.2 Analysis of "Current Practice" Solar Performance in Existing Homes and Communities

A detailed analysis of 17 communities identified as having a significant penetration of solar energy systems or otherwise utilizing solar ready or solar oriented development practices was analyzed to identify and assess the "current practice", or baseline performance data for both the solar ready homes and solar oriented development CASEs. In addition, performance of three neighboring non-solar communities were studies for comparative analysis. A total of 1,947 homes were surveyed, which

[82] Note: some respondents checked multiple descriptions

included a total of 1,050 PV installations with an estimated 2.2 MW nameplate PV capacity, and 324 SWH systems. Two communities are known to be specifically designed as “solar oriented developments” at the planning phase. The communities analyzed and key details are summarized in Figure 14. Appendix 7 – Survey of “Current Practice” Solar Performance in Existing Homes and Communities, presents detailed results. A brief summary of key findings is presented below.

Development	Homes	PV systems	PV Size (kW)	SWH Systems	SWH Size (SF)	Notes
Village Homes	196	40	0.48 - 3.76	0		Solar Oriented Development
Meadowoods	92	0	n/a	26	~40	Solar Oriented Development
Tiempo	287	124	1.2, 2.4	287	40	
Vista Montana	173	173	1.2, 1.6, 2, 2.4	0		
Walden Park	109	109	1	0		
Tarleton	107	75	1.6	0		
Arborage	104	40	1.2	0		
Premier Gardens	94	94	2	0		
Mosaic	83	44	2.4	0		
Sedona	79	79	2.4	5		
Evergreen	77	23	1.2, 1.6 , 2.4	0		
Claiborne	72	72	1.2	0		
Carsten Crossings	53	53	2.4	0		
Premier Oaks	47	47	2	0		
Fallen Leaf	32	32	2.4	0		
Avignon	30	30	3.5	6	40	
Sonata	15	15	2	0		
Natomas	114	0	n/a	0		Non solar community
Scripps	96	0	n/a	0		Non solar community
Ladera Ranch	87	0	n/a	0		Non solar community
Totals	1,947	1,050	2.2 MW (2 kW average)	324	~13,000	

Figure 14: Characteristics of existing communities surveyed

4.2.1 Poorly Oriented Systems

Figure 15 and Figure 16 summarize the PV installation performance versus azimuth. There are a significant number of poorly oriented systems. The highlighted cells, in Figure 16 indicate the orientation range that will produce ~90% of maximum TDV savings compared to an optimally oriented PV system (refer to section 4.3 and section 4.4 for a detailed discussion on the optimal PV and SWH orientation range). Twenty nine percent (29%) of all systems surveyed (380 systems) with a combined capacity of 380 kW are installed outside of the optimal range of 150-270^{o}, resulting in a significant drop in performance. This reduces the benefit to individual solar system owners, and reduces statewide cumulative benefits. An important component of a solar ready home measure is to reduce the prevalence of poorly oriented solar systems in new construction.

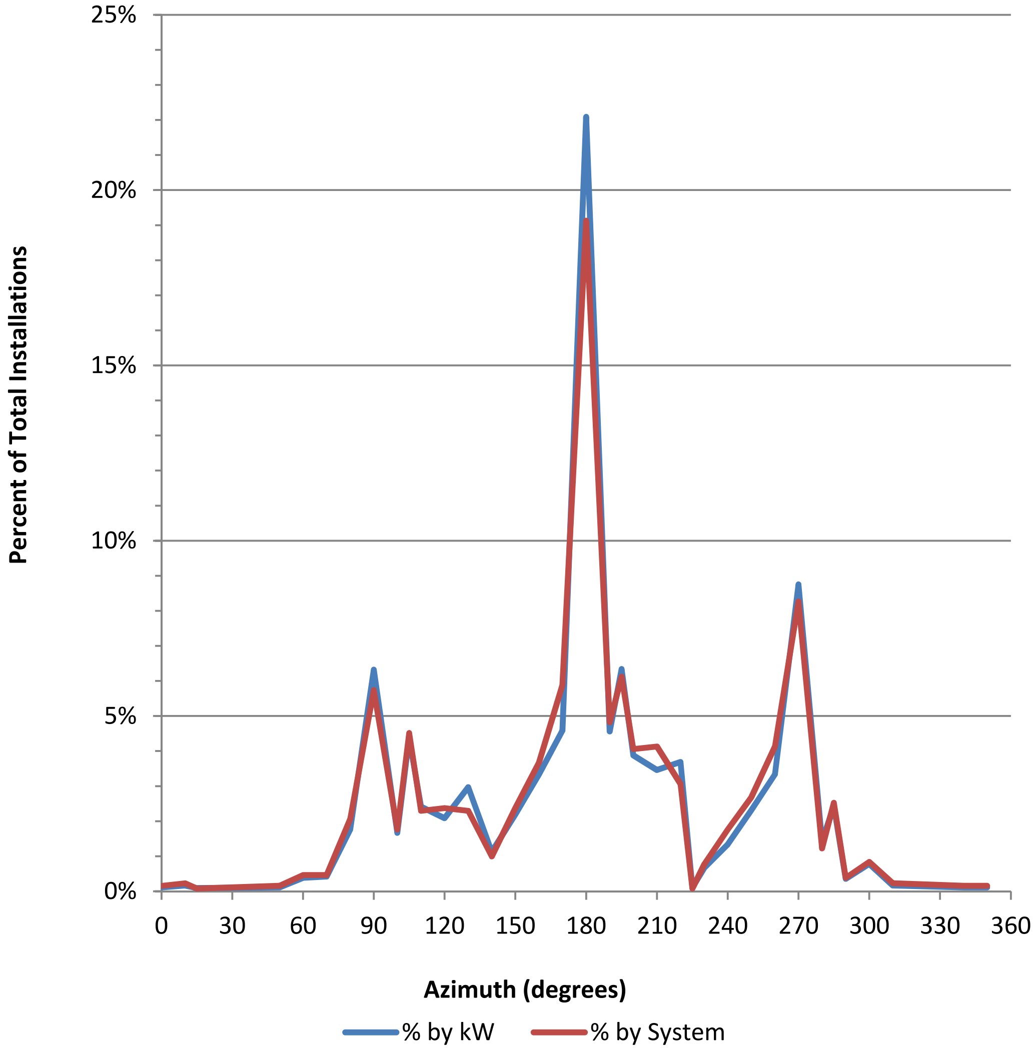

Figure 15: PV installations vs. azimuth

Azimuth	Total kW	Systems	% by kW	% by System
0	2.4	2	0.1%	0.2%
10	3.6	3	0.2%	0.2%
15	2	1	0.1%	0.1%
50	2.4	2	0.1%	0.2%
60	8.4	6	0.4%	0.5%
70	9.2	6	0.4%	0.5%
80	39	27	1.8%	2.1%
90	139.2	75	6.3%	5.7%
100	36.7	23	1.7%	1.8%
105	96.4	59	4.4%	4.5%
110	53.2	30	2.4%	2.3%
120	45.9	31	2.1%	2.4%
130	65.4	30	3.0%	2.3%
140	24.7	13	1.1%	1.0%
150	48.4	31	2.2%	2.4%
160	73.5	48	3.3%	3.7%
170	101.1	77	4.6%	5.9%
180	486.6	250	22.1%	19.1%
190	100.4	63	4.6%	4.8%
195	139.6	80	6.3%	6.1%
200	85.4	53	3.9%	4.1%
210	76.2	54	3.5%	4.1%
220	81.2	40	3.7%	3.1%
225	2.4	1	0.1%	0.1%
230	14.7	10	0.7%	0.8%
240	29.5	23	1.3%	1.8%
250	50.9	35	2.3%	2.7%
260	73.5	54	3.3%	4.1%
270	192.8	108	8.8%	8.3%
280	31.2	16	1.4%	1.2%
285	53.6	33	2.4%	2.5%
290	7.8	5	0.4%	0.4%
300	17.3	11	0.8%	0.8%
310	3.6	3	0.2%	0.2%
340	2.4	2	0.1%	0.2%
350	2.4	2	0.1%	0.2%
Total	**2203**	**1307**	**100%**	**100%**

Figure 16: PV system orientation in existing solar communities

4.2.2 Performance Variation between Solar Oriented Developments and Typical Developments

There is significant performance variation between neighborhoods. The blue bars in Figure 17 show each community's total annual PV kWh generation as a percent of maximum PV output if all systems were optimally oriented. Some communities have done a good job at providing well oriented roofs. Village homes has provided south facing roof area for all homes and its PV systems are producing very near their total potential output. Village Homes is a known solar oriented community that planned for well oriented roofspace and solar access from early neighborhood planning stages. Meadowoods (not shown on the following graph as it has no PV[83]) is another community known to have specifically incorporated solar oriented development into the early planning stages, and provides ample south facing roof area on all homes and would achieve similar performance. Performance drops off rapidly to around 91-92%, and then drops off to a low near 86%—a 12% difference. There are a number of subdivisions with particularly poor performance which have not done a good job at providing well oriented roof space. The majority of the poor performing communities are believed to be typical production home developments that did not consider, or at least did not plan for a large solar implementation. This is significant, and shows the impacts that including solar oriented design into the early planning stages can have.

This has significant implications for various state policy, but is particularly relevant to the California Homebuyer Solar Option and Solar Offset Program (SB1, 2006), which requires production homebuilders to offer solar as an option to all homebuyers. Installing solar systems on typical production home developments without consideration for solar oriented development in earlier planning phases will likely result in a 5% to 10% reduction in overall PV output. There is even larger variation between individual homeowner system performance.

The red bands in Figure 17 shows the potential PV output possible if the individual PV systems that are poorly oriented were corrected to the outer bounds of the recommended orientation range (solar oriented). The dashed lines show overall weighted averages for all communities surveyed. The primary results of this analysis show that there is approximately a 5% overall improvement opportunity for improving solar system orientation, either through a solar oriented development measure and/or the solar ready homes measure.

[83] Meadowoods was built before PV became an affordable market option, but it does have a 20% SWH penetration.

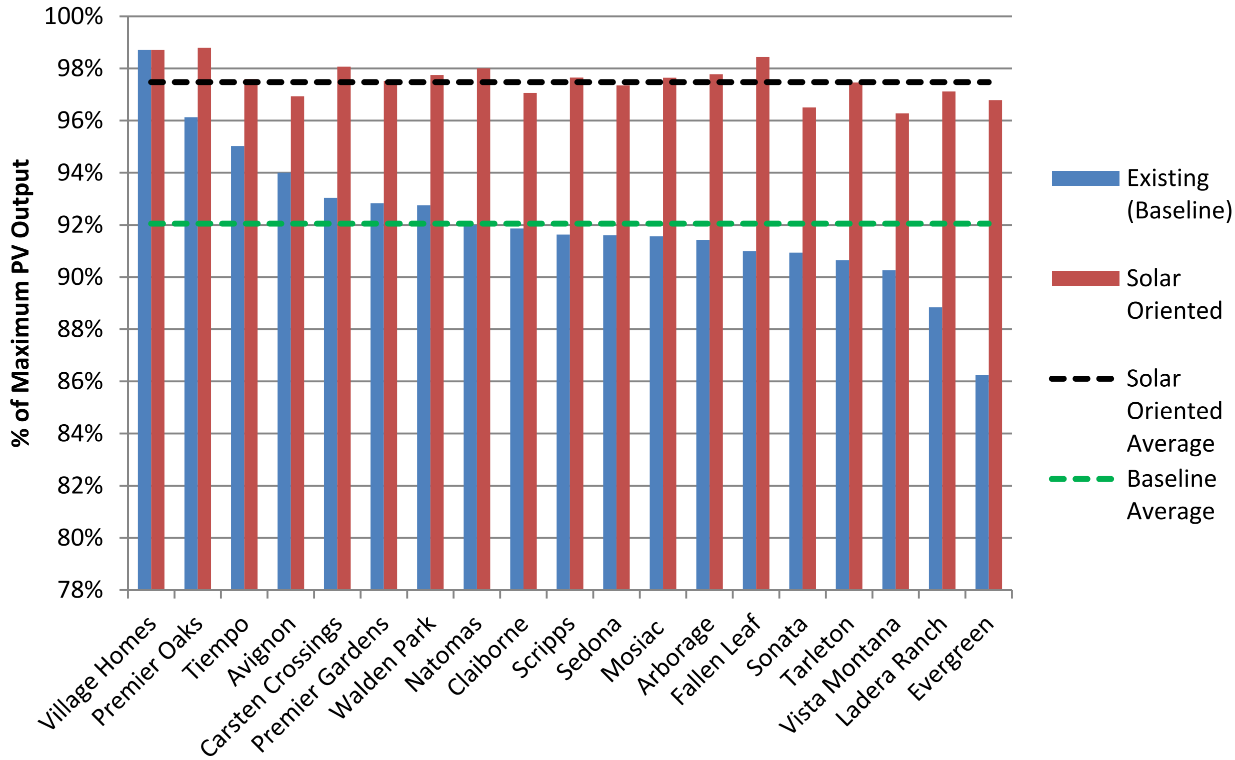

Figure 17: Comparison of community-wide PV performance in existing solar communities

4.2.3 Consideration of Solar Zone during Floorplan Placement in a Community

It is standard practice to use the same basic floorplan multiple times throughout a community in different orientations, mirror images, and minor roof profile modifications (e.g., see **Error! Reference source not found.** and Figure 34). Floorplans vary on which orientation (front, back, left, right) is best suited for solar. Figure 18 shows the same or similar house floorplan used throughout one community that installed solar on all homes. Green arrows indicate PV systems that are within optimal orientation, red arrows indicate homes with PV systems in non-optimal orientations. Based on the CASE author's review of existing communities, in many cases the proposed solar ready solar zone area and orientation can achieved by simply considering floorplan placement, without the need to change roof design, etc. Refer to 4.5.2 for additional discussion.

Figure 18: Floorplan placement and PV in a community

4.2.4 Consideration for Solar Zone Provision During Architectural Design

Figure 18 also illustrates several opportunities where consideration of including a solar zone in the architectural design can significantly improve the roofs ability to accommodate solar. Some of the roof plans have an excellent capability to accommodate solar, where other homes with very similar house shapes have roof designs that make siting solar challenging. Other factors include placement of chimneys to minimize shading and minimizing roof complexity, particularly on exposures not visible to the street that will have minimal aesthetic impacts. Also, it appears that many of the systems do not have the recommended CalFire fire setbacks, and it is likely many of these systems would not meet more stringent fire marshal review. This can be significantly addressed during architectural design, by considering the solar zone area and fire setbacks along with the many other factors that impact roof design. For example, builders often provide multiple roof elevations for a single model (e.g., see **Error! Reference source not found.**, Figure 33 and Figure 34). Similar roof variants could be provided which provide more solar area on certain exposures (e.g., a hip vs. gable roof), or minimized complex roof lines in the vicinity of the solar zone which would trigger additional fire access requirements.

4.2.5 Landscape Design Guidelines, Solar Access and Shading Considerations

Figure 19 shows two large trees between the houses with PV shading the rear home's collector. This illustrates the opportunity to include solar access and shading issues in the landscape design guidelines and/or master landscape design. Landscape plans routinely specify tree and plant palettes to meet aesthetic, water use, fire resistance and other requirements. These can be modified to include, for example, specifying tree species that only grow to a certain height for placement within a 20 feet of the south side of homes to protect solar access.

Figure 19: Landscape shading impacts

4.3 PV System Parametric Analysis

The CASE team conducted a parametric analysis of PV output on different roof pitches and azimuths for each climate zone using the CECPV Tool. This section summarizes the general results and big-picture implications relevant to both solar ready homes and solar oriented development. The analysis was conducted using a prototypical system configuration, but the results have been normalized to the rated nameplate capacity to facilitate analysis of different sized PV systems on different available roof areas, etc. Furthermore, the "Solar Orientation Factor" (SOF) has been calculated, which is the percent output for an arbitrarily oriented PV collector array compared to an optimally oriented collector. Appendix 5 – Solar PV Parametric Study Results presents a detailed summary of key outputs, including annual kWh and TDV outputs and solar orientation factors for each climate zone. A summary of key results is presented below.

One important note is that the optimal orientation for maximum energy (kWh) output is ~ due south (180 degrees), as shown in Figure 20. However, the optimal orientation for maximum TDV savings is 30^{o} to the west of south, or 210^{o}, as shown in Figure 21 (the "dome" is the region of highest PV output)The TDV savings account for time of use impacts such as peak demand and other issues which value afternoon energy production more highly. A solar system with a westward orientation produces more energy during high value afternoon periods. The general graph shape and conclusions are true for all California climate zones.

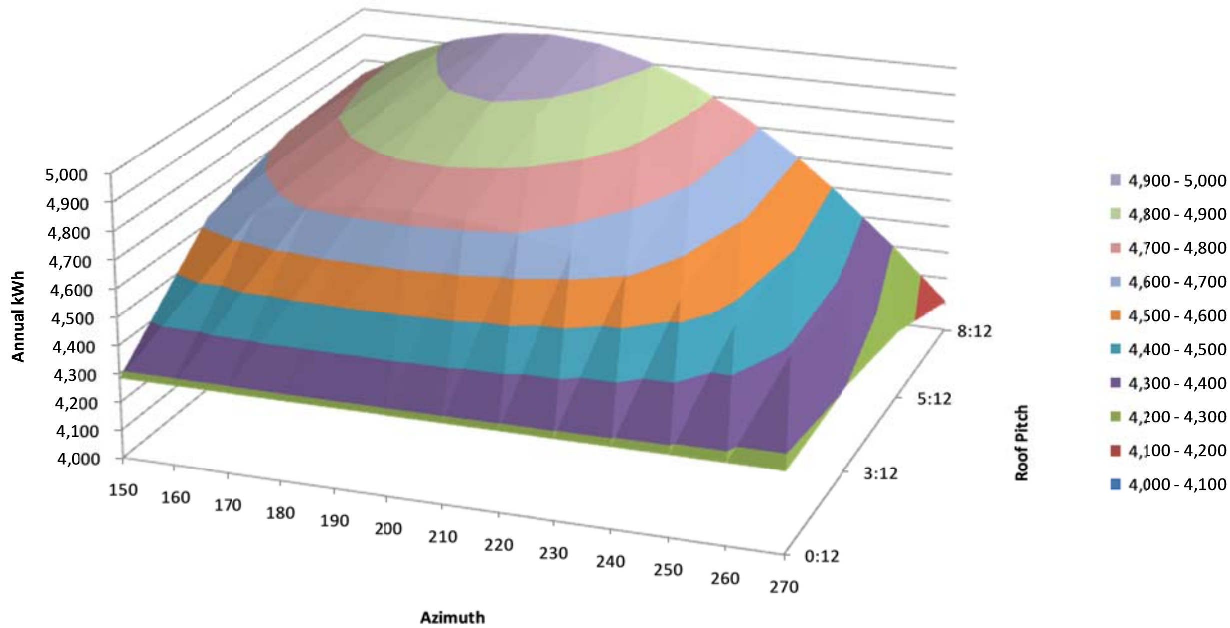

Figure 20: Annual PV energy (kWh) savings verses tilt and azimuth (CZ1)

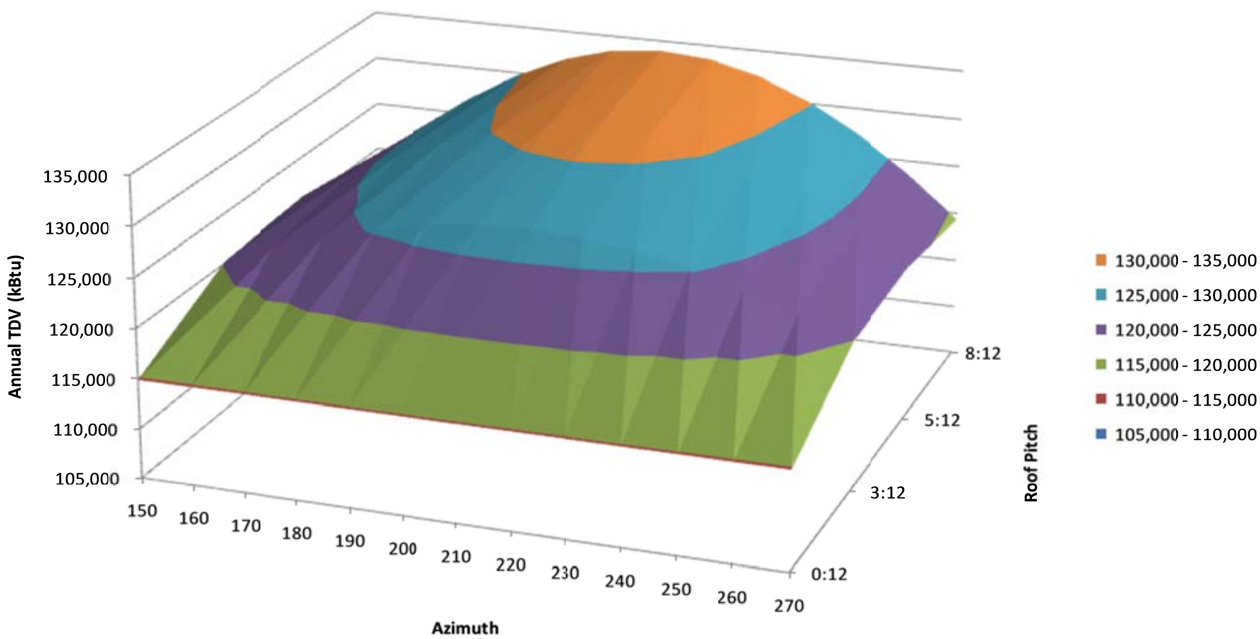

Figure 21: Annual PV TDV (kBtu) savings verses tilt and azimuth (CZ1)

Figure 22 shows the "Solar Orientation Factors" (SOF) for PV systems at a range of tilts and orientations, for Climate Zone 1. Both graphs present the same data. The left graph is useful for understanding the general graphs shape and how performance drops off, while it is easier to read the numbers on the right graph. The "optimal" orientation range is generally between 150 ^{o} and 270^{o}, which maintains a solar orientation factor of ~90% or higher.

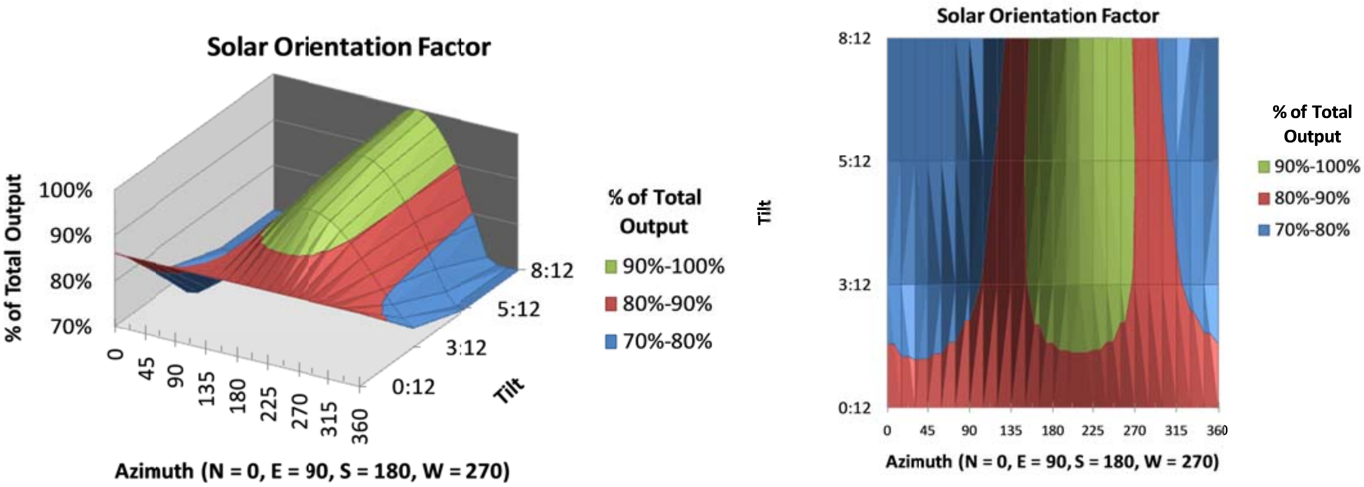

Figure 22: Solar orientation factor verses tilt and azimuth (CZ1)

Figure 23 plots the solar orientation factor for a single roof pitch for comparison between climate zones.

Figure 69 (Appendix 5 – Solar PV Parametric Study Results) presents the solar orientation factor data for all climate zones, in tabular format. This data was used to estimate the output of PV systems for the study of current practice, and to estimate the savings potential for requiring an optimally oriented solar zone on solar ready homes, and for estimating performance of solar oriented developments.

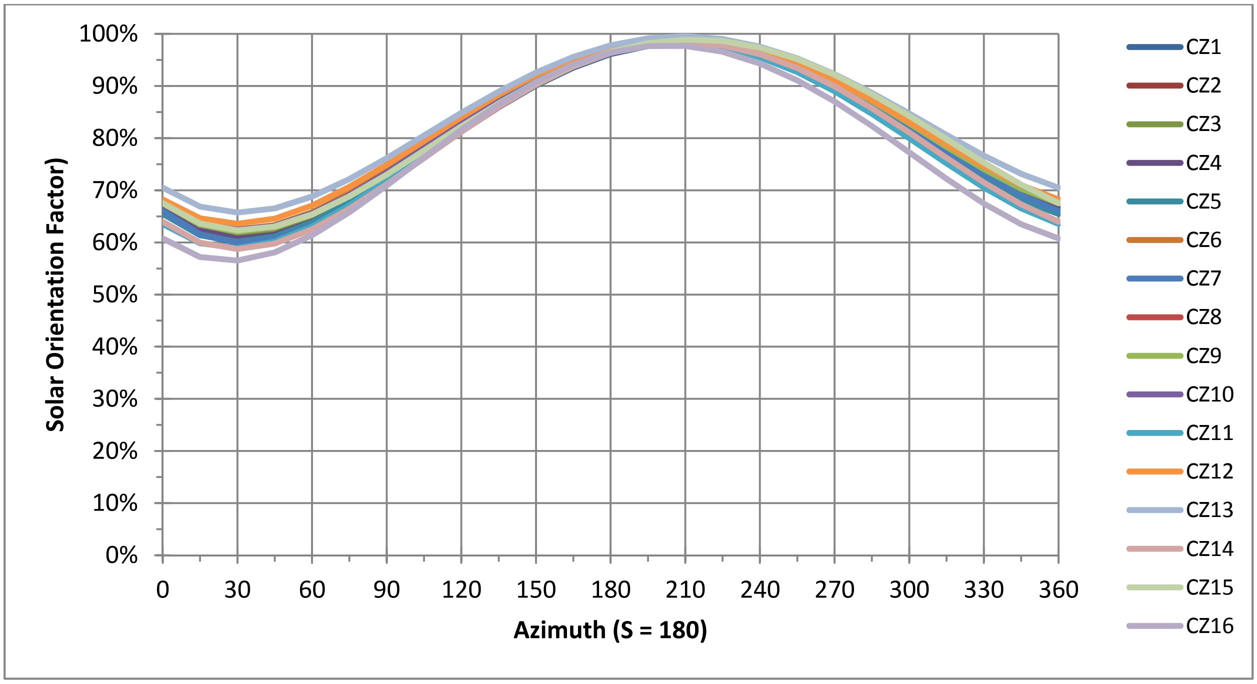

Figure 23: PV Solar Orientation Factor vs. azimuth for a 5:10 pitch

The conclusions of the PV analysis results are that there is a wide azimuth range from 150^{o} to 270^{o} that provides within 10% of the maximum PV output (in TDV). Beyond this range, performance drops off rapidly, particularly for steeper pitched roofs. The solar ready homes proposed solar zone orientation requirements are based on this range. This data is also shows that PV output is more sensitive to orientation than building energy use (refer to section 4.6.2).

4.4 Solar Water Heating (SWH) Parametric Analysis

The CASE team conducted a parametric analysis of SWH output on different roof pitches and azimuths for each climate zone using the National Renewable Energy Laboratory's Solar Domestic Hot Water Analysis Tool, developed for the Building America Program. This section summarizes the general results and big-picture implications relevant to both solar ready homes and solar oriented development..

Several prototypical SWH systems were initially analyzed, including:

- System 1: An active flat plate collector system with tank-type natural gas backup heater,
- System 2: An active flat plate collector system with a tankless natural gas water heater,
- System 3: An Integrated Collector-Storage (ICS) system with tank-type natural gas backup heater, and
- System 4: An Integrated Collector-Storage (ICS) system with a tankless natural gas water heater,

Final savings analyses for the solar ready homes proposal is based on System 1, the active flat plate system with a tank type back up heater. This is most representative of systems currently being installed (see section 4.1). Figure 24 and Figure 25 show the general relationship between solar collector orientation, pitch, and solar output, measured as the solar orientation factor, or percent output compared to the output at optimal orientation for up to an 8:12 roof pitch. Green graph shading indicates the zone of highest PV output, and red shading indicates worst output. The graph shape and variation with pitch is similar for all climate zones.

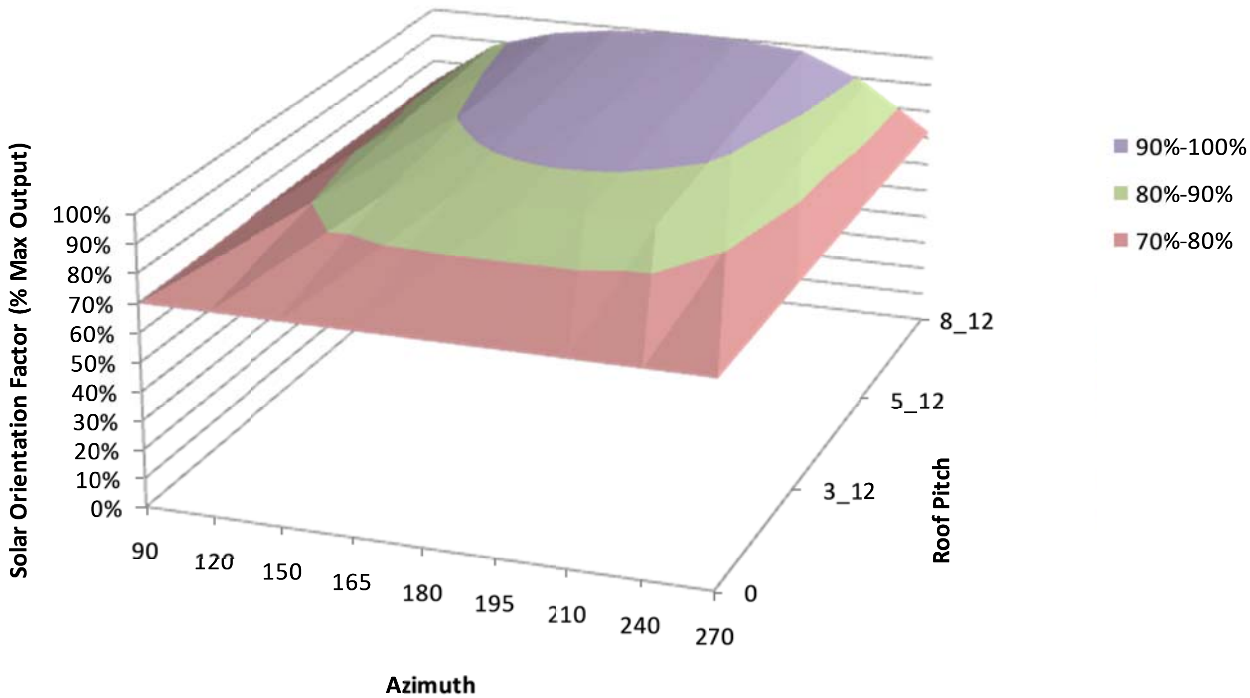

Figure 24: Solar orientation factor verses pitch and azimuth (CZ1)

	Roof Pitch			
	0:12	3:12	5:12	8:12
90	70%	71%	72%	72%
120	70%	80%	85%	89%
150	70%	85%	91%	95%
165	70%	87%	94%	99%
180	70%	87%	95%	100%
195	70%	87%	94%	100%
210	70%	86%	92%	98%
240	70%	80%	85%	89%
270	70%	71%	72%	72%

Figure 25: Table of solar orientation factors verses pitch and azimuth for (CZ1)

Figure 26 summarizes the annual TDV savings verses azimuth for a 5:12 roof pitch (typical roof pitch used for the cost effectiveness analysis) and climate zone. Figure 27 shows the Solar Orientation Factor, or percent performance for an arbitrarily oriented collector compared to the performance of an optimally oriented system. Note that for solar water heating, the optimal orientation is due south, in contrast to PV systems. This is because the natural gas TDV factors do not have the same hourly variation and sensitivity to afternoon peak demand periods as the electricity TDV factors. Figure 28 shows the solar fraction. The solar fraction is the percentage of total water heating met by the solar system. Data is shown for all climate zones except climate zone 16. Analysis runs indicated potential freeze issues in climate zone 16 that require special design considerations, therefore the solar ready homes cost effectiveness savings analysis does not include solar water heating savings in climate zone 16. This does not imply that SWH does not work in climate zone 16 however, simply that the CASE is not accounting for SWH savings in the cost effectiveness analysis (The PV savings are accounted for in climate zone 16. PV TDV savings are significantly larger than SWH savings, and this does not affect the cost effectiveness).

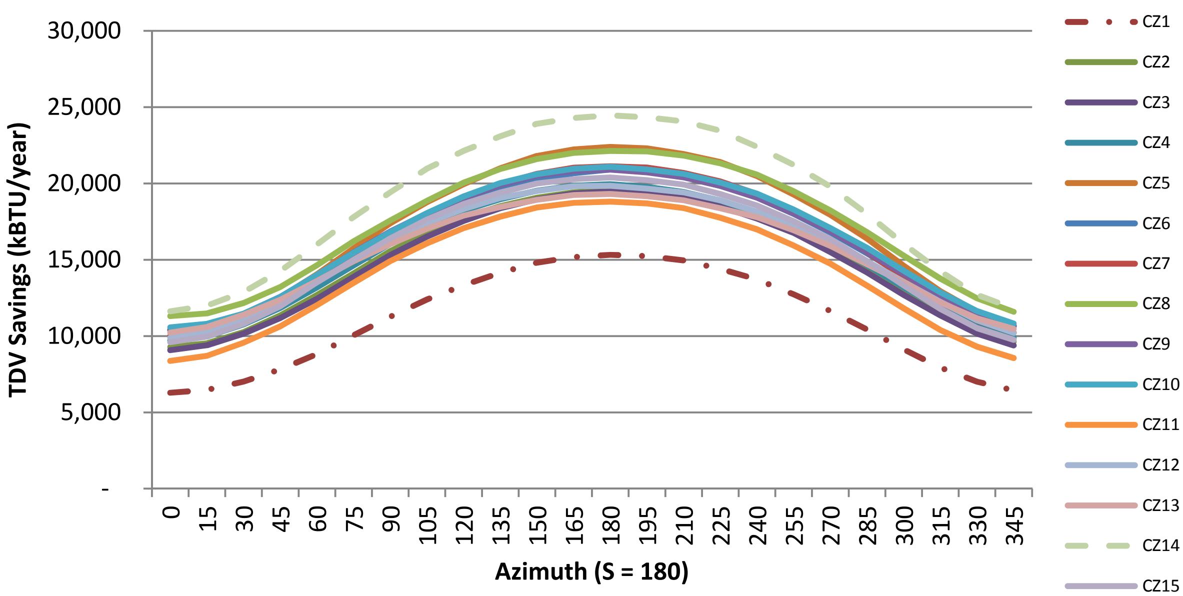

Figure 26: Annual solar water heating TDV savings for system 1 vs. azimuth for a 5:12 tilt

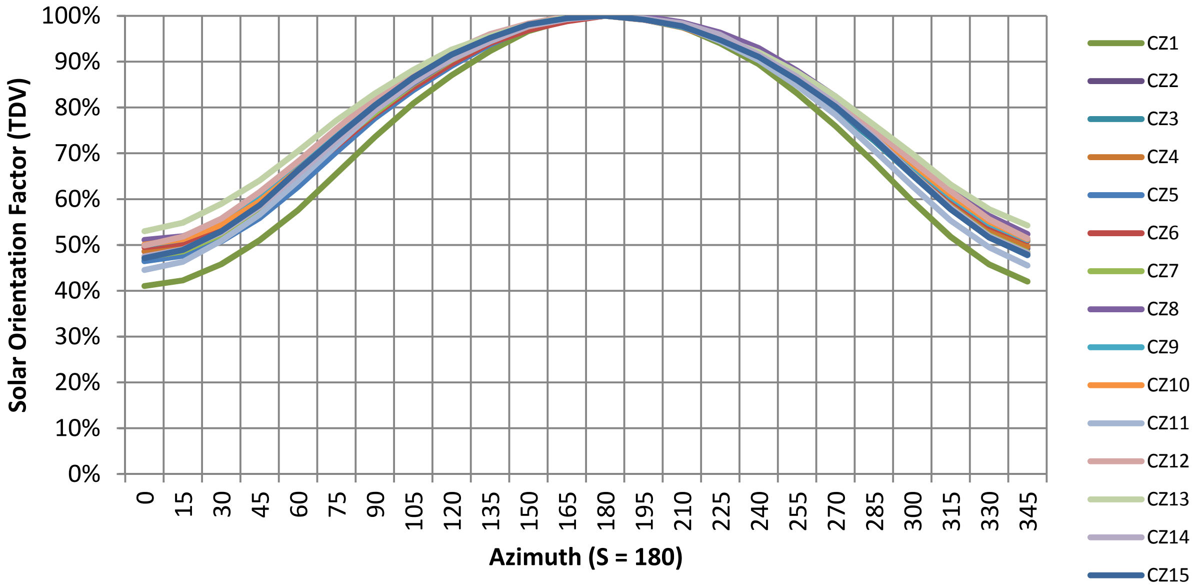

Figure 27: Solar Orientation Factor for system 1 vs. azimuth for a 5:12 tilt

	Azimuth																							
	0	15	30	45	60	75	90	105	120	135	150	165	180	195	210	225	240	255	270	285	300	315	330	345
CZ1	31%	31%	32%	34%	37%	40%	43%	47%	49%	52%	54%	55%	56%	56%	56%	54%	53%	50%	47%	44%	40%	37%	34%	32%
CZ2	43%	43%	45%	48%	51%	55%	59%	63%	66%	68%	70%	72%	73%	73%	72%	70%	69%	66%	63%	59%	55%	51%	48%	45%
CZ3	42%	43%	44%	47%	50%	54%	58%	62%	65%	68%	70%	71%	72%	72%	72%	70%	68%	65%	62%	58%	54%	50%	46%	44%
CZ4	46%	46%	47%	50%	54%	58%	62%	65%	69%	71%	73%	74%	75%	75%	74%	73%	71%	68%	65%	61%	57%	53%	49%	47%
CZ5	46%	46%	47%	50%	54%	59%	64%	68%	71%	74%	77%	78%	79%	79%	78%	77%	75%	72%	68%	64%	59%	54%	50%	47%
CZ6	48%	47%	49%	52%	55%	59%	63%	67%	70%	73%	75%	77%	78%	78%	77%	76%	74%	71%	67%	63%	59%	55%	51%	49%
CZ7	47%	47%	49%	52%	56%	61%	65%	69%	73%	76%	78%	80%	80%	80%	80%	78%	76%	73%	69%	65%	60%	56%	51%	49%
CZ8	47%	47%	48%	51%	55%	59%	62%	66%	69%	72%	74%	75%	76%	76%	76%	75%	73%	70%	67%	63%	59%	55%	51%	48%
CZ9	49%	49%	51%	54%	58%	62%	66%	69%	72%	75%	77%	79%	79%	79%	78%	77%	75%	72%	69%	65%	61%	56%	53%	50%
CZ10	50%	50%	51%	54%	58%	62%	66%	70%	73%	76%	78%	79%	80%	80%	79%	78%	76%	73%	69%	66%	61%	57%	54%	51%
CZ11	42%	43%	45%	48%	52%	56%	60%	64%	67%	69%	71%	72%	73%	73%	72%	71%	68%	66%	62%	58%	54%	50%	46%	44%
CZ12	43%	43%	44%	47%	51%	54%	58%	61%	64%	66%	68%	69%	69%	69%	69%	68%	66%	63%	61%	57%	54%	50%	47%	44%
CZ13	45%	45%	47%	49%	52%	56%	59%	62%	64%	66%	68%	69%	69%	69%	68%	67%	66%	64%	61%	58%	55%	51%	48%	46%
CZ14	48%	48%	50%	53%	58%	62%	67%	71%	74%	77%	79%	80%	81%	81%	80%	79%	76%	74%	70%	66%	61%	56%	52%	49%
CZ15	51%	52%	54%	57%	62%	67%	71%	75%	79%	81%	83%	85%	85%	85%	84%	83%	80%	77%	74%	69%	64%	60%	55%	52%

Figure 28: Solar Fraction for system 1 vs. azimuth for a 5:12 tilt

The SWH analysis shows that the optimal orientation range or solar thermal systems is centered at 180 with the 10% performance degradation limits at 120^{o} and 150^{o}. The solar ready homes measure aligns with the optimal PV orientation limits of 150^{o} to 270^{o}, due to the larger TDV savings, and lower cost of the SWH system (i.e., lower incremental costs to increase SWH system costs to offset reduced performance). SWH systems oriented between 250^{o} and 270^{o} will still deliver 80% or more of the maximum output. Also mitigating this is the fact that a more westward facing collector will produce more heat in the afternoon, and will benefit households who have larger evening hot water draw profiles than reflected in the residential ACM draw profile. Another significant result is that SWH systems are much more sensitive to poor orientation than building energy use. A poorly oriented SWH system may only produce 50% of the maximum output, whereas building energy consumption typically only varies between 2% to 6% with building orientation (refer to section 4.6.2).

4.5 Analysis of Solar Ready Homes Measures

This section summarizes the analysis and findings of the specific solar oriented homes measure. This analysis draws from the general supporting background analyses summarized in sections 4.1 through 4.4.

4.5.1 Solar Zone Sizing

One of the primary features of a "solar ready" home is the provision of a rooftop "solar zone" that can accommodate a future solar system. There is debate on the necessary "solar zone" size. Solar zone sizing arguments include : 1) size the system to meet current retrofit system sizes, 2) align with current or previously proposed solar zone requirements, 3) size the zone to make a home "zero net energy" (i.e., align with California Long Term Energy Efficiency Strategic Plan), or 4) size the system based on roof availability.

The first approach to sizing the solar zone is to base the area on current installation statistics and program requirements, assuming that current trends in system size will continue. The California Solar Initiative (CSI) and the New Solar Homes Partnership (NSHP) require a minimal PV size of 1 kW[84, 85] (requiring approximately 56 ft^2 for an efficient PV module[86]). Factoring in conversion efficiency and other losses results in a *minimal* area of ~90 ft^2. Note that this also meets the area requirements for a typical solar water heating (SWH) system, which has typical areas ranging from 40 to 80 ft^2.

The upper bound is set by the NSHP's maximum system size of 7.5 kW (~ 422 ft^2). The solar system size in existing solar communities (i.e., PV systems installed on new homes) ranges from less than 1 kW to 3.8 kW (~213 ft^2), with a median around 2 kW (~112 ft^2), as shown in Figure 14. The average system size installed under the CSI program is 5.6 kW (~315 ft^2) (**Error! Reference source not found.**). The average system size installed on homes surveyed in section 4.2 is 2 kW (~112 ft^2).

CALGreen's residential voluntary measures (Appendix A4), section A4.211.3 requires 300 ft^2 of unobstructed roof area within 30^o of south to accommodate future PV or solar water heating systems. This is a reasonable requirement, but may be larger than needed for a mandatory Title 24 Part 6 requirement. The City of Los Angeles tried to implement a solar ready requirement with a 400 ft^2 solar zone, which was rejected as too large and difficult to implement by stakeholders, and would likely face similar stakeholder resistance.

The solar zone could alternatively be sized to enable the house to achieve zero net energy (ZNE). The specific PV size to make a future home ZNE depends on house size, climate zone, future energy

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[84] CSI Handbook: http://www.gosolarcalifornia.org/documents/CSI_HANDBOOK.PDF

[85] California Energy Commission. New Solar Homes Partnership Guidebook, Third Edition CEC-300-2010-001-CMF-REV1) , April 2010, Chapter II.F, page 12, http://www.energy.ca.gov/2010publications/CEC-300-2010-001/CEC-300-2010-001-CMF-REV1.PDF

[86] e.g., Sunpower E19/238 Solar Panels (http://us.sunpowercorp.com/), which are 19.1% efficient, have a rated power of 238 W, dimension of 31.42 in x 61.39 in = 13.4 sqft, and a power density of 17.77 W/SF. This analysis assumes optimal orientation and disregards other losses and inefficiencies.

efficiency measures implemented, occupant behavior, changes in equipment and appliance efficiency, plug loads, etc. As a starting point to understanding sizing requirements to make a new home ZNE, this CASE analyzed the PV size requirements to net out the TDV energy use of current energy consumption (both electricity and natural gas) regulated under Title 24 Part 6, as shown in Figure 29. It is of course possible to use both PV and SWH to achieve ZNE. This would likely be the more cost effective option. However, the purpose of this analysis is to show the “worst case” roof area requirements to achieve ZNE, which would likely be through PV due to its lower conversion efficiency. There is a large range in solar zone area requirements; however, the proposed solar zone area of 250 ft^2 should be sufficient to make a typical 2,600 ft^2 home ZNE in all but three climate zones.

		Home Size (ft^2)						
		1,000	**1,500**	**2,000**	**2,700**	**3,200**	**3,700**	**4,200**
Climate Zone	**01**	42	64	85	115	136	157	178
	02	43	64	86	116	137	159	180
	03	31	46	61	83	98	113	128
	04	41	62	82	111	131	152	172
	05	29	44	59	79	94	109	124
	06	36	53	71	96	114	132	150
	07	26	39	52	70	83	96	109
	08	47	70	94	127	150	174	197
	09	64	96	128	173	205	237	269
	10	69	104	138	187	221	256	290
	11	97	146	194	262	311	359	408
	12	71	107	142	192	227	263	299
	13	101	151	202	272	323	373	423
	14	76	113	151	204	242	279	317
	15	136	203	271	366	434	502	570
	16	76	114	152	205	243	281	319
	Statewide	56	85	113	152	180	209	237

Figure 29: Approximate PV size (ft^2) to “net out” regulated household TDV

Based on the information provided above, 250 ft^2 was determined to be the best balance between the need for a reasonably sized solar zone without unduly burdening or changing construction practices. Given the wide variability of potential solar system size and type(s) that homeowners may install, it is recommended that a single minimum solar zone area be required, even though there is significant variability with climate zone and house size. This keeps the code change simple to apply, easy for designers to incorporate, and aligns with existing solar zone sizing practice for a single area statewide in Title 24 part 11 (see section 4.1.2) and typical of industry practice. Analysis performed in section 4.5.2 shows that a 450 ft^2 solar zone should be able to be accommodated on most roofs, including smaller production homes of 2 stories with moderately complex roofs. The 250 ft^2 solar zone can provide for a range of different solar system(s), for example: a ~ 4.4 kW PV system using efficient solar panels[87], a ~ 2.5 kW PV system using lower efficiency panels, a 50 ft^2 solar water heating system with 3.5 kW of efficient PV, etc. It is likely that not all of the solar zone will be utilizable, depending on the geometry of the solar zone and solar panels used. The orientation requirements are based on the analysis in section 4.3 and 4.4, and enable annual PV TDV savings within 10% of the maximum.

4.5.2 Solar Zone Roof Area Availability

The solar zone roof availability is determined by two factors: 1) sufficient roof area, and 2) that area must meet the orientation requirements. There is concern that the three foot fire setback requirements (section 4.1.2) and the trend towards smaller, taller houses (per stakeholder feedback in the stakeholder meetings conducted for this CASE) will limit the roof area available for a solar zone. Stakeholders expressed particular concern that lower cost, affordable homes would not be able to meet these requirements, particularly as land prices continue to escalate and buildings trend towards smaller floorplans with more stories.

Two approaches were taken to determine the roof availability for the solar zone. First, a parametric analysis was performed of generic home geometry (e.g., area, number of stories, aspect ratio, roof configuration, etc.). Second, a sample of actual production homes were analyzed to develop ‘test fits’ for available solar zones that meet the fire setback requirements, with summary data presented in Figure 32. For the homes on which test fits were conducted, even smaller, 2-story homes with relatively complex roof designs have sufficient roof area to meet the 250 ft^2 solar zone proposal. The general conclusion of both roof area availability analyses is that there is sufficient roof area (excluding orientation concerns) to meet the proposed 250 ft^2 solar zone for up to two story buildings, even for small homes[88].

Roof Availability for General Roof Architecture

A parametric study of a rectangular home, an “L” shaped home, and a “T” shaped home, with both gable and hip roofs was conducted as described in section **Error! Reference source not found.**, with supporting details in Appendix 8 – Solar Zone Roof Calculations. Figure 30 and Figure 31 shows the solar zone area for prototypical 2-story 2,700 ft^2 rectangular home and a 1,500 ft^2 home with a 5:12 roof pitch. For the gable roof, there is always sufficient solar zone area, and at least one side of the roof will fall within the desired 150^o to 270^o orientation for 73% of all possible home orientations[89]. For the remaining 27% of possible orientations, a rectangular house with a gable roof would not meet the solar zone orientation requirements. The gabled roof has sufficient area for the solar zone on the

[87] e.g., Sunpower E19/238 Solar Panels (http://us.sunpowercorp.com/), which are 19.1% efficient, have a rated power of 238 W, dimension of 31.42 in x 61.39 in = 13.4 sqft, and a power density of 17.77 W/SF.

[88] Note that it is always possible to design a roof with enough complexity that the sufficient solar zone area is unavailable. However, this does not appear to be typical or common practice.

[89] This was analyzed in a spreadsheet by rotating a home with a gable roof through 360^o and counting the percent of all orientations in which one of the roof sections was within the proposed orientation requirements.

long side of the roof for rectangular homes (aspect ratio > ~1.75). For smaller homes, the short side of the hip roof generally does not have sufficient area to meet the desired solar zone area alone. However, in many cases, there are two roof sections that are within the desired the solar orientation. The results of the L-shaped and T-shaped geometry are more difficult to generalize due to the many independent parameters, but for typical roof configurations there is generally sufficient roof area. Roof availability for complex roofs is better demonstrated via the test fits described below. The general conclusions are that for two story homes with typical building configurations and simple roof geometries, there is generally sufficient area on the roof for the desired 250 sf^2.solar zone. The results of this analysis do not address the issue of whether the solar zone falls within the correct orientation. For three story buildings (not common, particularly for smaller homes, but possible and needs to be addressed), it becomes challenging to find sufficient roof area. Analysis shows that the 250 ft^2 roof area is not always available, depending on the house size and roof design. Therefore, a set of exceptions on the roof area and roof orientation are proposed to ensure that taller homes can meet the solar zone requirements.

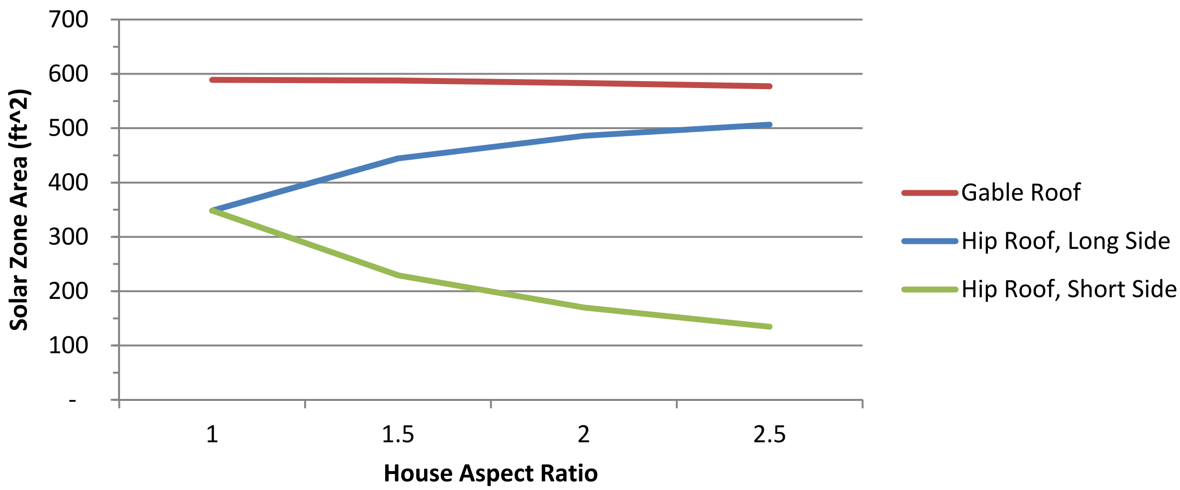

Figure 30: Solar zone area verses aspect ratio and roof type for a 2-story 2,700 ft^2 rectangular home

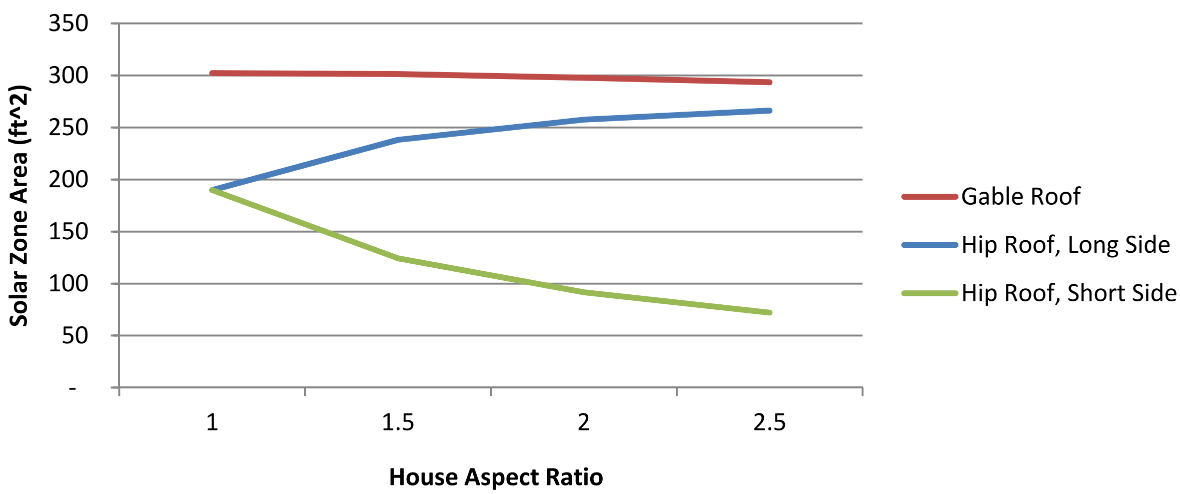

Figure 31: Solar zone area verses aspect ratio and roof type for a 2-story 1,500 ft^2 rectangular home

Solar Zone Roof Availability "Test Fits" on Typical Production Homes

The roof availability on typical production homes currently being built was analyzed to confirm actual solar zone roof area availability, with a focus on ensuring that smaller, entry level homes have sufficient roof area to meet the requirements[90]. A variety of new production home communities throughout the state were examined, and representative homes from three typical new production home communities were selected for analysis. The homes selected for analysis include a range of locations and builders, and were the homes that could potentially have the most challenges meeting the solar zone requirements. Homes selected were the smaller entry level homes in the community with the least or most complex roof areas, and were homes that did not prominently advertise solar[91]. Note that these homes were not part of the survey described in section 4.2. Figure 32 summarizes the results. All house plans examined have sufficient roof area to meet a 250 ft^2 solar zone requirement. The homes with more complex hip roofs perform better, in that they provide the required solar zone area on multiple exposures and are not constrained on how they are placed in a development, compared to the gable roof designs which have more room but require more careful placement to meet the orientation requirements.

[90] Stakeholders expressed concern that the solar zone requirement could potentially increase roof complexity or not be able to be met on lower cost entry level homes, thereby making these homes more expensive and unaffordable.

[91] The CASE authors could not find online advertisement of PV systems as an option on these homes, and existing homes in the community were not observed with solar.

Community		**Puesta del Sol at Las Haciendas**[92]				**The Gables at Vineyard Point**[93]		**Stone Hill**[94]
Location		Victorville				Sacramento		Roseville
Builder		KB Home				Lennar		K. Hovnanian
Model		**1896 (hip roof)**	**1896 (gable roof)**	**2205**	**2530**	**Ascot**	**Carlyle**	**#6**
Home Cost (Approx)		$155,000	$155,000	$160,000	$170,000	$186,000	$241,000	$327,870 - $345,995
Area (sf)		1,896	1,896	2,205	2,530	1,268	1,876	2,789
Stories		2	2	2	2	1	2	2
Bedrooms		4	4	3-5	4-6	3	3	4
Baths		2	2	2-3	2-3	2	2.5	3
Solar Zone Area (ft^2)	**Front**	259	339	684	684	0	252	439
	Left	261	71	0	0	883	329	275
	Back	424	560	760	790	0	348	390
	Right	349	71	0	0	791	322	254

Figure 32: Summary of production home solar zone roof availability

Puesta del Sol at Las Haciendas

The Puesta del Sol neighborhood of the Las Haciendas master planned development is a new production home development in Victorville offering three different two-story floorplans with 1,896 ft^2, 2,205 ft^2, and 2,530 ft^2, respectively. Bella Rosa is another neighborhood in the Las Haciendas development offering single story homes. The solar zone area of Floorplan 1896 (1,896 ft^2) was analyzed, as shown in Figure 34. This model comes with two different roof options: a hip roof and a gabled roof, as illustrated in Figure 33.

[92] Community and house details came from: http://www.kbhome.com/Community~CommID~00350373.aspx and http://newhomes.move.com/communitydetail/builder-732/community-50147/market-30

[93] Community and house details came from: http://www.lennar.com/New-Homes/California/Sacramento/Sacramento/The-Gables-at-Vineyard-Point and http://www.newhomesource.com/communitydetail/builder-2806/community-49819/market-31

[94] Community and house details came from: http://www.khov.com/InteractiveFloorPlan.asp?Path=/Channels/Home/CA/13188B/ModelsAvailable/226/InteractiveFloorPlan and http://www.newhomesource.com/communitydetail/builder-7534/community-53217/market-31

Figure 33: Puesta del Sol's Plan 1896, with hip roof option (left) and gable roof option (right)

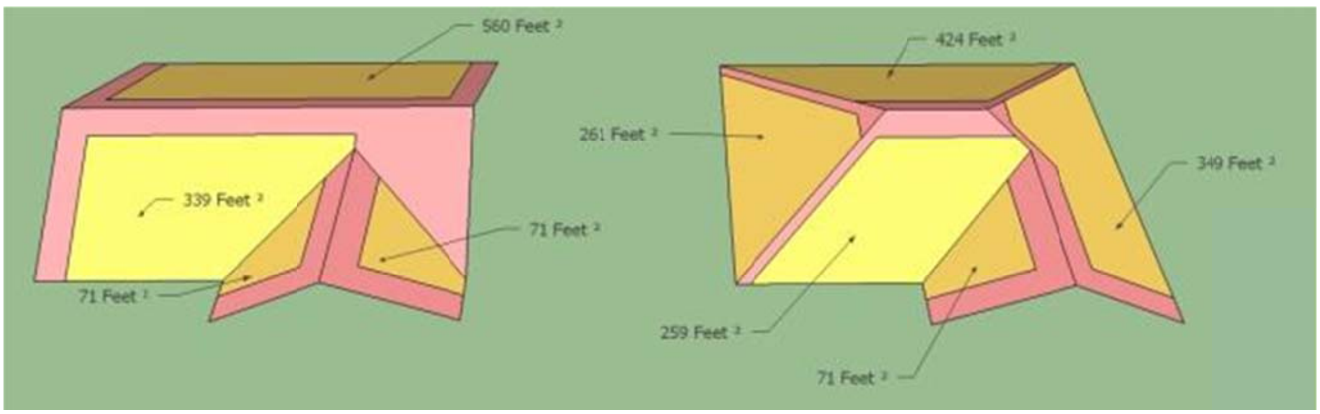

Figure 34: Available solar zones for Puesta del Sol, Plan 1896

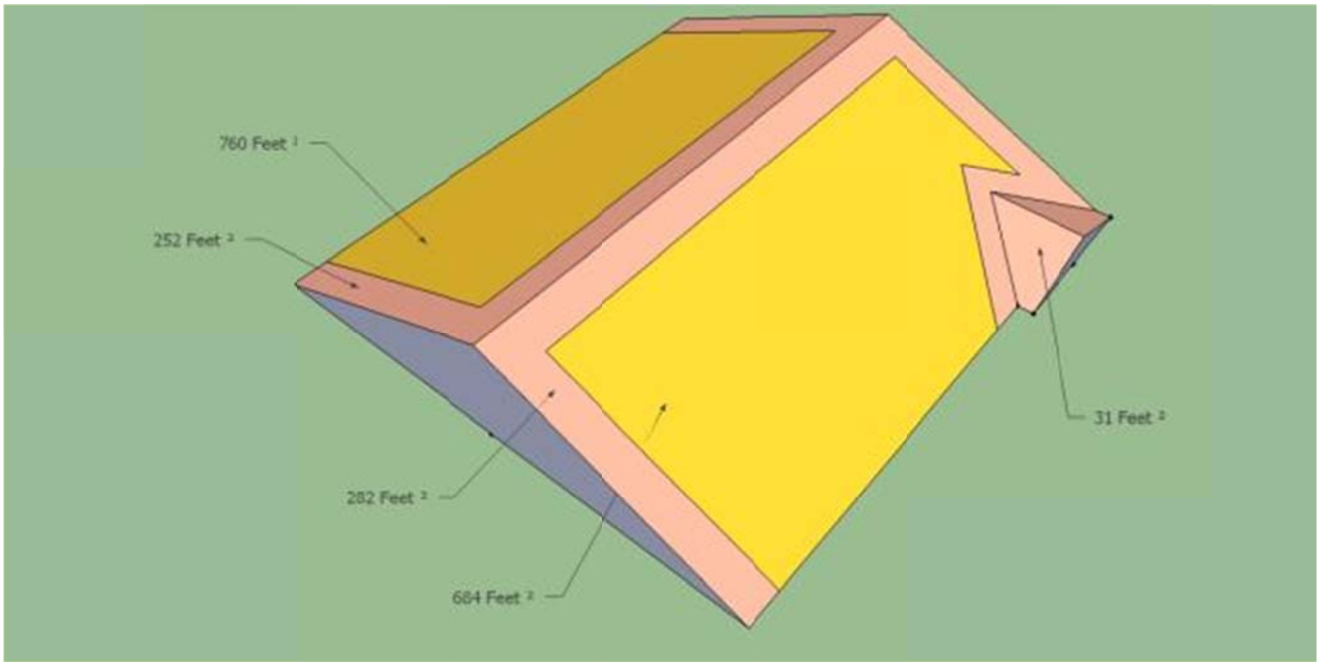

Figure 35: Available solar zones for Puesta del Sol, Plan 2205

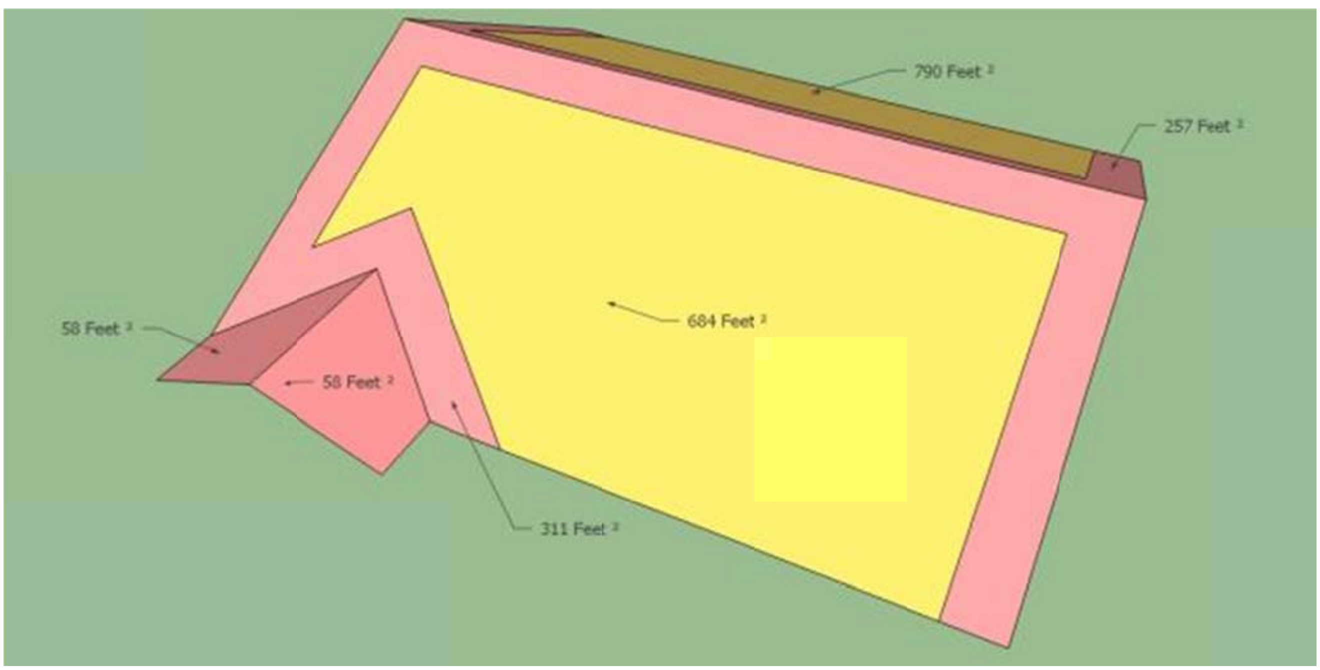

Figure 36: Solar zone area for Puesta del Sol, Plan 2530

Stone Mill Community

Stone Mill is a new community in the Fiddyment Farm master planned development, located in West Roseville. The community is composed of 107 home sites with three available floorplans ranging in size from 2,311 -2,753 ft^2 (one and two stories) Plan Number 6 was selected for analysis because it is nearly 2700 ft^2, and represented the most complex roof, making it most challenging to locate a solar zone. This plan can be built with three roof variants, as shown in **Error! Reference source not found.**. As shown in **Error! Reference source not found.**, there is sufficient roof space on each exposure for the proposed solar zone.

Figure 37: Plan #6 optional roof variants (a, b and c)[95]

[95] Images and home data from:
http://www.khov.com/InteractiveFloorPlan.asp?Path=/Channels/Home/CA/13188B/ModelsAvailable/226/InteractiveFloorPlan, and
http://www.newhomesource.com/homedetail/planid-861484/market-31

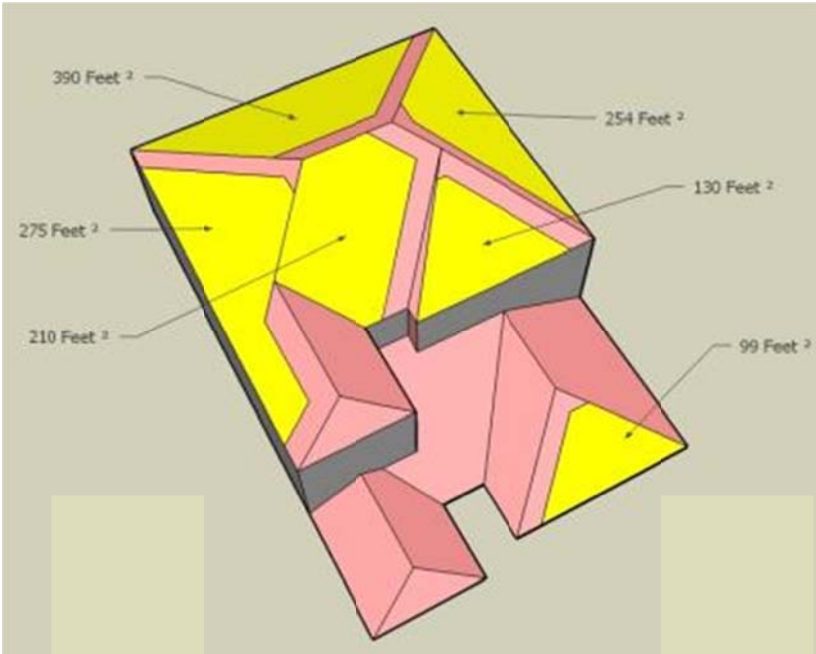

Figure 38: Available solar zones for Stone Hill Plan #6a

The Gables at Vineyard Point

The Gables is a new development in the Sacramento area feature three different home designs, shown in **Error! Reference source not found.**. The Ascot is the smallest home with a gable roof, single story. The Bristol is larger (1,428 ft^2) with a very similar roof configuration, but two stories. The Carlyle is the biggest home (1,876 ft^2), but has the most complex roof design. **Error! Reference source not found.** and **Error! Reference source not found.** shows the available solar zones for the Ascot and Carlyle.

Figure 39: The Gables Ascot (left), Bristol (center) and Carlyle (right) homes

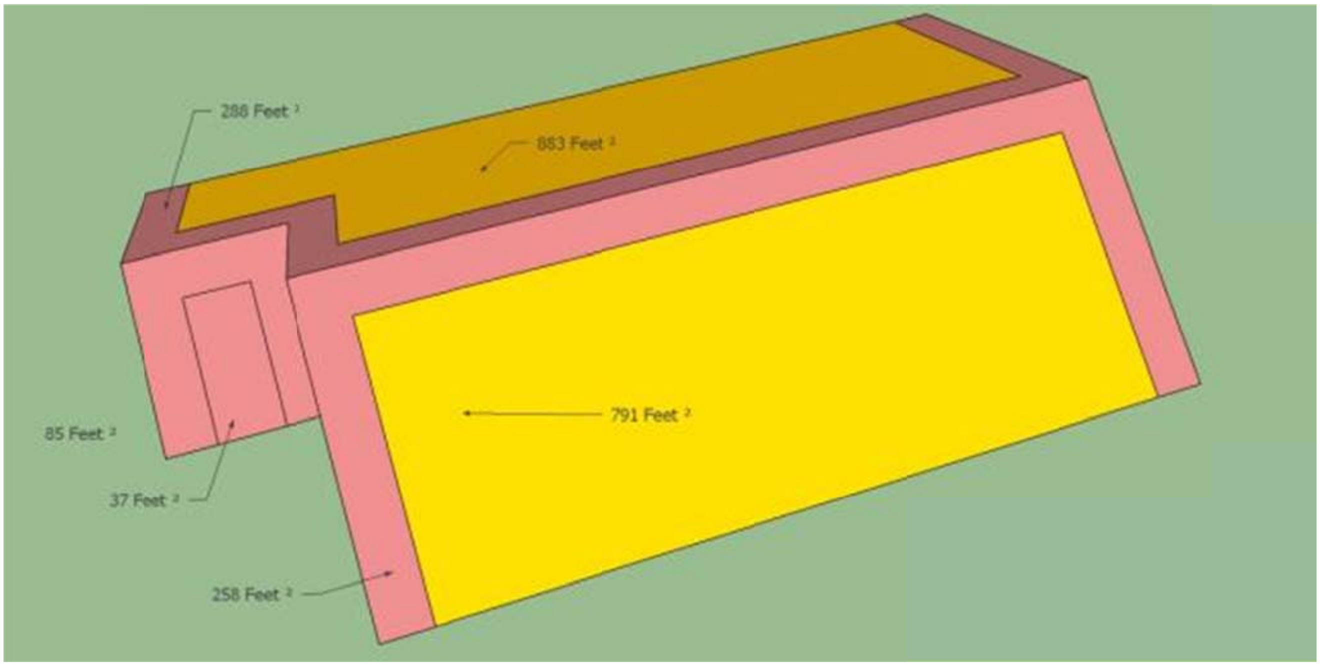

Figure 40: Available solar zones for the Gables "Ascot"

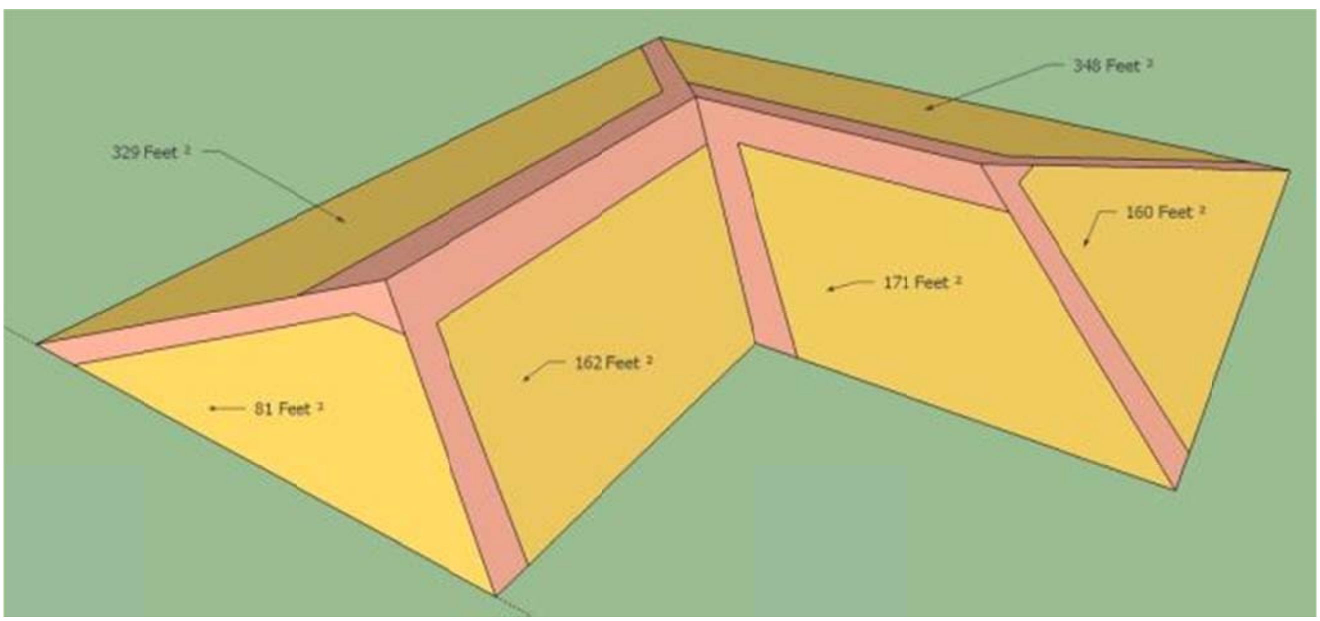

Figure 41: Available solar zones for the Gables "Carlyle"

4.5.3 Feasibility of Meeting Solar Zone Orientation Requirements

Section 4.5.2 shows that there is sufficient roof area to meet a 250 ft^2 solar zone requirement across a range of typical home sizes and roof configurations. Homes with hip roof designs may have sufficient roof space on all four orientations (front, back, left and right) and can meet the solar zone orientation requirements irrespective of the actual home orientation/placement in the development. Generally speaking, however, homes will not necessarily have available roof area on all orientations and will have some limitations on how they are placed in a development to meet the solar zone orientation requirements. This section examines the feasibility of meeting the solar zone orientation requirements.

From a statistical perspective, a house with a single solar zone will meet the proposed solar orientation range of 150^o to 270^o for 33% of all potential house orientations (i.e., a permissible orientation range of 120^o divided by 360^o). A house with two solar zones 90^o apart (e.g., an L-shaped roof) would meet the solar orientation requirements 59% of the time, a house with two zones 180^o apart (e.g., a rectangular house with a gable roof) would meet the requirements 73% of the time, and a house with three solar zones all 90^o apart would meet the requirements 86% of the time.

A survey of existing homes with solar (section 4.2.1) show that 29% of all systems surveyed are installed outside of the optimal range of 150-270^o. There are a variety of reasons for poorly oriented systems, including cases of overly complex roof designs or other roof designs where sufficient rooftop area was available on a better exposure. Of the different communities examined, there was a wide variation in the ability to provide roof area in the proper orientation. In general, considering solar zone orientation requirements when placing different floorplans in a community, considering solar zone requirements during architectural design and other factors should make it possible to provide all homes with a properly oriented solar zone.

To further confirm this, a detailed examination of the Las Haciendas master plan development in Victorville (see previous section on roof area analysis test fits) was analyzed to examine potential orientation challenges. This is a non-solar community composed primarily of lower cost homes currently being developed. The community includes a mix of street configurations (east/west orientation, north/south orientations, off-cardinal point orientation, curvilinear streets, cul-de-sacs, etc.). Figure 42 shows the community, with homes identified as having potential problems meeting the roof area and/or orientation requirements flagged. All of the homes shown (a total of 237 homes) were analyzed.

Figure 42: Las Haciendas development showing homes with potential solar zone orientation issues

<u>Legend</u>

- Solar zone is not within orientation requirements but house could be reoriented on lot to comply: total of 2 homes or 0.8%
- Solar zone is not within orientation requirements: total of 3 homes or 1.2%

- A Potential roof complexities may pose challenges to siting the solar zone: 5 homes or 2.1%
- B Solar zone orientation is close to (but still meets) the 150° minimum. These homes are on non-rectangular lots and could potentially be placed on the lot so they are out of the orientation requirements: total of 2 homes or 0.8%.

Of all the homes surveyed, only 2% (five homes) were identified with roof area that would not meet the proposed orientation requirements. Of these, two homes (flagged with 1) are sited on non-rectangular lots on cul-de-sacs which could have achieved proper orientation by a slightly modified house orientation on the lot. The B flagged homes are sited on similar non-rectangular lots and are close to the minimum orientation (but still within tolerance); they provide an example for how the 1 flagged homes could be reoriented slightly. The remaining three homes (2) have gable roofs on angled streets, and would either required placement of a different home model, or use of a different roof option. Homes marked with an A had complex roof geometry that may present a challenge locating solar panels while maintaining fire setback requirements, as illustrated in Figure 43.

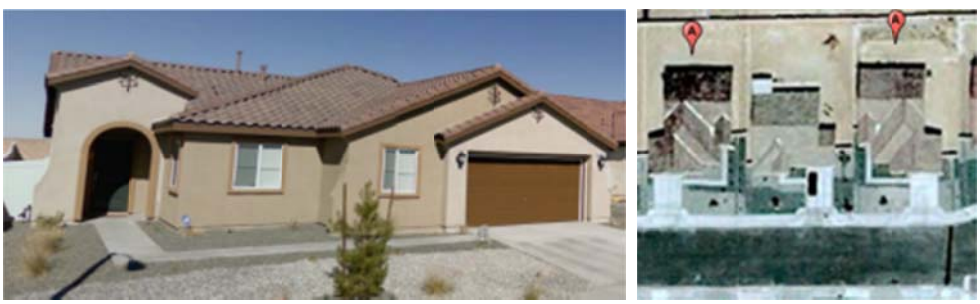

Figure 43: Homes with complex roof presenting potential challenges to solar

Overall, less than 5% of all homes would have had challenges meeting the orientation requirements, and these could have been readily addressed in the design by simply using different models in those particualr locations or minor orientation adjustments. This demonstrates that the proposed orientation requirements can be readily met without significant changes to current practice.

4.5.4 Recommended Solar Ready Home Measure Descriptions and Implementation Costs

The recommended solar ready home measures and their implementation costs are summarized below. The costs to implement each solar ready measure on all new homes at the time of construction to make them "solar ready" verses standard practice, as well as the cost differential for retrofitting solar onto a non solar ready home are shown. The latter costs are only incurred by homes that retrofit solar at some point in their lifetime.

Designated Solar Zone on Roof

One of the primary requirements of a solar ready home is the provision of a designated solar zone on the roof that can accommodate PV, solar water heating, or both. The proposed solar zone area is 250 ft^2, oriented between 150º to 270º. The solar zone can be divided into contiguous sections greater than 80 ft^2 each. The 80 ft^2 cutoff represents the size requirements of a typical two panel SWH system. Areas less than this become more challenging to fit significant numbers solar panels on and increase labor costs. The solar zone should be clearly marked on the construction documents and plans and clear of attic vents, plumbing vents, equipment, and other obstructions.

As shown by our analysis, most new homes, including smaller homes, generally have sufficient roof area to accommodate the proposed solar zone; therefore there are no increased implementation costs for reserving a solar zone. No changes in roof construction, increased roof area, or other changes to construction practice should result. Realizing this measure will require some additional attention by architects and designers. However, design costs are not included in Title 24 cost effectiveness analysis. There are no additional costs for this measure incurred during retrofit of a solar ready home.

The added costs incurred for installing a solar system on a non solar ready home can include a diverse range of factors, such as costs for vent relocation, added time for more complex solar installations, the need for more complex racking, etc. We estimated that on average, approximately five (~ 5) additional installation labor hours at $49.05/hour (per RSMeans) will be required to install solar in a non-solar ready home compared to a solar-ready home. This time estimate was derived from RSMeans time estimates to address the typical issues described above, discussions with installers, and vetted through the stakeholder meeting process.

In summary, the implementation costs and retrofit savings for providing a solar zone are estimated to be:

- Added implementation costs of measure in a solar ready home at time of construction is $0
- Added costs of installing solar on a non solar ready home at time of retrofit is $245.25

Minimal Shading of Solar Zone

Solar system shading is a critical issue that can significantly reduce system performance. The solar zone should be minimally shaded. This code proposal aligns with industry best practice, and the CSI[96] and the New Solar Homes Partnership[97] requirements that any vent, chimney, or other architectural feature shall be a minimum distance of twice the height from the reserved roof area(s). This measure excludes any vent, chimney, or other architectural feature to the north of the reserved roof area(s), as well as shading from trees, utility poles, other buildings, and other non-building sources. The rationale for this exclusion being that many of these features may be beyond the control of the homebuilder, are things that can be modified in the future if needed (e.g., a tree trimmed or replaced), and may be beneficial until a solar system is installed (e.g., shading from trees).

[96] CSI Handbook, Page 137, http://www.gosolarcalifornia.org/documents/CSI_HANDBOOK.PDF

[97] NSHP Handbook, p 46, http://www.energy.ca.gov/2010publications/CEC-300-2010-001/CEC-300-2010-001-CMF-REV1.PDF

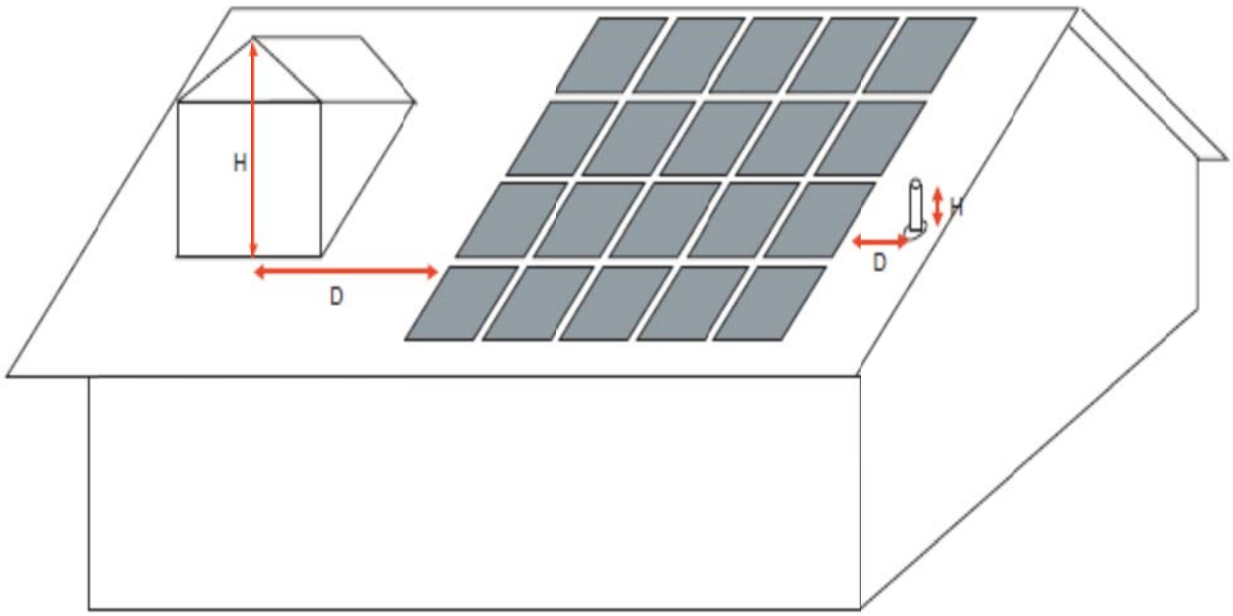

Figure 44: Minimal solar zone shading illustration[98]

Per stakeholder feedback, non-solar ready retrofit costs include additional coordination and installation time to move vents or other shading sources, and increased labor time for more complex installations to work around existing shading. A typical vent relocation is estimated at $357 per RSMeans[99], and this is typical for other types of increased installation costs to account for shading. Based on stakeholder conversations, feedback, and review of existing roof installations, we estimate that approximately 1/3 of the homes will incur these costs (the other 2/3 will have sufficient unshaded solar zone area without the need to take action), for an average cost of $119 per new home.

In summary, the implementation costs and retrofit savings for minimizing shading on the solar zone are estimated to be:

- Added implementation costs of measure in a solar ready home at time of construction is $0
- Added costs of installing solar on a non solar ready home at time of retrofit is $119

Fire Access and Venting Requirements

As discussed in section 4.1.2, fire access and ventilation requirements are important issues that are becoming more tightly enforced. Stakeholder feedback indicates that up to 30% of projects cannot go

[98] Source: NSHP handbook, http://www.energy.ca.gov/2010publications/CEC-300-2010-001/CEC-300-2010-001-CMF-REV1.PDF

[99] 2 roof Flashings (remove old flashing & install new) at ($37.5 materials+ $21 labor) each (RSMeans Costworks, 2010 Residential Cost Books, 73219104040, pipe flashing tile with rubber boot) plus 2 hours additional "skilled labor" to re-route vent ($120/hour per RSMeans Costworks, 2010 Residential Cost Books). Total cost ~ 2*(37.5+21+120) = $357

forward due to restrictions related to fire access clearances. A review of the existing solar communities (Appendix 7 – Survey of "Current Practice" Solar Performance in Existing Homes and Communities) shows significant numbers of solar installations that do not appear to have the recommended clearances.

This CASE proposes that the solar zone shall be designed to meet the requirements of the California Department of Forestry and Fire Protection, Office of the State Fire Marshal's "Solar Photovoltaic Installation Guideline," Section 2. This aligns with updates in the soon to be released 2011 International Fire Code, and likely changes to the California Fire Code during its next update cycle.

There are no estimated costs for implementing this measure at the time of construction. Non-solar ready retrofit costs include additional coordination and permitting time with the fire marshal and related costs. There is a wide range in the retrofit costs. Stakeholder report that in some cases, costs are minimal, whereas in other cases up to six meetings with the fire marshal and multiple design iterations may be required with costs over $1000. And in other cases, approval is unable to be obtained and the project cannot proceed. Based on solar industry and homebuilder input we estimate that the median retrofit cost savings due to expedited fire marshal approval for a solar ready home verses a non solar ready home is $300, which represents ~6 hours of time at an average rate of $50. This includes meeting time with the fire marshal, additional time to update the layout and install the array to meet fire setback requirements, and related costs.

In summary, the implementation costs and retrofit savings for providing smoke ventilation and fire access are estimated to be:

- Added implementation costs of measure in a solar ready home at time of construction is $0
- Added costs of installing solar on a non solar ready home at time of retrofit is $300, with a range of $0 to over $1000

Show Piping and Wiring Pathway on Plans

Although many solar ready codes or requirements include pre-wiring for PV and/or pre-plumbing for solar water heating, this was not found to be cost effective nor desired by many solar installers and other stakeholders. However, it was determined that including a pipe and wiring routing on the plans would be useful in helping reduce installation costs, and would encourage good design that more readily accommodates future solar system installation. This would be particularly synergistic with the California Homebuyer Solar Option and Solar Offset Program (refer to section 4.1.2), assuming that many production homebuilders opt to offer solar as an option rather than participate in the solar offset program, and would find it desirable to have designs that already anticipate and provide some type of design provisions for future piping and plumbing. Including piping and wiring layout into the home design will facilitate retrofitting, reduce installation costs and/or increasing builder profit, and help minimize unsightly piping and plumbing routed across roofs and exterior walls that could detract from community aesthetics.

It is estimated that consideration of plumbing and wiring routing can reduce ~five installation labor hours at a typical hourly rate of $49.05[100], compared to retrofitting solar in a non-solar ready home where no consideration for routing has been made.

In summary, the implementation costs and retrofit savings for showing the piping and wiring pathway on the plans are estimated to be:

- Added implementation costs of measure in a solar ready home at time of construction is $0
- Added costs of installing solar on a non solar ready home at time of retrofit is $242.25

Show Roof Structural Design Load on Plans

Current building code design requirements (refer to section 4.1.2) are generally sufficient to accommodate typical residential PV installations, which add ~ 2 to 5 lb/ft^2 of structural dead load. Wind loads are generally not an issue, except for some areas with high wind gusts (> 100 mph). The fire setbacks also keep the solar collectors away from exposed roof edges where wind loads are highest.

However, many code officials require a structural engineering evaluation or stamp for permitting, which in most cases unnecessarily increases costs. Based on stakeholder feedback, approximately 90% of solar PV installations do not require any structural upgrades. While there is general stakeholder consensus that adding additional roof structural requirements is unnecessary (and outside the jurisdiction of Title 24, Part 6), there is agreement on the benefit of documenting roof structure design loads on the plans, to help reduce the need for a structural engineering inspection at the time of retrofit to re-document this through field investigation.

This measure would have no initial implementation costs. Retrofit savings are based on a conservative estimate of eliminating a typical site visit, travel, and reporting time of 3 hours. Stakeholders report a typical civil engineering rate of $200 to $250/hour; the lower hourly rate of $200/hour is used for the analysis.

In summary, the implementation costs and retrofit savings for showing the roof structural design loads on plans are estimated to be:

- Added implementation costs of measure in a solar ready home at time of construction = $0
- Added costs of installing solar on a non solar ready home at time of retrofit = $600.00

Provide Adequate Electric Panel Capacity

A common installation problem is the lack of adequate electric panel capacity. Stakeholder feedback and interview with building and trades personnel indicate that approximately 20% of new homes do not have adequate electric panel capacity to accommodate the addition of a PV system and require an

[100] Based on typical cost data for a range of different types of solar system installers involved in solar projects, per RSMeans Costworks, 2010 Residential Cost Books

electric panel upgrade. Eighty percent (80%) of homes are built with adequate electric panel capacity (typically 200 Amps is sufficient). This proposal will require new homes to have an electric panel capacity with a minimum bus-bar rating of 200 Amps.

The solar ready home proposal will require 20% of homes to install a larger electric panel than they normally would have installed, incurring the incremental material costs of the 200 amp panel versus a smaller 100 amp panel. A new 200 Amp panel has an estimated cost of $1,700[101], and a new 100 amp electric panel has a cost of $978[102]. The panel upgrade cost equals the 200 Amp panel cost minus the 100 Amp panel cost, or $1799-$978=$722. Only 20% of new homes will require this upgrade, for an average cost of $722*20% = $144 for every new home start.

Installing PV on a non solar ready home with an insufficiently sized electric panel will either require a panel replacement or a line-side tap. Line side taps are currently not as common as panel replacements, and there are practitioner concerns about local jurisdictional acceptability, utility acceptability, potential to impact equipment UL rating equipment, and unfamiliarity[103]. It is anticipated that the popularity of line side taps will grow, and be more prevalent by 2014. The cost of this measure conservatively estimates that 50% of installations will implement a line-side tap, and 50% will require a panel upgrade.

Upgrading the electrical panel incurs the following costs:

- Remove Existing panel: $178[104]
- Install new 200 Amp panel: $1700[105]
- Total retrofit panel upgrade costs = 1700+178 = $1878

Installing a line side tap is estimated to cost ~ $600[106]

The average cost per home assumes that only 20% of homes require upgrade, and that 50% of homes replace panel at $1878 and 50% of homes use a line side tap at $600 = $248 average per new construction start.

In summary, the implementation costs and retrofit savings for providing adequate electric panel capacity are estimated to be:

- Added implementation costs of measure in a solar ready home at time of construction is $144

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[101] RSMeans Costworks, 2010 Residential Cost Book, item #260590101200, 200 amp panel, labor and materials, including overhead and profit

[102] RSMeans Costworks, 2010 Residential Cost Books, item #260590101200, 100 amp panel, labor and materials, including overhead and profit

[103] There is significant discussion on online forums for solar installers and electricians regarding line side taps (e.g., http://forums.mikeholt.com/showthread.php/114934-Solar-PV-Line-Side-Tap-Assistance-desired, and http://www.wind-sun.com/ForumVB/showthread.php?t=5403).

[104] RSMeans Costworks, 2010 Residential Cost Books, item #260505101230, 100 Amp up to 20 circuits, labor and materials, including overhead and profit

[105] RSMeans Costworks, 2010 Residential Cost Books, item #260590101200, 200 amp panel, labor and materials, including overhead and profit

[106] RSMeans Costworks, 2010 Residential Cost Books does not provide cost data for a line side tap. Costs are estimated by interpolating between the closest RSMeans classifications, item #262416100400, rainproof load center, 100 amp main lugs, including overhead and profit

- Added costs of installing solar on a non solar ready home at time of retrofit is $600-$1878 per home affected or $248 averaged across all new home starts

Provide Spare Electrical Breaker Space

Another significant retrofit cost often encountered is the lack of spare electrical breaker space for a PV system. Lack of space requires either a panel upgrade (same amperage, more space) or installation of a line-side tap. Installing a panel with additional spare breaker space reserved during new construction is significantly cheaper than either of these options. Approximately 75% of new homes need additional breaker space.

The cost to increase panel size (while maintaining constant amperage rating) to accommodate more breakers during new construction ranges from $14 to $64, depending on the starting panel size, panel type, etc.[107] This analysis assumes a conservative cost of $50 for upgrading to the next biggest panel size to accommodate spare breakers. The average cost per construction start is 75%*$50 = $38.

Retrofit costs assume that 50% of installations will implement a line-side tap, while 50% will upgrade the electrical panel. Panel replacement costs entail removing the existing panel for $178[108] and installing a new panel of same amperage but more breaker capacity for $1700[109], for a total cost of $1,878. A line side tap costs ~ $600[110].

The average cost per new home start assumes that 75% of homes require upgrades * (50% of homes replace panel at $1878 + 50% of homes use a line side tap at $600) = 75% * $1239 = $929

Total Recommended Measure Costs

Figure 45 summarizes the total implementation costs for the proposed solar ready homes, the average incremental costs for retrofitting either a PV system or a PV and SWH systems onto a non-solar ready home[111], the retrofit cost range, and the total incremental implementation cost savings for the solar ready homes measure on a per home basis. Figure 46 shows the same data, but with savings if only a SWH system is installed (there is no cost savings associated with the electrical panel and breaker measures).

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[107] Based on a review of panel costs from WW Grainger , http://www.grainger.com/Grainger/wwg/viewCatalogPDF.shtml?browserCompatable=true&adobeCompatable=true&toolbar=false&CatPage=258&Catalog=main)

[108] RSMeans Costworks, 2010 Residential Cost Books, item #260505101230, 100 Amp up to 20 circuits, including O&P

[109] RSMeans Costworks, 2010 Residential Cost Books, item #260590101200, 200 amp panel, labor & materials, including O&P

[110] Interpolating between closest RS Means classifications, 262416100400, rainproof load center, 100 amp main lugs, including O&P

[111] Averaged for all new home starts

	Added Implementation Costs of Measure in a Solar Ready Home at Time of Construction	Average Added Costs of Installing Solar on a Non Solar Ready Home at Time of Retrofit	Range of Added Retrofit Costs
Reserved roof area for solar zone	$ -	$245.25	
Roof design to minimize shading	$ -	$119.00	
Provide smoke ventilation & fire access for solar roof area	$ -	$300.00	$0 - $1,000+
Indicate pathway for piping and wiring	$ -	$245.25	
Show roof structural design loads on plans	$ -	$600.00	
Provide adequate electrical capacity	$144	$248	$600-$1,878 per home affected
Provide Spare Electric Breaker Space	$38	$929	$600-$1,878 per home affected
Total Costs	**$182**	**$2,687**	
Solar Ready Cost Saving	**$2,505**		

Figure 45: Total implementation costs and savings for solar ready homes measures if PV, or PV and SWH are implemented

	Added Implementation Costs of Measure in a Solar Ready Home at Time of Construction	Average Added Costs of Installing Solar on a Non Solar Ready Home at Time of Retrofit	Range of Added Retrofit Costs
Reserved roof area for solar zone	$ -	$245.25	
Roof design to minimize shading	$ -	$119.00	
Provide smoke ventilation & fire access for solar roof area	$ -	$300.00	$0 - $1,000+
Indicate pathway for piping and wiring	$ -	$245.25	
Show roof structural design loads on plans	$ -	$600.00	
Provide adequate electrical capacity	$144	No cost savings if only solar water heating (SWH) is installed	
Provide Spare Electric Breaker Space	$38	No cost savings if only solar water heating is installed	
Total Costs	**$182**	**$1,510**	
Solar Ready Cost Saving	**$1,328**		

Figure 46: Total implementation costs and savings for solar ready homes measures if only SWH is installed

4.5.5 Energy Savings

The solar ready homes measure will save energy through the following mechanisms:

- Increased solar system performance due to providing a solar zone with improved solar orientation.
- Increased solar system performance due to reduced shading.
- Requiring homes to have appropriate rooftop area for solar systems, t.

For the cost effectiveness analysis, only savings associated with improving solar system orientation are accounted for. These savings have been well documented in this study. Savings due to shading and increases in the number of homes that can install PV are more difficult to estimate, and to be conservative, are not included in the cost effectiveness savings.

Figure 47 shows the basecase distribution of solar system orientation (black line, read on the left axis). As can be seen, there are a significant number of systems being installed at non-optimal azimuths outside of the proposed 150^{o} to 270^{o} limits. The red and yellow lines (read on the right axis) show the percent savings that would be realized by re-orienting poorly oriented solar systems to the minimum proposed range (for example, the savings for reorienting a collector that would have been installed at 290^{o} in the non solar ready case to the 270^{o} solar ready limit, or a collector oriented 90^{o} to 150^{o}). Note that this figure shows average savings; actual savings analysis is performed for each climate zone. Per system savings can be quite significant for very poorly oriented systems. The per system savings are then multiplied by the percentage of systems at that orientation (i.e., multiply the red or yellow per system savings by black line percentage of total systems).

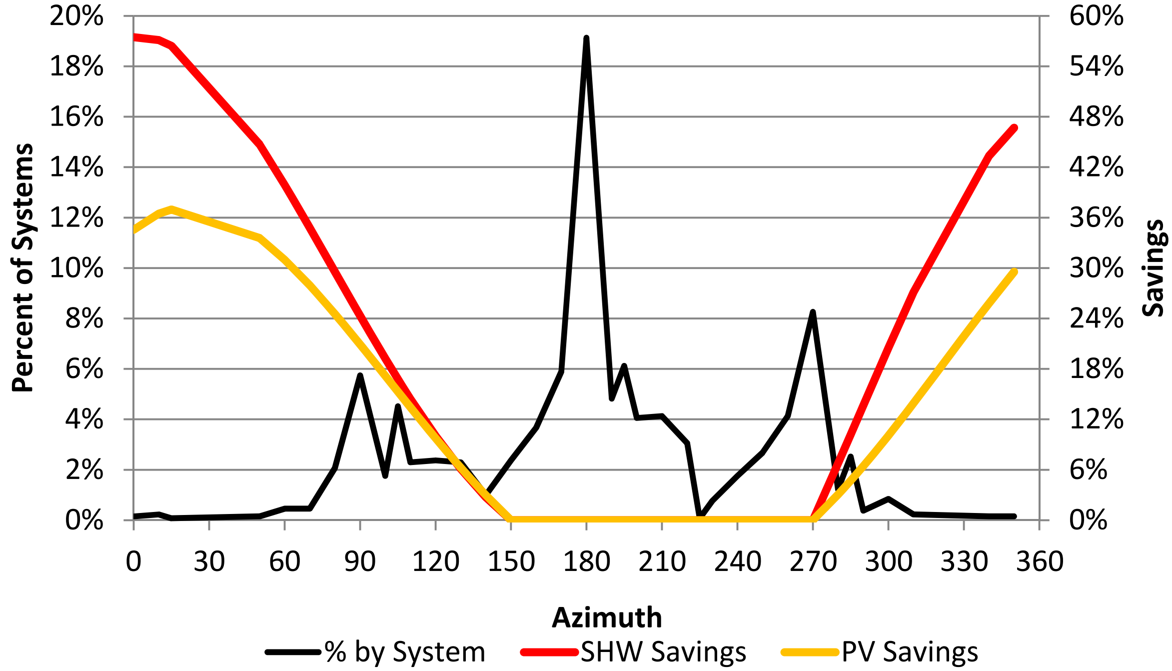

Figure 47: Basecase solar system distribution by azimuth and savings potential

The energy savings and cost effectiveness study is based on the 3.6 kW_{DC} nameplate rated capacity PV system described in 3.3, and the "system 1" SWH system described in section 3.4. The 3.6 kW_{DC} system is midway between the 2.0 kW average system size installed on new solar homes (Figure 14) and the 5.64 kW average size for retrofitted systems installed under the CSI program (section 4.1). Both of these systems will fit within the proposed 250 ft^2 solar zone.

Figure 48 shows basecase system performance (weighted average TDV savings/year for all azimuths), system performance with poorly oriented systems re-oriented to minimally comply (i.e., azimuths < 150^o reoriented to 150^o, and azimuths > 270^o reoriented to 270^o) with the proposed solar oriented home solar zone orientation requirements, and reorienting to the optimal orientation (210^o for PV and 180^o for SWH). Statewide weighted average savings for reorienting poorly oriented systems to the minimum orientation requirements saves 5,479 $kBTU_{TDV}$ (4.1%) per PV system, and 768 $kBTU_{TDV}$ (4.3%) per SWH system. Optimally reoriented systems save 8,711 $kBTU_{TDV}$ (6.5%) for PV, and 1,116 $kBTU_{TDV}$ (6.2%) for SWH.

		PV system basecase energy generation	PV system energy generation and savings (TDV/year) for a solar ready home, minimal orientation improvement	PV system energy generation and savings (TDV/year) for a solar ready home, optimal orientation improvement	SWH system basecase energy generation	SWH system energy generation and savings (TDV/year) for a solar ready home, minimal orientation improvement	SWH system energy generation and savings (TDV/year) for a solar ready home, optimal orientation improvement
Climate Zone	1	120,293	125,462	128,606	13,653	14,410	14,759
	2	134,696	140,612	144,110	17,852	18,650	19,011
	3	138,715	144,614	148,123	17,718	18,537	18,910
	4	138,444	144,601	148,185	18,225	19,014	19,372
	5	147,693	154,059	157,749	20,354	21,332	21,778
	6	133,599	139,019	142,210	19,019	19,875	20,266
	7	139,591	145,636	149,333	19,279	20,159	20,560
	8	131,508	136,882	140,133	20,359	21,244	21,647
	9	134,548	140,082	143,388	19,144	19,956	20,325
	10	134,645	140,134	143,467	19,307	20,141	20,521
	11	133,236	139,127	142,451	17,079	17,880	18,245
	12	129,886	135,089	138,051	18,275	19,013	19,345
	13	128,964	133,902	136,749	17,845	18,514	18,816
	14	143,078	149,565	153,344	22,372	23,380	23,839
	15	130,036	135,262	138,556	18,636	19,453	19,823
	16	130,036	135,262	138,556	0	0	0
Statewide Wtd. Average		**133,112**	**138,592**	**141,823**	**18,053**	**18,820**	**19,168**
Savings	TDV	n/a	5,479	8,711	n/a	768	1,116
	%	n/a	4.1%	6.5%	n/a	4.3%	6.2%

Figure 48: Summary of solar system performance with and without the solar ready measures (TDV/system/year)

4.5.6 Cost Effectiveness and Statewide Savings

The cost effectiveness of the solar ready homes measure was explored for the following scenarios:

1) Minimum Expected: NREL's worst case future projections based on high PV Costs, resulting in a ~ 2% PV penetration by 2030[112], and extrapolating out from there at the same growth rate. A similar 2% penetration for SWH is assumed. This would result in a in a 3.2% and 3.5% penetration of PV and SWH, respectively, by 2044 (the end of the 30 year analysis period).
2) Minimum Cost Effective: The minimal PV and SWH penetration required to make the measure cost effective, which is a 6.53% penetration of PV and SWH by 2044.

[112] Based on the National Renewable Energy Laboratory's "Modeling the US Rooftop PV Market" report dated 09/2010, using the high PV cost scenario, which equates to an approximate 2% PV penetration by 2030. A similar trend for SWH is assumed.

3) CSI Goals: Assuming that the CSI PV goal of ~1.5% penetration by 2016 and the CSI Thermal goal of ~2.2% penetration by 2017, and extrapolating out at the same growth rate (resulting in a 7.8% PV penetration and 12% SWH penetration by 2044).
4) Strategic Plan Goals: Assuming that the California Long Term Energy Efficiency Strategic Plan goals for residential existing homes are met, resulting in a 25% PV and SWH penetration by 2020, with no increase in penetration after 2020.
5) Towards ZNE: Assuming that the above Strategic Plan goals are met, but that PV and SWH penetration continues to grow at the same pace, resulting in a an ~ 90% penetration in both PV and SWH by 2044.

All of the scenarios assume the same base-case penetration of 0.58% for PV and 0.01% for SWH systems on new construction in 2011, as discussed in 4.1.1. New construction penetrations for 2014 are projected linearly based on the scenario projections. "Solar ready" costs are excluded from homes that would install solar during new construction. Solar ready costs of $182/home are applied to single family new homes constructed. These costs are applied to all homes irrespective of whether or not they ever install a solar system. Based on the scenario, the PV penetration is projected throughout 30 year lifecycle. The number of homes built in 2014 that retrofit solar is based on the overall PV and SWH penetration curves. Retrofit cost savings are calculated for the number of homes which install PV in each year. The retrofit cost savings for the SWH systems are also calculated, with the one modification: it is assumed that a certain percentage of homes will install both solar PV and SWH. In this analysis, it is conservatively estimated that 25% of homes will install both a PV and SWH system. Retrofit cost savings are only counted once in these cases.

The cost effectiveness analysis was conducted using both the CEC's housing start projections (103,438 new single family homes projected to be constructed in 2014), as well as a significantly lower projection of ~60,000 new single family home starts provided by the California Building Industry Association (CBIA) [113]. The California Legislative Analyst's Office's also provides projections which are between the two[114], but closer to the CBIA data.

The graphs and tables below summarize the cost effectiveness results. Figure 49 shows the total cost savings for each scenario. This measure is cost effective for all scenarios except for the very worst-case penetration of scenario 1. Based on current policy supporting renewables and trajectory of PV and SWH growth, future PV and SWH should be well into the cost effective range for this measure. Figure 51 and Figure 52 shows the cost effectiveness analysis using the CBIA housing start projections. There is no change in the results and solar penetrations required to make this measure cost effective.

[113] The California Building Industry Alliance's estimate of housing start projections is 50,000-60,000 single family units in 2013 and another 30,000-40,000 multifamily units for a total of 80,000-100,000 units. For the purpose of this analysis, the upper value of 60,000 new housing starts in 2013 is used as a proxy for 2014 housing starts.

[114] The California Legislative Analyst Office, "The 2010-11 Budget: California's Fiscal Outlook." November 2009. http://www.lao.ca.gov/2009/bud/fiscal_outlook/fiscal_outlook_111809.pdf provides additional housing projections.

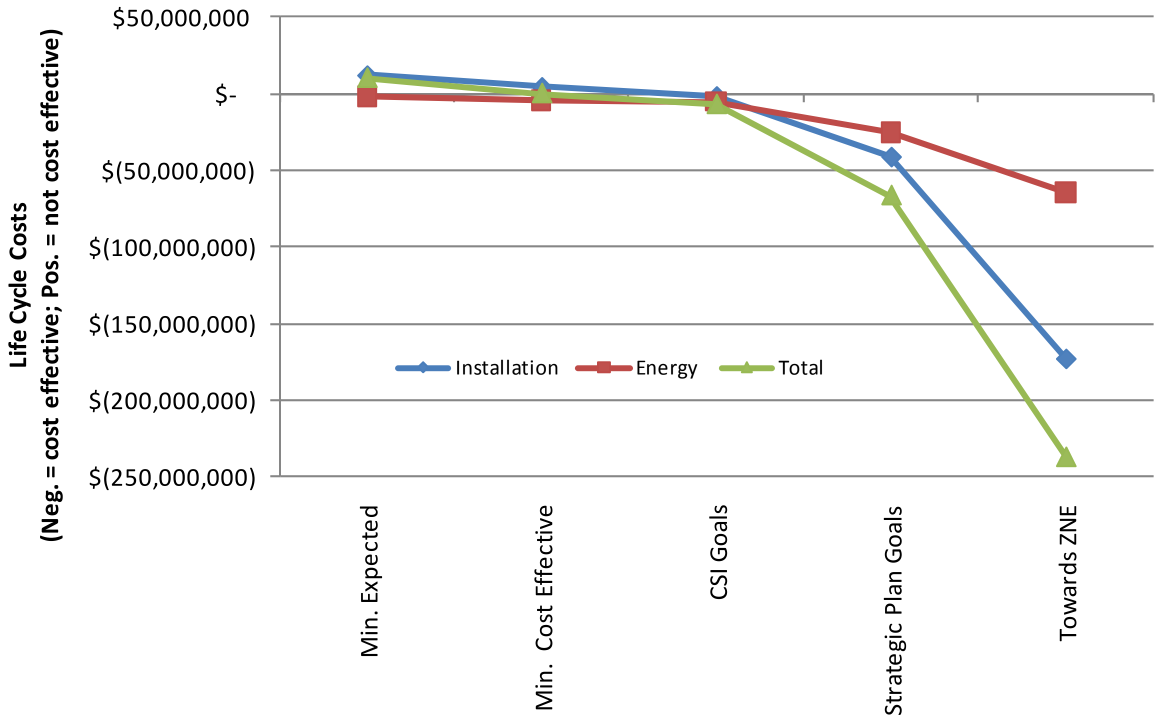

Figure 49: Solar ready homes life cycle costs, CEC housing start data

Scenario	1 NREL Min Penetration Scenario	2 Minimum cost effective Scenario	3 Meet CSI Goals	4 Meet CA Long Term Energy Efficiency Strategic Plan Goals	5 Towards ZNE (Meet 4 and continue same growth rate)
30-Year PV Penetration	3.20%	6.53%	CSI PV goal of 1.5% in 2016, extrapolated to 7.8% in 2043	25% by 2020, then flat	25% by 2020, 100% by 2043
30-year SWH Penetration	3.50%	6.53%	CSI Thermal goal of 3% by 2016, extrapolated to 20% by 2043	25% by 2020, then flat	25% by 2020, 100% by 2043
% homes with both SWH & PV	25%	25%	25%	25%	25%
Solar-Ready Costs	$18,671,687	$18,614,697	$18,592,962	$17,184,114	$17,169,053
Retrofit Costs	$6,751,038	$14,354,088	$20,253,683	$58,455,304	$190,231,080
Δ Installation Costs	$11,920,650	$4,260,608	$(1,660,722)	$(41,271,190)	$(173,062,027)
Δ Energy Costs	$(1,930,928)	$(4,271,769)	$(5,512,412)	$(25,311,176)	$(64,344,662)
Δ Total Costs (negative = cost effective)	$9,989,722	$(11,161)	$(7,173,134)	$(66,582,366)	$(237,406,690)

Figure 50: Table of solar ready homes cost effectiveness results, CEC housing start data (~103,438 new homes in 2014)

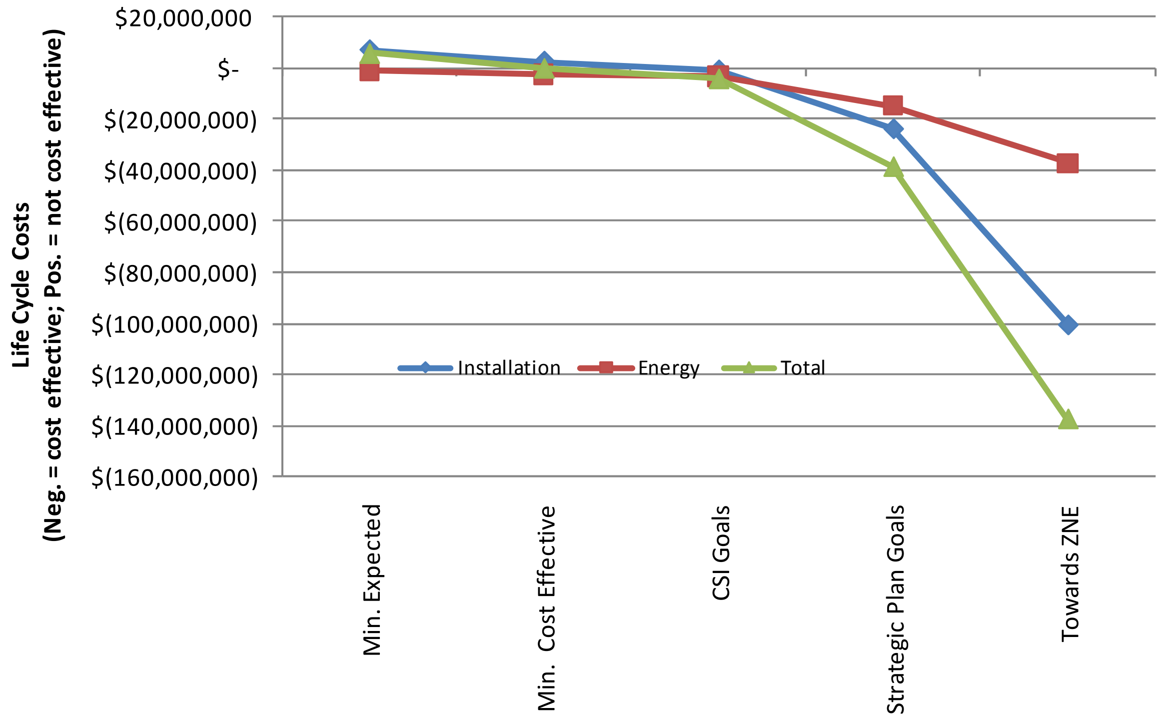

Figure 51: Solar ready homes cost effectiveness results, CBIA housing start data

	1	2	3	4	5
Scenario	**NREL Min Penetration Scenario**	**Minimum cost effective Scenario**	**Meet CSI Goals**	**Meet CA Long Term Energy Efficiency Strategic Plan Goals**	**Towards ZNE (Meet 4 and continue same growth rate)**
30-Year PV Penetration	3.20%	6.40%	CSI PV goal of 1.5% in 2016, extrapolated to 7.8% in 2043	25% by 2020, then flat	25% by 2020, 90% by 2043
30-year SWH Penetration	3.50%	6.40%	CSI Thermal goal of 3% by 2016, extrapolated to 20% by 2043	25% by 2020, then flat	25% by 2020, 90% by 2043
% homes with both SWH & PV	25%	25%	25%	25%	25%
Solar-Ready Costs	$10,830,655	$10,797,597	$10,784,989	$9,967,776	$9,959,040
Retrofit Costs	$3,915,991	$8,326,198	$11,748,303	$33,907,444	$110,344,988
Δ Installation Costs	$6,914,664	$2,471,398	$(963,314)	$(23,939,668)	$(100,385,948)
Δ Energy Costs	$(1,120,049)	$(2,477,872)	$(3,197,517)	$(14,681,940)	$(37,323,612)
Δ Total Costs (negative = cost effective)	$5,794,614	$(6,474)	$(4,160,831)	$(38,621,609)	$(137,709,559)

Figure 52: Table of solar ready homes cost effectiveness results, CBIA housing start data (~60,000 new homes in 2014)

Appendix 9 - Solar Ready Homes Cost Effectiveness Supporting Data, provides detailed calculation tables for this measure.

4.6 Solar Oriented Developments

Solar oriented development is not a new concept. Solar oriented development is at the nexus of several traditionally distinct, but rapidly converging and intermingled policy drivers. This includes building-level policy (e.g., Title 24 Parts 6 and 11), planning and entitlement (e.g., the Subdivision Map Act, and the California Environmental Quality Act), California's longstanding body of solar rights, solar access, solar easement and related laws promoting and incenting renewable energy, and new climate policy such as AB 32, SB375, etc. Each of these policy and regulatory drivers contains elements relating to, enabling, or in some cases requiring aspects of solar oriented development. Unfortunately, these various policies have not been as effective as they can be, due in part to lack of enforcement, coordination, and documentation.

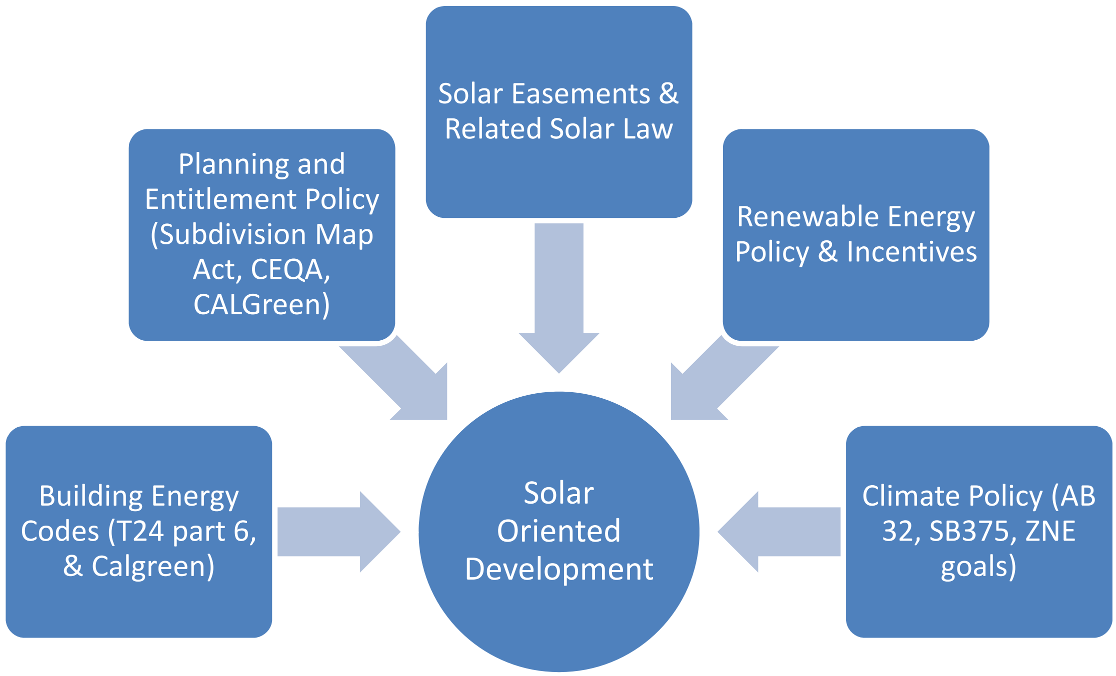

Figure 53: Converging policy drivers impacting solar oriented development

Analysis for this CASE shows that realizing a good performing solar oriented development is complex, and at times contradictory. There are several key findings:

First, solar energy generation systems are sensitive to orientation. Figure 23**Error! Reference source not found.** and Figure 27 show that both PV and SWH output can vary by as much as 50% with orientation. Even within the optimal orientation range of 150° to 270° proposed in the solar ready homes measure, there is an approximate 10% variability in PV output verses orientation. In other words, poorly oriented developments will result in significant reductions in average solar energy generation. This CASE has documented that in current practice, developments are generally non-optimized for rooftop solar generation.

The second primary finding of this CASE analysis is that there is surprisingly little variation on building energy with respect to building orientation for typical homes. The analysis summarized in section 4.6.2 indicates that for typical production home designs (20% total glazing to wall ratio) and typical glazing distributions (25% front, 50% back, 12.5% on each side), there is very little impact on building HVAC energy use verses rotation—in most cases (excluding the heating driven climate zones of 1, 3, and 7), optimal orientation has less than a ±2% impact on building energy, and that this will become diluted at the neighborhood scale when there necessarily has to be a mix of different house orientations. Increased window performance requirements as proposed in the residential windows CASE will further reduce the impacts that orientation has on building energy use. In other words, a solar oriented development will have relatively little impact on building energy use for typical production homes that are not specifically designed to take advantage of passive solar design principles.

Another challenge related to optimizing streets and lots to minimize building HVAC loads is that there is surprising lack of consistency between the "best" and "worst" orientations across climate zones, as shown in Figure 58. This presents a challenge for developing a consistent statewide requirement based on building energy reductions. This will be particularly problematic for some climate zones (i.e., climate zones 10 and 11), where the optimal building orientation is south (resulting 50% of the glazing facing north), but the worst orientation is north. An "optimally oriented" east/west street layout would result in 50% of the homes being optimally oriented and 50% having the worst possible orientation. This results in the same average building TDV energy use as a randomly oriented neighborhood layout. This assumes that the same home models are put on both sides of the street, and that specific designs optimized for the north vs. south sides of the street are not developed.

The conclusions are:

- A 'solar oriented development' requirement should prioritize obtaining good rooftop solar access/orientation over trying to optimize street or lot orientation to minimize building energy loads. The CASE authors believe the best way to do this is through a robust mandatory "solar ready homes" requirement in Title 24 Part 6.
- Simply laying out a "solar oriented" street grid is likely to have little impact on typical production home energy use without specific architectural design attention. Achieving a truly high performing solar oriented development that both maximizes rooftop solar generation and minimizes building energy use through passive design strategies will not happen by simply requiring a few general rules of thumb (i.e., orient streets east/west). High performance will only be achieved by establishing solar oriented development goals early in the planning phase, and these goals must be transmitted to the architects and designers who must specifically design homes to take advantage of passive and low energy design principles.
- Solar oriented design is complex, and effective design will require site specific analysis (verses simply relying on rules of thumb).

Therefore, the proposed code language has tried to push designers and developers in the planning stage to more rigorously and analytically consider current solar oriented development requirements in a way that is not typically done, and consider potential synergies across the regulatory spectrum (i.e., developing a solar oriented development may also be an effective CEQA mitigation measure, or comply with SB375 sustainable community strategies). Secondly, for the voluntary or "reach" measures, this CASE proposes moving towards performance based goals based on an analytical approach to determining the best combination of measures for a specific development.

4.6.1 Street Orientation Versus Solar Access

Conventional wisdom holds that east/west street orientation provides optimal southern exposure for buildings to take advantage of passive solar energy. While this certainly can be true in some cases, it is not necessarily a prerequisite to a solar oriented development. Figure 54 illustrates four different street layouts that have achieved some aspects of a high performing "solar oriented development." The top left neighborhood is Village Homes with curvilinear streets but north/south lot orientation. At top right is a section of the Avignon neighborhood that has established good PV orientation for most lots in a cul-de-sac. While the neighborhood as a whole has not done this good of a job, this illustrates how, with a little planning, even oddly oriented lots can be designed for a high penetration of well oriented solar. The bottom left neighborhood is Premier Oaks, which has north/south streets but has achieved a very high percentage of homes with optimally oriented PV. This illustrates the potential disconnect between optimizing street orientation to minimize building HVAC energy use verses for optimal solar orientation. The bottom right image is from Meadowoods, which has taken a "classic" approach to solar oriented neighborhood design with east/west street layouts to provide every home with south facing windows, clerestory windows for daylighting, and other passive features.

Figure 54: Examples of "Solar Oriented Development" with different street orientation

4.6.2 Building Energy Use Impacts Due to Orientation

Building energy simulations were performed to analyze the impact of building orientation on energy use. Standard residential prototype D energy models were used, with the exception that glazing distribution and glazing type was modified (Note: a constant 20% window to wall ratio was maintained). Two different glazing distributions were examined. First, a "typical" production home glazing distribution of 25% of the window area on the front, 50% on the back, 12.5% on the right, and 12.5% on the left was analyzed. This results in a building which is more sensitive to the heat gains with respect to orientation. Second, we examined the impacts of limiting the West facing glazing to 2% (with an equal distribution on the remaining orientations).

		Equal	**Typical**	**2% West Limit**
Glazing distribution by window area	Front	25%	25%	10%
	Back	25%	50%	30%
	Left	25%	12.5%	30%
	Right	25%	12.5%	30%
	Total	**100%**	**100%**	**100%**
Glazing distribution by wall area	Front	5%	5%	2%
	Back	5%	10%	6%
	Left	5%	2.5%	6%
	Right	5%	2.5%	6%
	Total	20%	20%	20%

Figure 55: Building energy model window distributions examined

Typical Production Home Glazing Distribution (25% front, 50% back, 12.5% sides)

Figure 56 shows the average home energy use (in kTDV/ft^2) for a home with 25% of the glazing on the front, 50% on the back, and 12.5% on each side (with a total glazing area equal to 20% of the wall area). 2008 "Package D" glazing requirements are modeled. The cross on each data point represents the average home energy use, and the vertical "error bars" for each point represents the maximum and minimum home energy use as the model is rotated in different orientations. Note: the vertical range for some climate points is nearly indistinguishable, indicating very minimal variation with orientation..

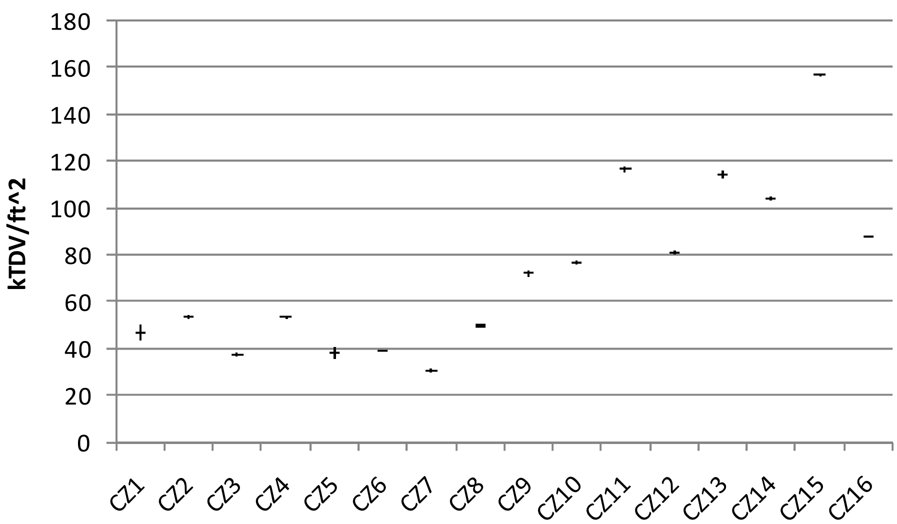

Figure 56: Variance in building energy use with azimuth for a "typical" production home glazing distribution.

Figure 57 shows the same data, but showing the TDV variation as a percent change with respect to the average.

Zones 1, 3, 5 and 7 all have minimal cooling loads, and show the largest percent variability with respect to solar orientation (and therefore have the most to gain from optimal solar orientation). Also, zones 1 and 3 have no glazing requirement (modeled as 0.65 SHGC in 2008 compliance runs here). The rest of the runs show very minimal opportunities to improve building energy use through optimal neighborhood orientation.

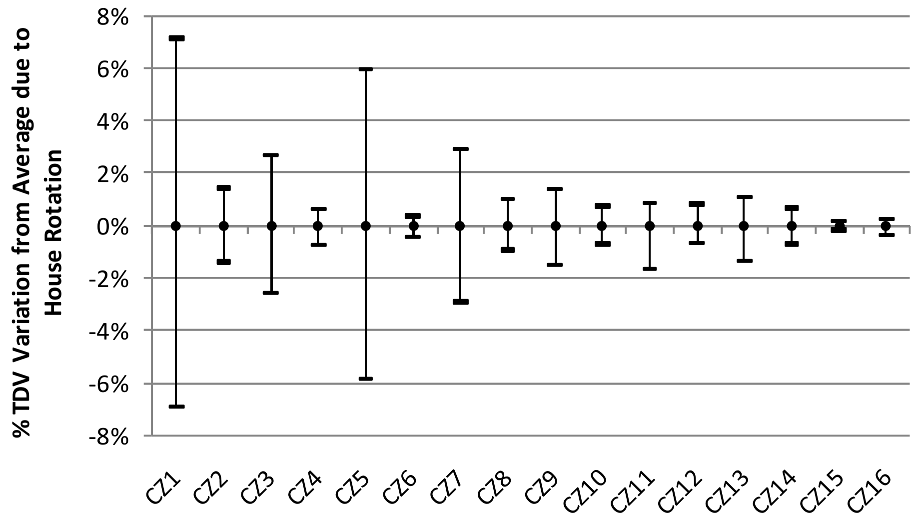

Figure 57: Percent variance in building energy use with azimuth for a "typical" production home glazing distribution.

Figure 58 provides the same data in tabular format, and specifies which orientation is the best and worst performer. There is no consistent best performing orientation. Furthermore, for Climate Zones 10 and 11, north is the best orientation but south is the worst orientation, which will make it very difficult to "optimize" street layout, as an east/west street is at the same the best and worst orientation. One issue that came up trying to interpret the data is that the ASHRAE load calculations, which determine the cooling equipment size, are calculated based on house orientation (broken into eight orientations). Thus, anytime the house is rotated through a 22.5 degree boundary, the cooling equipment loads change in a non-continuous and not insignificant manner. Given the generally very small building energy impacts based on orientation, it is very possible that the optimal and worst orientations are being influenced by equipment sizing verses actual solar heat gains through the envelope.

CZ	Max TDV/ft^2	Min TDV/ft^2	Avg TDV/ft^2	Worst House Orientation	Best House Orientation
CZ1	49.8	43.3	46.5	West	North
CZ2	54.5	53.0	53.7	West	North
CZ3	38.1	36.1	37.1	West	South
CZ4	53.6	52.9	53.3	East	South
CZ5	40.3	35.8	38.1	West	North
CZ6	39.3	39.0	39.2	East	South
CZ7	31.2	29.4	30.3	North	West
CZ8	50.2	49.3	49.7	North	West
CZ9	73.1	71.0	72.1	East	South
CZ10	77.1	76.0	76.6	North	South
CZ11	117.7	114.8	116.7	North	South
CZ12	81.5	80.3	80.8	North	West
CZ13	115.7	112.9	114.4	East	South
CZ14	104.5	103.0	103.8	East	South
CZ15	156.9	156.4	156.7	South	West
CZ16	88.1	87.5	87.8	East	South

Figure 58: Building energy use with azimuth for a "typical" production home glazing distribution.

The following figures provide detailed building energy use details verses rotation for four key climate zones. Climate zone 1 shows clear benefit for orienting the home with large southern window exposures for winter heat gains, as shown in Figure 59.

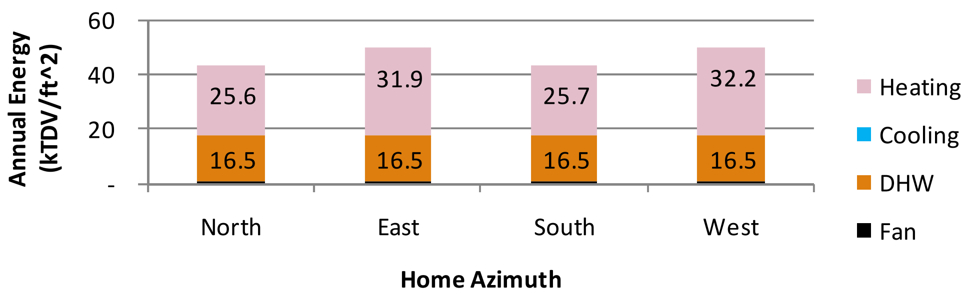

Figure 59: Climate zone 1 building energy use verses orientation

Climate zone 3 shows similar results for heating (large south facing windows are beneficial for meeting winter heating loads), but also shows that this adversely impacts cooling energy use. Heating savings outweigh cooling penalties, though. It should also be noted that zones 1 and 3 have no title 24 glazing requirements (modeled here as 0.65 SHGC). This is advantageous for solar heating, but has significant cooling penalties; cooling energy varies by nearly a factor of two.

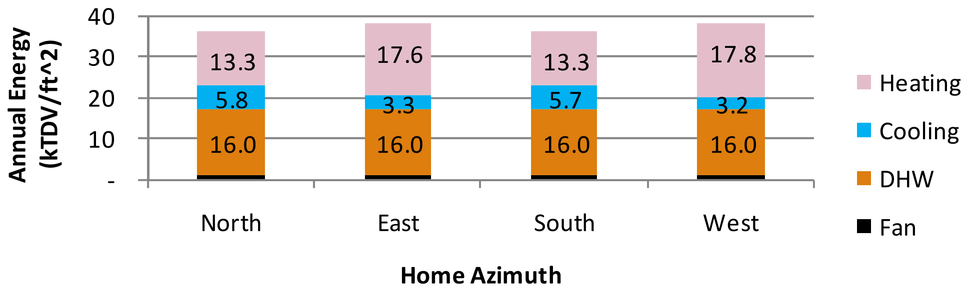

Figure 60: Climate zone 3 building energy use verses orientation

The data for climate zones 9 and 11 show some of the challenges of finding an optimal orientation. For climate zone 9, a north/south orientation is the worst for cooling due to summer heat gains on the south windows, but best from a heating perspective. While cooling is the largest component of the home energy use, it does not vary as much with orientation as does the heating load. The heating load shows a greater total variation versus orientation, and the heating benefits cancel out the cooling penalty. The best orientation is south but and the worst orientation is east.

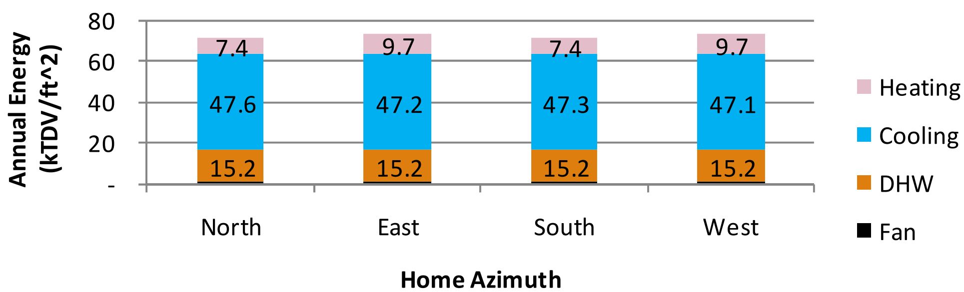

Figure 61: Climate zone 9 building energy use verses orientation

In climate zone 11, the balance of heating to cooling loads result in a situation where the best orientation is with the front of the house facing south, and the worst orientation is with the front facing north. As discussed in the introduction, this results in a situation where the benefits of solar orientation cancel at the neighborhood level, and an "optimally oriented" east/west street layout which would provide for south facing homes would also result in 50% of the homes facing the worst orientation. This results in the same average building TDV energy use as a randomly oriented neighborhood layout.

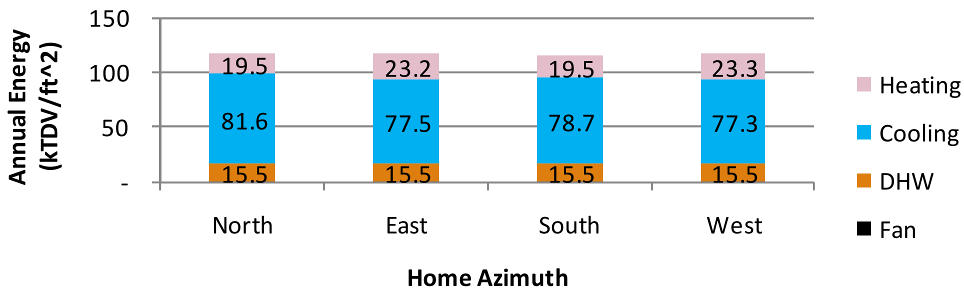

Figure 62: Climate zone 11 building energy use verses orientation

Impacts of Optimized Glazing

The residential windows CASE topic is proposing improved glazing requirements. The impacts of the proposed glazing change verses rotation was studied for the "typical" production home window distribution described above. Climate zones 1, 3 and 5 are modeled with high solar heat gain, low-e glass (U = 0.32, S = 0.60). The rest of the climate zones are modeled with extra low solar heat gain, low-e glass (U = 0.30, S = 0.25). Results are presented in the following two figures. As expected, energy variability due to house orientation is reduced due to improved window performance. Nearly all homes, except heating dominated climate zones 1, 3 and 5, show less than 2% variability in annual energy use with respect to orientation.

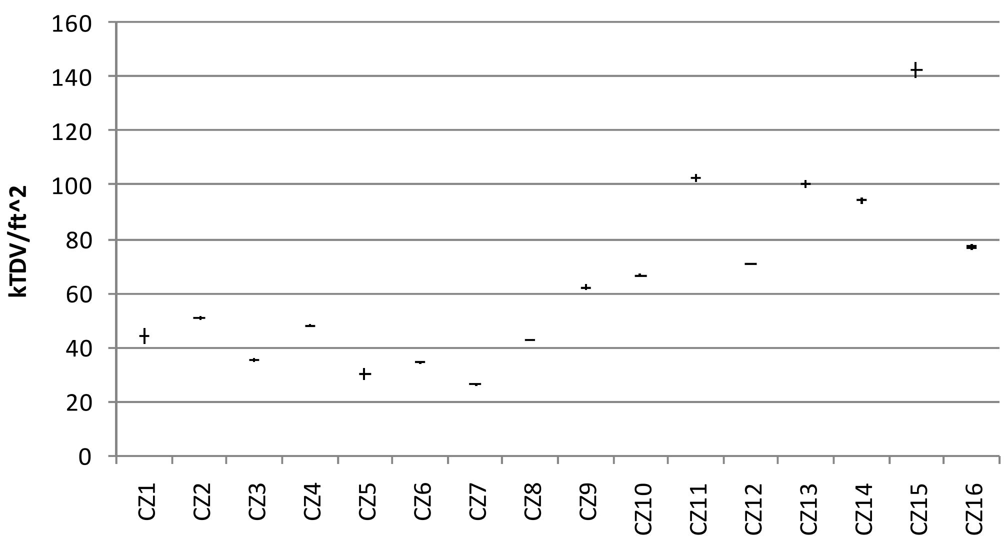

Figure 63: Optimized glazing performance verses rotation for a typical glazing distribution

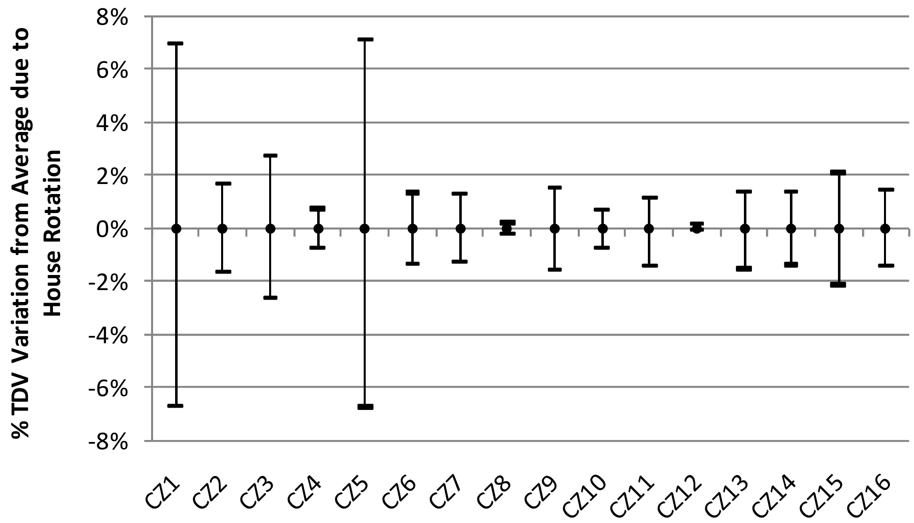

Figure 64: Optimized glazing percent performance variation verses rotation for a typical glazing distribution

2% West Glazing Distribution (2% on one orientation, 6% on remaining)

In coordination with other residential proposed measures examining window requirements, we examined the performance of a home limiting glazing to 10% of west facing exposure and the rest equally distributed (30%) on the other exposures. This corresponds to the limit of "2% west facing glazing" distribution being examined for other code change measures. We rotated the house plan around the cardinal axes to examine performance impacts. Results are presented in the following two figures with 2008 package D glazing requirements. As expected, there is very little variation with rotation.

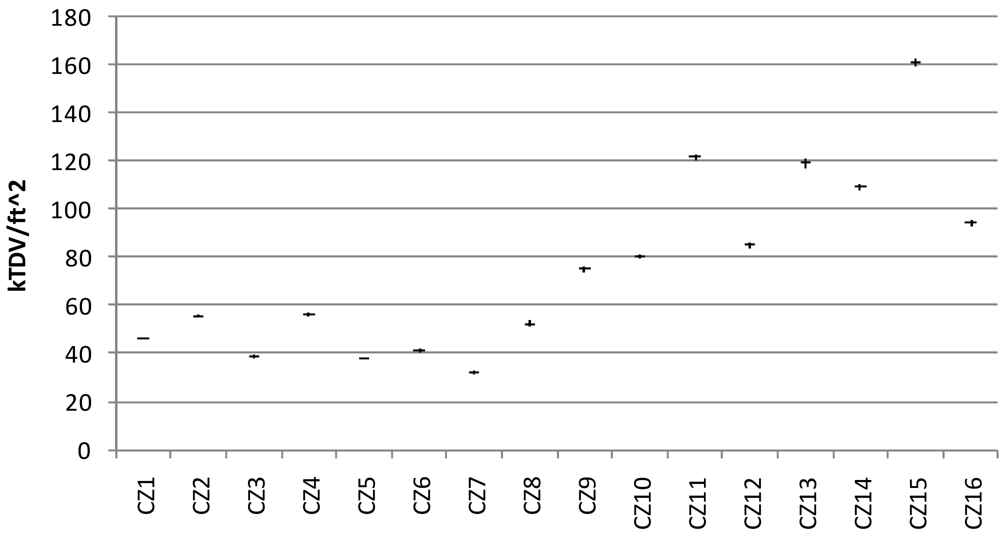

Figure 65: Performance verses rotation for a 2% west glazing distribution

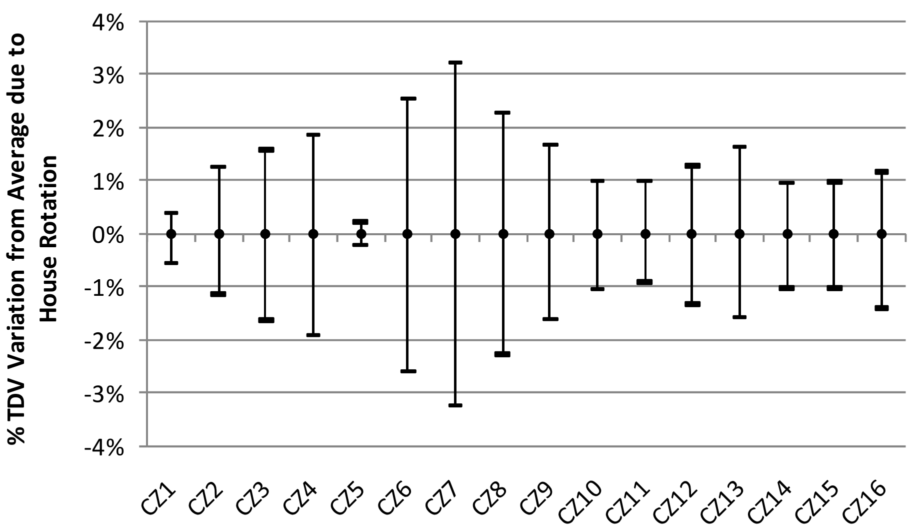

Figure 66: Percent performance variation verses rotation for a 2% west glazing distribution

5. Recommended Language for the Standards Document, ACM Manuals, and the Reference Appendices

Language recommendations are provide below. Additions are indicated by blue underlined text, and deletions are marked as ~~red strikethrough.~~

5.1 Solar Ready Homes

Two code change proposals related to solar ready homes are proposed: a definition to be added to section 101, and a new mandatory requirement for Section 150.

Section 101– Definitions and Rules of Construction

SOLAR ZONE is a section of the roof that has been specifically designated and reserved for the future installation of a solar photovoltaic (PV) system, solar water heating system, and/or other solar generating system. The solar zone must meet specific minimum area and orientation requirements, must be kept free from roof penetrations, have minimal shading, and meet other requirements as specified in section 150(q).

SUBCHAPTER 7 (LOW-RISE RESIDENTIAL BUILDINGS – MANDATORY FEATURES AND DEVICES),

SECTION 150 – MANDATORY FEATURES AND DEVICES

150(q) Solar Readiness. Single family residences shall provide for the future installation of rooftop solar photovoltaic system (PV), solar water heating system (SWH), and/or other solar energy system. The building plans shall show an allocated solar zone and the pathway for interconnecting the PV or SWH system with the building electrical or plumbing system.[115]

Exception 1 to Section 150(q). A single family residence where it can be documented that there is no viable solar zone due to shading on the south facing, east facing, and west facing roof exposures which reduces the annual incident solar radiation by 30% or greater.

1. Allocated Solar Zone

[115] This proposal is meant for newly constructed single family residences. Additional language will be developed for Section 152 that excludes additions and alterations except in the case of a single family residence with an existing solar zone.

A. **Minimum Area and Orientation**. The rooftop Solar Zone shall meet the minimum area requirements shown in Table 150-A. The Solar Zone shall be oriented between 150° to 270°. This area can be divided into two noncontiguous sections, the smallest section having an area of no less than 80 square feet. Both sections of the solar zone shall meet the orientation requirements.

TABLE 150-A SOLAR ZONE MINIMUM AREA REQUIREMENTS

Number of Stories	Total Conditioned and Unconditioned Building Area	Solar Zone Area Requirement (ft^2)
1	All	250
2	All	250
3	≤ 2,000 ft^2	150
	> 2,000 ft^2	250

- **Exception 1 to Section 150(q)1**. For single family residences which cannot meet the solar zone orientation requirement due to lot orientation or roof configuration, the solar zone orientation range can be extended to between 90° to 270°. The solar zone area requirement shall be increased by 20%.
- **Exception 2 to Section 150(q)1**. The area of any permanent solar photovoltaic system, solar water heating system, and/or other solar energy system installed on the building site (including non-roof installations) at the time of construction shall be counted as part of the solar zone area requirement.

B. **Roof Obstructions**. The solar zone shall be kept clear of attic vents, plumbing vents, chimneys, equipment, and other obstructions.

C. **Shading.** Any vent, chimney, architectural feature, mechanical equipment or other obstruction shall be located at a minimum distance from the solar zone that is two times the height difference of the obstruction and lowest point of the solar zone.

- **Exception 1 to Section 150(q)(1)(C)**: Any obstruction within 45 degrees of true north of the solar zone, including 45°00'00" east of north (NE), but excluding 45°00'00" west of north (NW) shall be exempt from the minimum shading requirement.

D. **Location of Solar Zone**. The location of the Solar Zone shall be in compliance with Section 2 of the California Department of Forestry and Fire Protection Office of the State Fire Marshal Solar Photovoltaic Installation Guideline (Final Draft, dated April 22, 2008)[116].

[116] The International Code Council (ICC) has approved a revised version of these CAL FIRE guidelines for inclusion in the 2012 International Fire Code (2012 IFC), to be published in May 2011. It is anticipated that this will become the basis for 2013 California Fire Code (Title 24, Part 9) updates, and it is expected that this reference will be updated to the appropriate sections of the 2013 California Fire Code.

E. **Structural Integrity**. The as-designed roof dead load and live load for the solar zone shall be clearly marked on the building plans.

2. **Electrical and plumbing Interconnection Pathways**

A. The building plans shall indicate a pathway for routing of conduit from the solar zone to the electrical panel. The documented pathway may run on the interior or exterior of the building.

B. The building plans shall indicate a pathway for routing plumbing from the dedicated solar zone to the water heater location. The documented pathway may run on the interior or exterior of the building.

3. **Documentation.** A copy of the building plans or comparable document showing the information required in 150(q)(1) and 150(q)(2) shall be left for the homeowner's reference.

4. **Electric Panel Capacity**

A. Electric panel capacity shall have at minimum a busbar rating of 200 Amps.

B. The electric panel shall have reserved space for the future installation of a double pole circuit breaker for a solar photovoltaic installation.

- **1. Location.**The reserved space shall be positioned at the opposite (load) end from the input feeder location or main circuit location.
- **2. Marking.** The reserved space shall be permanently marked as "For Future PV".

5.2 Solar Oriented Development

Three additions to the reach code (CALGreen) are proposed. The first change is to include solar oriented development language to the mandatory planning and design/site development measures. This involves a small addition in section 4.106.1, and the addition of a new section 4.106.4. Related two compliance forms are proposed for Chapter 8 – Compliance Forms and Worksheets, Residential Mandatory Measures. The final code change proposal is in Appendix A4, Residential Voluntary Measures, Section A4.106 – Site Development. The current voluntary "Building Orientation" requirement is proposed to be changed into a two tier performance based voluntary requirement.

CALIFORNIA GREEN BUILDING STANDARDS CODE (CALGREEN), CALIFORNIA CODE OF REGULATIONS TITLE 24, PART 11

CHAPTER 4, RESIDENTIAL MANDATORY MEASURES

Division 4.1 – Planning and Design

Section 4.106 – Site Development

4.106.1 General. Preservation and use of available natural resources shall be accomplished through evaluation and careful planning to minimize negative effects on the site and adjacent areas. Preservation of slopes, management of storm water drainage, and erosion controls, and solar oriented development shall comply with this section.

4.106.4 Solar Oriented Development.

Planning and design decisions, including street layout, lot orientation, master landscaping, design guidelines, HOA agreements, etc. have significant and long-term impacts on building energy use and onsite renewable energy generation. Projects shall evaluate planning and design opportunities to minimize building energy use and maximize onsite renewable energy generation potential.

Projects involving the design of a subdivision for which a tentative map is completed after January 1, 2014, pursuant to Section 66426 of the California Government Code (Subdivision Map Act), shall meet the following requirements:

A. **MEET SUBDIVISION MAP ACT REQUIREMENTS.** Comply with §6647.3 of the Subdivision Map Act[117], and provide, to the extent feasible, for future passive or natural heating or cooling opportunities in the subdivision.

B. **ANALYTICAL ASSESSMENT REQUIREMENTS.** Projects shall perform an analytical assessment of solar oriented development measures relevant to the project, using a Commission approved tool or procedure[118], to inform determination of economic and environmental feasibility.

- Results shall be documented per §4.1.106(G).

C. **CEQA EIR MITIGATION MEASURES AND COMMITMENTS**. Any project that is required to conduct an Environmental Impact Report (EIR) to comply with California Environmental Quality Act (CEQA) requirements shall evaluate siting, orientation and design as potential energy mitigation measures, as allowed per CEQA Guidelines, Appendix F: Energy Conservation (effective March 2010, pursuant to SB 97).

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[117] Subdivision Map Act §6647.3 Requirements:

> *The design of a subdivision for which a tentative map is required pursuant to Section 66426 of the California Government Code (Subdivision Map Act)* ***shall provide, to the extent feasible, for future passive or natural heating or cooling opportunities in the subdivision. Examples of passive or natural heating opportunities in subdivision design, include design of lot size and configuration to permit orientation of a structure in an east-west alignment for southern exposure. Examples of passive or natural cooling opportunities in subdivision design include design of lot size and configuration to permit orientation of a structure to take advantage of shade or prevailing breezes. In providing for future passive or natural heating or cooling opportunities in the design of a subdivision, consideration shall be given to local climate, to contour, to configuration of the parcel to be divided, and to other design and improvement requirements****, and such provision shall not result in reducing allowable densities or the percentage of a lot which may be occupied by a building or structure under applicable planning and zoning in force at the time the tentative map is filed. The requirements of this section do not apply to condominium projects which consist of the subdivision of airspace in an existing building when no new structures are added. For the purposes of this section, "feasible" means capable of being accomplished in a successful manner within a reasonable period of time, taking into account economic, environmental, social and technological factors.*

[118] Note: Intent is to leave the specific tool/methodology loosely defined to enable the use of a diverse range of analytical tools currently in use or under development and allow alignment with similar analyses conducted for CEQA, SB375, etc. If desired, a simple spreadsheet based tool can be developed based on analysis performed by this case.

- Any siting, orientation and design energy mitigation measures identified shall be documented per §4.1.106(G).

D. "SUSTAINABLE COMMUNITY STRATEGIES". Projects shall evaluate and incorporate to the extent feasible the local Metropolitan Planning Organization (MPO)'s "sustainable communities strategy (SCS)", and if applicable, the "alternative planning strategy" practices and guidelines that impact solar oriented development issues.

- Any relevant Sustainable Community Strategies relating to development layout, design and siting shall be documented per §4.1.106(G).

E. SOLAR READY HOMES. Site development shall evaluate the Solar Ready Home requirements [proposed] in Title 24, Part 6 §150q. Site development, road orientation, and lot orientation shall enable realization of solar ready home orientation requirements.

F. **Solar Easements.** Pursuant to California's Government Code section 65850.5, projects shall evaluate and incorporate to the extent feasible development-wide solar easements applicable to all plots within the subdivision in their plans. to protect the designated Solar Ready Solar Zone.

- Solar easements shall be documented per §4.1.106(G).

G. DOCUMENTATION. Document Worksheets WS-4 and WS-5 (Chapter 8 – Compliance Forms and Worksheets) shall be completed documenting the solar oriented development strategies incorporated into the design, or documenting the economic, environmental, social or technical factors making this unfeasible.

CALGREEN, CHAPTER 8 – COMPLIANCE FORMS AND WORKSHEETS, RESIDENTIAL MANDATORY MEASURES

WORKSHEET (WS-4) [draft]

SOLAR ORIENTED DEVELOPMENT MEASURES AND BEST PRACTICES

Solar Oriented Development Measure / Best Practice	**Used (y/n)**	**Description or Reason Infeasible**
Local climate, topography, parcel configuration, building HVAC needs, and other design requirements evaluated with respect to natural heating and cooling strategies, and solar energy generation.		
Streets predominantly oriented east-west to provide southern building exposure and minimize east-west building exposure		
Streets predominantly oriented north-south to provide optimal roof space for rooftop solar generation		
Street layout impacts on building energy use and solar generation have been analyzed and optimized.		
Lot size and configuration permit east-west building orientation for southern exposure		

Lot size and configuration permit building orientation to take advantage of shade or prevailing breezes		
Buildings oriented to optimize the use of solar energy with the long side of the house oriented within 30° of south.		
Master landscaping plan/design guidelines provide summer shade, minimize desirable winter shading, and minimize shading of roofs to limit solar energy utilization.		
Solar Easements Incorporated into all or some lots per California's Government Code section 65850.5.		
Other (Describe):		
Other (Describe):		
Other (Describe):		
Other (Describe):		
Other (Describe):		
Other (Describe):		
Other (Describe):		
Other (Describe):		

CALGREEN, CHAPTER 8 – COMPLIANCE FORMS AND WORKSHEETS, RESIDENTIAL MANDATORY MEASURES

WORKSHEET (WS-5) [draft]

SOLAR ORIENTED DEVELOPMENT ANALYSIS DOCUMENTATION

<table>
<tr><th colspan="2">Development Description</th></tr>
<tr><td colspan="2">Neighborhood Name</td></tr>
<tr><td>County</td><td>Total SF Units</td></tr>
<tr><td>City</td><td>Total MF Low-Rise Units</td></tr>
<tr><td>Zip</td><td>Total MF High-Rise Units</td></tr>
<tr><td>Address or Parcel ID</td><td>Total Area (Acres)</td></tr>
<tr><td colspan="2">Description of development</td></tr>
<tr><th colspan="2">Solar Oriented Development Analysis Tool Description</th></tr>
<tr><td colspan="2">Name of Analysis Tool(s)</td></tr>
<tr><td colspan="2">Narrative Description of Tool Capabilities</td></tr>
<tr><th colspan="2">Analysis Description</th></tr>
<tr><td>Check Features Analyzed</td><td>❑ Prototypical building energy use for each lot orientation
❑ Building energy use for specific model homes proposed for each lot orientation
❑ PV energy generation based on lot orientations and proposed roof configurations
❑ SWH energy generation based on lot orientations and proposed roof configurations
❑ Landscape shading and urban heat island mitigation impacts
❑ Prevailing winds
❑Other (describe)</td></tr>
<tr><td colspan="2">Narrative Description of Analysis Results</td></tr>
<tr><td colspan="2">Neighborhood Lot Summary Details</td></tr>
</table>

Lot Orientation Range	# of Lots	Average Lot Size (ft2)	Average lot length parallel to street	Lot Orientation, if not perpendicular to street
0 - 30				
31 - 60				
61 - 90				
91 - 120				
121 - 150				
151 - 180				
181 - 210				
211 - 240				
241 - 270				
271 - 300				
301 - 330				
331 - 360				
Cul-de-Sacs				

Summary of Solar Oriented measures incorporated into the development	

APPENDIX A4, RESIDENTIAL VOLUNTARY MEASURES

Section A4.106 – Site Development

A4.106.1 ~~**Building orientation** Orient buildings to optimize the use of solar energy with the long side of the house oriented within 30° of south.~~ **Solar Oriented Development**.

A4.106.1.1 Tier 1. Perform an analytical assessment of the site design and layout to demonstrate that the proposed street and lot layout using prototypical building energy models with proposed solar generating technologies results in [7%] less energy use compared to an identical number of the same homes (no change in energy efficiency measures or design) with the same solar generating technologies laid out in a grid with equal percentage of homes facing due South, West, North and East, using the Commission approved tool or procedure.

A4.106.1.2 Tier 2. Perform an analytical assessment of the site design and layout to demonstrate that the proposed street and lot layout using prototypical building energy models with proposed solar generating technologies results in [15%] less energy use compared to an identical number of the same homes (no change in energy efficiency measures or home design) with the same solar generating technologies laid out in a grid with equal percentage of homes facing due South, West, North and East, using the Commission approved tool or procedure.

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7. Appendix 1 – Solar Ready Best Practices Online Survey

CASE Res Solar Ready Best Practice

Exit this survey

1. General

The California Investor Owned Utilities (IOUs) are actively supporting the California Energy Commission (CEC) in developing the state's building energy efficiency standard (Title 24). Their joint intent is to achieve significant energy savings through the development of reasonable, responsible, and cost-effective code change proposals for the 2011 code update.

Through Codes and Standards Enhancement (CASE) Studies, the C&S Program provides standards and code-setting bodies with the technical and cost-effectiveness information required to make informed judgments on proposed regulations for promising energy efficiency design practices and technologies. As part of the IOU effort, we invite you to fill out this survey and help shape the next cycle of building codes.

The purpose of this brief 14-question survey is to obtain info on various solar ready measures that are currently being implemented, and obtain relevant project information. Audience of the survey are stakeholders with relevant experience, including solar installers and retailers, manufacturers, vendors, planners, architects, developers, builders, and others.

1. What best describes you or your organization's focus? (Select all that apply)

Equipment manufacturer or vendor

Planner

Developer

Home builder

Design team (engineer, architect, consultant, etc.)

Contractor, installer, or tradesperson

Government

Academics & research

Other (please specify)

Section 2: Existing "solar ready" measures

2. Measure: Require home buyers or tenants to be offered the option of solar electricity, or photovoltaic (PV) panels.

No

Yes. Please provide building/project name, contact and other details.

3. Measure: Require home buyers or tenants to be offered the option of solar water heating.

No

Yes. Please provide building/project name, contact and other details.

4. Measure: Require roof space be reserved for future solar systems.

No

Yes. Please provide building/project name, contact and other details.

5. Measure: Require buildings be pre-wired for future solar PV systems.

No

Yes. Please provide building/project name, contact and other details.

6. Measure: Require buildings be pre-plumbed for solar water heating system.

No

Yes. Please provide building/project name, contact and other details.

7. Measure: Landscape guidelines to minimize shading of solar systems.

No

Yes. Please provide building/project name, contact and other details.

8. Measure: Ensure buildings have solar access.

No

Yes. Please provide building/project name, contact and other details.

9. Measure: Require that the building have a chase between the attic and water heat for future solar hot water.

No

Yes. Please provide building/project name, contact and other details.

10. Measure: Require that the building have a chase between the attic and an electrical panel for future photovaltaic.

No

Yes. Please provide building/project name, contact and other details.

11. Please describe other solar ready measures not mentioned above and provide building/project and contact to the extend possible.

Section 3: "Solar ready" designs

12. If you are willing to share any design guidelines, ordinances, case-studies, or other relevant "solar ready" information, please provide some descriptions and links here (or kindly email them to jroberts@ctgenergetics.com).

13. If you have any additional data, feedback, or comments related to solar-ready homes, please describe here (or kindly email them to jroberts@ctgenergetics.com).

14. Can we contact you to follow-up with any of the information provided? If so, please provide your name and contact info below.

Name:	
Company:	
Email Address:	
Phone Number:	

8. Appendix 2 – Solar Oriented Development Online Survey

CASE Res Solar Oriented Development Best Practice

Exit this survey

1. General

The California Investor Owned Utilities (IOUs) are actively supporting the California Energy Commission (CEC) in developing the state's building energy efficiency standard (Title 24). Their joint intent is to achieve significant energy savings through the development of reasonable, responsible, and cost-effective code change proposals for the 2011 code update.

Through Codes and Standards Enhancement (CASE) Studies, the C&S Program provides standards and code-setting bodies with the technical and cost-effectiveness information required to make informed judgments on proposed regulations for promising energy efficiency design practices and technologies. As part of the IOU effort, we invite you to fill out this survey and help shape the next cycle of building codes.

The purpose of this brief 11-question survey is to solicit examples, design guidelines, city ordinances, and other data relevant to solar oriented development to help inform the market understanding, identify examples, and identify stakeholders. Audience of the survey are land use planners, consultants, developers, home builders, cities and others who may potentially influence solar oriented development.

1. What best describes you or your organization's focus? (Select all that apply)

Equipment manufacturer or vendor

Planner

Developer

Home builder

Design team (engineer, architect, consultant, etc.)

Contractor, installer, or tradesperson

Government, including planning or building department

Academics & research

Other (please specify)

2. Existing "solar oriented" developments

Are you aware of any projects or communities that have been designed and/or oriented, on various levels stated below, to account for solar energy (e.g., minimize unwanted solar heat gains, maximize solar energy utilization)?

2. Level: Street layout design and/or orientation.

No

Yes. Please provide any details (e.g., community name and location, design team name(s), or other relevant contact information.)

3. Level: Lot size and/or orientation.

No

Yes. Please provide any details (e.g., community name and location, design team name(s), or other relevant contact information.)

4. Level: Building design and/or orientation.

No

Yes. Please provide any details (e.g., community name and location, design team name(s), or other relevant contact information.)

3. "Solar oriented" design guidelines

SDGE A Sempra Energy utility · The Gas Company A Sempra Energy utility · SOUTHERN CALIFORNIA EDISON An EDISON INTERNATIONAL Company · PG&E Pacific Gas and Electric Company

5. Are you aware of any project or community-level design guidelines, specifications, covenants, etc. with requirements for solar energy?

No

Yes. Please provide any details (e.g., community name and location, design team name(s), or other relevant contact information.)

6. Are you aware of any project or community-level design guidelines, specifications, covenants, etc. that would NEGATIVELY affect solar utilization at the community level?

No

Yes. Please provide any details (e.g., community name and location, design team name(s), or other relevant contact information.)

7. Are you aware of any city or local ordinances with requirements for solar energy (e.g., solar orientation, solar access, etc.)?

No

Yes. Please provide any details (e.g., city names, ordinances, or other relevant contact information.)

8. If you have any additional data, feedback, or comments related to solar-oriented communities, please describe below.

4. Solar Orientation and Greenhouse Gas Emissions

SDGE A Sempra Energy utility · The Gas Company A Sempra Energy utility · SOUTHERN CALIFORNIA EDISON An EDISON INTERNATIONAL Company · PG&E Pacific Gas and Electric Company

9. Are you aware of any planning department requirements for solar access and/or solar orientation as part of an overall climate action plan or green building strategy to reduce greenhouse gas emissions?

No

Yes. Please provide any details (e.g., city/county names and other relevant contact information.)

10. Are you aware of any planning department requirements for solar access and/or solar orientation as specific, feasible mitigation measures for minimizing greenhouse gas emissions to a level of insignificance pursuant to CEQA guidelines?

No

Yes. Please provide any details (e.g., city/county names and other relevant contact information.)

11. Can we contact you to follow-up with any of the information provided? If so, please provide your name and contact info below.

Name:	
Company:	
Email Address:	
Phone Number:	

9. Appendix 3 – Summary of Relevant Codes and Regulations

9.1 Relevant Codes and Standards from Other States

9.1.1 Colorado: House Bill 1149, "Solar Ready Homes"

House Bill 1149, signed May 4, 2009, now requires homebuilders in Colorado to offer prospective homeowners the option of having their home pre-wired for solar and provide homeowners with a list of contractors[119].

9.1.2 Hawaii: Act 204, now HRS 196-6.5 (2008)

As of January 1, 2010, all new single family dwellings built in the State of Hawaii are required to have a solar water heater. Exemption requests may be submitted by a licensed architect or engineer, and are processed by the Department of Business, Economic Development & Tourism (DBEDT)[120].

9.1.3 New Mexico: House Bill 610

The department, the construction industries division of the regulation and licensing department and the construction industries commission shall jointly promulgate rules, standards or codes that establish requirements for new construction that will accommodate the installation of solar collectors to or on the new construction after that construction is otherwise complete, including roof orientation, roof strength, location of obstructions to sunlight, access to installation locations, built-in conduit, wiring and piping and brackets for attaching solar collectors[121]

9.1.4 The Guam Energy Code (2000)

The Guam Energy Code, which became effective in October of 2000, requires that piping stub outs be provided for water heaters installed in low-rise residential buildings to enable the future installation of solar collectors[122].

9.1.5 U.S. Virgin Islands: Act 7075

This legislation established the requirement that developers install in all new developments, and substantial building modifications, energy efficient solar water heaters that provide at least 70% of the buildings water heating needs[123].

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[119] http://www.colorado.gov/cs/Satellite/GovRitter/GOVR/1241443584034

[120] http://hawaii.gov/dbedt/info/energy/SWHVariance/requestinfo

[121] http://legis.state.nm.us/Sessions/07%20Regular/final/HB0610.pdf

[122] http://www.dsireusa.org/incentives/incentive.cfm?Incentive_Code=GU01R&re=1&ee=1

[123] http://www.dsireusa.org/incentives/incentive.cfm?Incentive_Code=VI07R&re=1&ee=1

9.2 Local and Municipal Codes for Solar Ready Homes

Local and municipal codes for solar-ready homes vary widely, from local restrictions on solar panel placement to strict building regulations requiring the installation of solar systems. The relative change in cost of solar-ready housing to homebuyers is insignificant, and with efficient standards regulating the specifications of solar-ready infrastructure, laws requiring solar-ready housing may dramatically improve the ease of solar system installation.

9.2.1 Santa Cruz County, CA: Solar Access Protection

Although the California Solar Rights Act of 1978 requires local governments to plan for future passive or natural heating or cooling opportunities in new residential construction, and the California Shade Control Act protects solar systems from shading by vegetation, current state and local laws do not protect installed solar energy systems from shading caused by structures. The County of Santa Cruz has developed a process for registering solar energy systems to provide additional protection to solar energy system owners.

The County's Building Regulations Code requires that any obstructions of solar access to a registered solar energy system be mitigated to the maximum extent feasible during the review of any permit to construct a building, wall, fence or other structure, or part of structure on a property that could have an impact on the system. The Code also contains a provision to protect registered systems from shading by vegetation on neighboring property.

http://www.dsireusa.org/incentives/incentive.cfm?Incentive_Code=CA34R&re=1&ee=1

9.2.2 Los Angeles, CA: Zoning Code

Chapter I of Los Angeles' Municipal Code, Height of Building or Structures, provides an exemption for solar energy devices, or similar structures. They may be erected above the height limit specified in the district in which the property is located if, for each foot such structure exceeds the height limit, an equal setback from the roof perimeter is provided.

Chapter IX, Building Regulations, Section 91.107.2.2. Stipulates that no additional permit or fee is needed for solar as part of other improvements of new construction.

http://www.dsireusa.org/incentives/incentive.cfm?Incentive_Code=CA04R&re=1&ee=1

9.2.3 Brentwood, CA: Residential Growth Management Program (RGMP)

The RGMP staff, Planning Commission, and City Council evaluate each allocation application against the Allocation Evaluation Criteria and require projects to meet a score of 156 of 195 points. Solar-ready homes, including pre-plumbing for a solar water heating system and roofing engineered to support the system weight, account for 2 possible points. 5 points are awarded for installed domestic solar hot water heating systems that deliver 50% of the hot water energy needs.

http://www.ci.brentwood.ca.us/citycouncil/pastagenda/packet_2001/ccap20010627/ccap20010627_01.htm

9.2.4 Santa Monica, CA: Municipal Code 9.04.10.02.220

Santa Monica law restricts the development of solar power systems by not allowing solar energy systems, excluding the collector panels, necessary support structure, and conduit, to be visible from the public right-of-way adjacent to the front property line. Additionally, solar collector panels are to be installed in the location that is the least visible from abutting streets directly facing the subject property, so long as installation in that location does not significantly decrease the energy performance or significantly increase the cost of the solar energy system.

http://www.solarsantamonica.com/documents/SolarOrdinancematerials8.14.09_000.pdf

9.2.5 Tucson, AZ: Solar Ready Requirements

In 2008, the Tucson Mayor and Council voted to require all new residences to be solar ready for electric and hot water, with a minimum area of 4 square feet of best roof space for PV equipment, a minimum 3800 volt-ampere electrical load entry, and an electric panel schedule with a 240 volt circuit breaker space for PV.

http://www.tucsonaz.gov/dsd/What_s_New/PV_Prep.pdf

9.2.6 Oro Valley, AZ: Ordinance 09-11

Oro Valley's Town Council amended the building codes to set a new standard in which all single- or two-family residences built after June 17, 2010, shall install sleeves, conduits, water stub-outs, roof to water heater space conduit, or other connections required for the future connection of solar PV generation and water heating systems.

http://www.orovalleyaz.gov/Assets/_assets/newsroom/pdf/Ordiance_09-11_residential_solar.pdf

9.2.7 Vancouver, BC: By-Law No. 9691, Section 12.2.2.9

A vertical service shaft shall extend from the service room, which contains the service water heater, to the attic space, consisting of at least two 50 mm PVC pipes, capped at both ends, and having at least a 20 degree angle.

http://vancouver.ca/blStorage/9691.PDF

9.3 Local and Municipal Codes for Solar Oriented Developments

Current local and municipal codes enforcing regulations for solar oriented developments and subdivision designs range from broad policy goals to specific numerical standards. With regards to the more specific solar orientation regulations, development allocation applications are generally subject to a review process in which the percentage of solar oriented houses or a point system denotes the requirement to which new home builders must adhere. In many cases, the regulation standard refers to streets oriented along a true east-west axis to allow for maximum south-facing windows. However, more flexible standards involving the use of strategic layouts for solar access and passive design have also been enacted in certain municipalities.

9.3.1 Marin County, CA: Solar Access Code

Marin County's Energy Conservation Code is designed to assure new subdivisions provide for future passive or natural heating or cooling opportunities in the subdivision to the extent feasible. Streets, lots, and building setbacks must be designed so that habitable buildings are oriented with their long axis running east to west (with a possible variation of thirty degrees to the southwest and thirty degrees to the southeast) for the purpose of solar access. The planning director or planning commission may require solar access easements or restrictive covenants to protect solar access.

http://www.dsireusa.org/incentives/incentive.cfm?Incentive_Code=CA35R&re=1&ee=1

9.3.2 San Diego County, CA: Solar Access Regulations

The County of San Diego requires that the site plan of new subdivisions demonstrates that the orientation and location of buildings, structures, open spaces and other features preserve solar access of adjacent properties.

http://www.dsireusa.org/incentives/incentive.cfm?Incentive_Code=CA31R&re=1&ee=1

9.3.3 Sacramento, CA: Zoning and Subdivision Regulations

Sacramento City Code, Title 16, Section 16.48.110 ensures that the Director of Parks and Community Services gives consideration to solar access, to the extent feasible, when selecting and planting residential street trees near residential buildings.

Sacramento City Code, Title 17, Section 17.220.010 contains a provision requiring the planning commission or zoning administrator to consider energy conservation issues, including adequate orientation for maximum solar access. Furthermore, Section 17.60.040, which contains the zoning code’s height regulations, contains an exception for a solar energy systems on top of buildings. The exception allows solar systems to be of a greater height than the limit established for the zone.

http://www.dsireusa.org/incentives/incentive.cfm?Incentive_Code=CA09R&re=1&ee=1

9.3.4 San Jose, CA: Solar Access Design Guidelines

The San Jose Environmental Services Department has developed voluntary guidelines to encourage solar orientation in new construction. These Solar Access Design Guidelines specify that the long axis of new dwellings should face within 30 degrees west and 45 degrees east of true south. Because houses in a subdivision usually face the street, planners in San Jose found that the easiest way to achieve solar orientation was to orient the streets within 30 degrees of the true east-west axis. Homes in such a subdivision would have good solar orientation by default.

Further suggested design guidelines include aesthetic concerns for residential communities. Solar devices should not block views or be placed where they are visible from the public right-of-way. If devices are attached to the building, they should lay flush with the roof line. If they are not attached to the building, collectors should be located in side or rear yards and screened by whatever landscaping is available to reduce their visibility. Exposed hardware, frames and piping should have a matte finish, and be consistent with the color scheme of the primary structure.

http://www.dsireusa.org/incentives/incentive.cfm?Incentive_Code=CA11R&re=1&ee=1

9.3.5 Santa Cruz, CA: Solar Access Ordinance

Before a development plan can be approved in the City of Santa Cruz, it must be found that the orientation and location of buildings, structures, open spaces and other features of the site plan preserve solar access of adjacent properties. In addition, buildings and structures should be designed and oriented to make use of natural elements such as solar radiation, wind and landscaping for heating, cooling and ventilation. Developers must also show that heating systems for hot tubs and swimming pools are solar when possible, and in all cases, energy efficient.

http://www.dsireusa.org/incentives/incentive.cfm?Incentive_Code=CA32R&re=1&ee=1

9.3.6 Sebastopol, CA: Solar Access

As a condition of approval of a property subdivision parcel map, the City of Sebastopol has the right to ask for dedication of solar easements for the purpose of assuring that each parcel or unit in the subdivision receives sunlight for any solar energy system. Sebastopol also has the right to place restrictions on vegetation or building that would interfere with solar access. These easements can be required as long as they do not reduce allowable densities or the percentage of a lot that can be occupied by a structure according to applicable zoning laws. The easements do not apply to condominium projects subdividing airspace in an existing building.

http://www.dsireusa.org/incentives/incentive.cfm?Incentive_Code=CA33R&re=1&ee=1

9.3.7 Berkeley, CA: Downtown Plan Goals, Objectives, Policies

Per the energy objective to reduce the reliance on non-renewable resources in the downtown, Policy DT-27 holds to develop building design guidelines that will maximize active and passive solar gain and protect solar access.

http://www.ci.berkeley.ca.us/ContentDisplay.aspx?id=19038

9.3.8 Brentwood, CA: Residential Growth Management Program (RGMP)

The RGMP staff, Planning Commission, and City Council evaluate each allocation application against the Allocation Evaluation Criteria and require projects to meet a score of 156 of 195 points. Solar orientation development requirements account for 7 points, and vary with unit density: i) for less than 10 units/acre, 80% of units must be solar oriented, ii) for 10-25 units/acre, 65% of units must be solar oriented, and iii) for more than 25 units/acre, 50% of units must be solar oriented. “Solar oriented” refers to streets oriented within 30 degrees of a true east-west axis, with houses minimizing east- and west-facing windows, maximizing south-facing windows, and having sufficient roof area with southerly exposure for active solar power generation.

http://www.ci.brentwood.ca.us/citycouncil/pastagenda/packet_2001/ccap20010627/ccap20010627_01.htm

9.3.9 Multnomah County, OR: Solar Access Provisions for New Development

New developments for lots in 12 zones in Multnomah County are subject to this ordinance. The basic requirements entail the orientation of 80% of lots in the development to have a north-south dimension of 90 feet or more and have a front lot line oriented within 30 degrees of a true east-west axis. Options also exist for protective solar building line and shading performance housing to fulfill the requirement.

http://www.sunschools.org/Community_Services/LUT-Planning/urban/zonordin/solar/11.15.6815.html

9.3.10 Eagle County, CO: ECO-Build Regulations

ECO-Build applies to all new construction, as well as additions/reconstruction over 50 percent of the existing floor area, and exterior energy uses such as snowmelt, spas, and pools. The checklist for residential development requires points based on square footage, with 5 points for 7% FAR and 10 points for 12% FAR south-facing windows.

http://www.eaglecounty.us/EnvHealth/Sustainability/Eco-Build/

9.3.11 Fort Collins, CO: Land Use Code, Solar Access, Orientation, and Shading

The Fort Collins Land Use Code specifies that at least 65% of the lots less than 15,000 square feet in area in single- and two-family residential developments must conform to the definition of a "solar-oriented lot" in order to preserve the potential for solar energy usage. Development plans must, to the maximum extent possible, protect access to sunshine and prevent shading from adjacent properties.

http://www.colocode.com/ftcollins/landuse/article3.htm#div3d2

9.3.12 Pullman, WA: Planned Residential Development (PRD) Standards

Pullman's residential density requirements can be met using PRD bonus density points based on energy conservation goals. 2.5 density bonus points are awarded if legally guaranteed solar access is provided to the south-facing surfaces of at least 50% of proposed structures, and an additional 2.5 density bonus points are awarded if natural topography, grading, and planting are effectively used to decrease the energy consumption of structures in the PRD and to enhance the seasonal use of open spaces.

http://www.pullman-wa.gov/Content/WYSIWYG/CityCode/ZoningCode/17.107_Planned_Res._Dev.pdf

9.3.13 Portland, OR: Solar Access Criteria

The approval criteria of the solar access chapter apply to land division proposals for single-dwelling detached development lots. On streets within 30 degrees of a true east-west axis, the narrowest lots should be interior lots on the south side of the street and corner lots on the north side of the street. On streets within 30 degrees of a true north-south axis, the widest lots should be interior lots on the east or west side of the street.

http://www.portlandonline.com/shared/cfm/image.cfm?id=72542

9.3.14 Salt Lake City, UT: The Sustainable Community Development Code Revision Project

Salt Lake City is currently in the process of drafting ordinance revisions determined to making the city one of the most sustainable communities in the country. Among many other land use regulatory provisions, the project considers requirements for building orientation for solar exposure and readiness of buildings for alternative energy production.

http://www.slcgov.com/slcgreen/code/DevCodeProj_Phase1_final.pdf

9.4 Voluntary Standards and Other Relevant Programs

9.4.1 LEED for Neighborhood Development (LEED ND)

LEED ND offers a credit for tree lined and shaded streets. While this is not a direct solar oriented development requirement, it is related. A copy of the actual text is excerpted below.

NPD Credit 14: Tree-Lined and Shaded Streets

1–2 points

Intent

To encourage walking, bicycling, and transit use and discourage excessive motoring speeds. To reduce urban heat island effects, improve air quality, increase evapotranspiration, and reduce cooling loads in buildings.

Requirements

OPTION 1. Tree-Lined Streets (1 point)

Design and build the *project* to provide street trees on both sides of at least 60% of new and *existing streets* within the project and on the project side of bordering streets, between the vehicle travel way and walkway, at intervals averaging no more than 40 feet (excluding driveways and utility vaults).

AND/OR

OPTION 2. Shaded Streets (1 point)

Trees or other structures provide shade over at least 40% of the length of sidewalks on streets within or contiguous to the project. Trees must provide shade within ten years of landscape installation. Use the estimated crown diameter (the width of the shade if the sun is directly above the tree) to calculate the shaded area.

AND

FOR ALL PROJECTS INVOLVING STREET TREE PLANTINGS

Obtain a registered landscape architect's determination that planting details are appropriate to growing healthy trees, taking into account tree species, root medium, and width and soil volume of planter strips or wells, and that the selected tree species are not considered *invasive* in the project context according to USDA or the state agricultural extension service.

Figure 67: LEED ND Tree-lined and shaded streets requirements

9.5 Summary of Current Practice and Examples of Solar Ready Homes

CTG also conducted a review of the literature, the web and solicited stakeholder input via an online survey and in stakeholder meetings to identify current practices and examples of solar ready homes practices. Findings are briefly summarized below.

- **Natomas, CA: Fallen Leaf -** The 32 ZNE homes at Fallen Leaf built by Treasure Homes include a 2.4kW DC photovoltaic integrated roofing system from BP Solar which, coupled with other energy efficient features, will produce almost as much electricity as it needs to power the house on an annual basis[124].

[124] http://www.bira.ws/projects/fallen-leaf.php

- **Rancho Cordova, CA: Premier Gardens -** The 98 single-family home community built by Premier Homes combines mechanical and passive design features with 2 kW AC solar home power systems to save residents over 60% on their utilities costs[125].
- **Watsonville, CA: Vista Montaña -** 257 single-family homes were built in 2005 by Clarum Homes to use nearly zero net energy. All homes have a 1.2 to 2.4 kW PV system and range of energy efficiency measures to reduce utility bills by up to 90%[126].
- **Pleasanton, CA: Avignon -** Centex Homes' Avignon development consists of 32 larger estate homes containing 3.5 kW PV systems designed to reduce total energy bills by 70%. They are designed to draw no more than 1 kW of electricity during peak times[127].
- **Redding, CA: Sonata -** Seastar Communities built an 84 single-family home development designed to save homebuyers up to 50% on utility costs by including in each a 2 kW solar electric home power system[128].
- **Roseville, CA: Premier Oak -** Premier Homes' second standard ZNE community, Premier Oaks, is designed to save 60% of all utilities costs using energy efficiency features including 2 kW AC solar electric home power system[129].
- **San Diego, CA: Tiempo and San Angelo -** Shea Homes built two neighborhoods in 2001 allowing homeowners to reduce their utilities costs by 30% to 50% by providing solar hot water heaters (implemented in 293 of 306 homes) and solar electric systems (implemented in 120 homes)[130].
- **Ladera Ranch, CA: Terramor -** Over 450 of the houses at Terramor in Ladera Ranch have PV solar electric energy systems installed. The community, constructed by 10 different builders, has a variety of other sustainable features that make its houses 20% more energy and water efficient than comparable conventional homes[131].
- **Rocklin, CA: Carsten Crossings -** Built by Grupe, the 144 homes in the Carsten Crossings neighborhood are built with 2.4 kW solar roof tile electric power systems and designed to exceed Title 24 standards by 36%[132].
- **Lopez Island, WA: Common Ground -** The Lopez Community Land Trust constructed Common Ground beginning in 2007, including a mixed income development of 11 homes and 2 rental units complete with PV solar arrays and solar water heaters[133].

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[125] http://www.bira.ws/projects/premier-gardens.php

[126] http://www.bira.ws/projects/vista-montana.php

[127] http://www.bira.ws/projects/avignon.php

[128] http://www.bira.ws/projects/sonata.php

[129] http://www.bira.ws/projects/premier-oaks.php

[130] http://www.toolbase.org/PDF/CaseStudies/ZEH_NRELfarhar2.pdf

[131] http://www.laderaranch.com/

[132] http://www.pvdatabase.org/urban_view_details.php?ID=19

- **Las Vegas, NV: Maplewood Springs -** All homes in this gated community, built by Pinnacle Homes, are built solar-ready and with certified green construction[134].
- **Saskatoon, SK, Canada: Suncastle Park -** Suncatcher Solar and Sun Plans designed this solar-oriented community to include with each lot an installed, 2 kW grid-tied solar power system[135].
- **Palm Grove, India: Palm Meadows -** As an initiative towards 'green energy, Palm Meadows is equipped with a solar hybrid system with a capability to generate solar power. Up to 2 Megawatts of solar can be generated from entire community 20 kW is currently commissioned. Standard home specifications additionally include a 300 L capacity solar water heating system with a built-in electrical backup heater on the terrace[136].
- **Hyderabad, India: Aparna Palm Meadows -** The high-end villas of Aparna Palm Meadows are Andhra Pradesh's first solar ready homes, integrated by a smart micro-grid for reduction in transmission losses[137].

[133] http://www.lopezclt.org/common-ground/

[134] http://www.pinnaclelv.com/community.php?id=2

[135] http://www.suncatchersolar.com/SuncastlePark.htm

[136] http://www.sahabitat.com/ready/palmmeadows.html#solo=solar-ready-homes

[137] http://content.magicbricks.com/aparna-palm-meadows-aps-first-solar-ready-homes

10. Appendix 4 – Current Homes and Communities Incorporating Solar Design Features

This appendix provides a more detailed summary of the homes and communities identified as having significant penetrations of solar and other solar design features. Refer to sections 4.1.7and 4.1.8for discussion.

10.1 Examples of Solar Ready Homes and Neighborhoods with Large Solar Penetrations

- **Natomas, CA: Fallen Leaf -** The 32 ZNE homes at Fallen Leaf built by Treasure Homes include a 2.4kW DC photovoltaic integrated roofing system from BP Solar which, coupled with other energy efficient features, will produce almost as much electricity as it needs to power the house on an annual basis[138].
- **Rancho Cordova, CA: Premier Gardens -** The 98 single-family home community built by Premier Homes combines mechanical and passive design features with 2 kW AC solar home power systems to save residents over 60% on their utilities costs[139].
- **Watsonville, CA: Vista Montaña -** 257 single-family homes were built in 2005 by Clarum Homes to use nearly zero net energy. All homes have a 1.2 to 2.4 kW PV system and range of energy efficiency measures to reduce utility bills by up to 90%[140].
- **Pleasanton, CA: Avignon -** Centex Homes' Avignon development consists of 32 larger estate homes containing 3.5 kW PV systems designed to reduce total energy bills by 70%. They are designed to draw no more than 1 kW of electricity during peak times[141].
- **Redding, CA: Sonata -** Seastar Communities built an 84 single-family home development designed to save homebuyers up to 50% on utility costs by including in each a 2 kW solar electric home power system[142].
- **Roseville, CA: Premier Oak -** Premier Homes' second standard ZNE community, Premier Oaks, is designed to save 60% of all utilities costs using energy efficiency features including 2 kW AC solar electric home power system[143].
- **San Diego, CA: Tiempo and San Angelo -** Shea Homes built two neighborhoods in 2001 allowing homeowners to reduce their utilities costs by 30% to 50% by providing solar hot

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138 http://www.bira.ws/projects/fallen-leaf.php

139 http://www.bira.ws/projects/premier-gardens.php

140 http://www.bira.ws/projects/vista-montana.php

141 http://www.bira.ws/projects/avignon.php

142 http://www.bira.ws/projects/sonata.php

143 http://www.bira.ws/projects/premier-oaks.php

water heaters (implemented in 293 of 306 homes) and solar electric systems (implemented in 120 homes)[144].

- **Ladera Ranch, CA: Terramor -** Over 450 of the houses at Terramor in Ladera Ranch have PV solar electric energy systems installed. The community, constructed by 10 different builders, has a variety of other sustainable features that make its houses 20% more energy and water efficient than comparable conventional homes[145].
- **Rocklin, CA: Carsten Crossings -** Built by Grupe, the 144 homes in the Carsten Crossings neighborhood are built with 2.4 kW solar roof tile electric power systems and designed to exceed Title 24 standards by 36%[146].
- **Lopez Island, WA: Common Ground -** The Lopez Community Land Trust constructed Common Ground beginning in 2007, including a mixed income development of 11 homes and 2 rental units complete with PV solar arrays and solar water heaters[147].
- **Las Vegas, NV: Maplewood Springs -** All homes in this gated community, built by Pinnacle Homes, are built solar-ready and with certified green construction[148].
- **Saskatoon, SK, Canada: Suncastle Park -** Suncatcher Solar and Sun Plans designed this solar-oriented community to include with each lot an installed, 2 kW grid-tied solar power system[149].
- **Palm Grove, India: Palm Meadows -** As an initiative towards 'green energy, Palm Meadows is equipped with a solar hybrid system with a capability to generate solar power. Up to 2 Megawatts of solar can be generated from entire community 20 kW is currently commissioned. Standard home specifications additionally include a 300 L capacity solar water heating system with a built-in electrical backup heater on the terrace[150].
- **Hyderabad, India: Aparna Palm Meadows -** The high-end villas of Aparna Palm Meadows are Andhra Pradesh's first solar ready homes, integrated by a smart micro-grid for reduction in transmission losses[151].

10.2 Examples of Solar Oriented Development

Developers' increasing focus on building green communities very often includes strategic layout designs incorporating elements of passive solar heating and cooling designs and access to sunshine.

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[144] http://www.toolbase.org/PDF/CaseStudies/ZEH_NRELfarhar2.pdf

[145] http://www.laderaranch.com/

[146] http://www.pvdatabase.org/urban_view_details.php?ID=19

[147] http://www.lopezclt.org/common-ground/

[148] http://www.pinnaclelv.com/community.php?id=2

[149] http://www.suncatchersolar.com/SuncastlePark.htm

[150] http://www.sahabitat.com/ready/palmmeadows.html#solo=solar-ready-homes

[151] http://content.magicbricks.com/aparna-palm-meadows-aps-first-solar-ready-homes

Building orientation, shading, fenestration, window distribution, and ventilation are important elements in passive solar designs that decrease the need for lighting, heating, and cooling electric power. Many communities, in addition, use building layouts to protect solar access and allow for solar power generation.

- **Davis, CA: Village Homes -** In the 70-acre subdivision of Village Homes, all streets trend east-west and all lots are oriented north-south, allowing the houses with passive solar designs to efficiently utilize solar energy[152].
- **Claremont, CA: Meadowoods Neighborhood –** This 140-acre subdivision of 92 homes was specifically designed with numerous solar oriented development features.
- **San Diego, CA: C-Street -** The mixed-use urban development design for C-Street orients both commercial and residential units for natural lighting and cross-ventilation. Private and public green spaces are implemented for socialization and relaxation, and axes along the ground floor allow for sufficient circulation[153].
- **San Diego, CA: Quarry Falls -** Quarry Falls is a developing mixed-use, self-sustaining community designed to include a mix of low, medium, and high density homes designed and oriented to allow every building to maximize its potential use of solar energy. Currently in the construction phase, no current data or photographs are available for the development[154].
- **Wilmington, NC: Tonbo Meadow Green Sustainable Community -** In this eco-friendly community, builders make use of passive solar orientation to keep the house cooler in the summer, warmer in the winter, and reduce the need for electrical lighting[155].
- **Lopez Island, WA: Lopez Community Land Trust Sustainable Community Homes** - The non-profit, community-based organization, LCLT (developers of Common Ground, Morgantown, Innisfree, and COHO) secured 7 acres of Lopez Island for an Urban Growth Area, and are using specific sustainability measures including passive solar orientation and modeling and strategic window distribution and shading[156].
- **Pattonsburg, MO: Pattonsburg's Design Process -** A design charette was assembled to employ a planning model for the rebuilding of the village of Pattonsburg after flooding severely damaged the buildings and architecture. The community adopted the team's sustainable design plan which included the solar orientation of all buildings[157].

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[152] http://www.villagehomesdavis.org/public/about

[153] http://designorigin.org/portfolio.pdf

[154] http://www.quarryfalls.com/concept.htm

[155] http://www.greenecocommunities.com/North-Carolina/Tonbo-meadow-green-community.html

[156] http://www.lopezclt.org/new-site/wp-content/uploads/HP4_green_list071.pdf

[157] http://www.smartcommunities.ncat.org/articles/Pattonsburg_design.shtml

- **Saskatoon, SK, Canada: Suncastle Park -** Solar home designs in Suncastle Park are provided by Suncastle Park and Sun Plans, Inc., including over 80 home plans designed to maximize passive solar energy gain and reduce the energy needed for heating[158].
- **British Columbia, Canada: Seabird Island Sustainable Community Demonstration Project -** The environmentally designed housing development on Seabird Island has garnered Canada wide attention for its low tech approach. In addition to many other innovative sustainable features, the development utilizes solar orientation and passive solar convective air flow systems. Main living areas and solariums are oriented to the south in a semi-circular pattern[159].
- **South Africa: Sustainable Design Group -** The Sustainable Design group, in collaboration with PEER South Africa, has designed and built passive solar low-cost housing and communities for the homeless throughout South Africa. Passive solar heating keeps the homes warm in winter, while shading and natural ventilation keep the homes cool during summer[160].

158 http://www.suncatchersolar.com/SuncastlePark.htm

159 http://www.broadwayarchitects.com/sustainable-environmental-design-projects/seabird-island-sustainable-community.html

160160 http://www.sustainabledesign.com/community_planning1.html

11. Appendix 5 – Solar PV Parametric Study Results

The following set of tables presents the Solar Orientation Factors (SOF) for PV systems verses azimuth, tilt and climate zone. Green shading represents azimuth range with highest output, and red shading indicates worst performance.

	CZ1	0:12	3:12	5:12	8:12
Azimuth	0	86%	74%	66%	55%
	15	86%	71%	61%	49%
	30	86%	70%	60%	47%
	45	86%	71%	61%	48%
	60	86%	72%	63%	52%
	75	86%	75%	67%	57%
	90	86%	77%	71%	63%
	105	86%	81%	76%	70%
	120	86%	84%	81%	76%
	135	86%	87%	86%	83%
	150	86%	90%	90%	89%
	165	86%	92%	94%	93%
	180	86%	94%	96%	97%
	195	86%	95%	98%	99%
	210	86%	95%	98%	100%
	225	86%	94%	98%	99%
	240	86%	93%	96%	97%
	255	86%	92%	94%	94%
	270	86%	90%	90%	89%
	285	86%	87%	86%	84%
	300	86%	84%	82%	78%
	315	86%	81%	77%	71%
	330	86%	78%	73%	65%
	345	86%	76%	69%	59%
	360	86%	74%	66%	55%

	CZ2	0:12	3:12	5:12	8:12
Azimuth	0	88%	76%	67%	55%
	15	88%	73%	62%	49%
	30	88%	71%	61%	47%
	45	88%	72%	61%	48%
	60	88%	73%	64%	52%
	75	88%	76%	68%	57%
	90	88%	79%	72%	63%
	105	88%	82%	77%	70%
	120	88%	85%	82%	76%
	135	88%	88%	86%	83%
	150	88%	91%	91%	88%
	165	88%	93%	94%	93%
	180	88%	94%	97%	97%
	195	88%	95%	98%	99%
	210	88%	96%	99%	100%
	225	88%	95%	98%	99%
	240	88%	94%	97%	97%
	255	88%	93%	94%	94%
	270	88%	91%	91%	90%
	285	88%	88%	87%	84%
	300	88%	85%	83%	78%
	315	88%	82%	78%	72%
	330	88%	80%	74%	65%
	345	88%	77%	70%	60%
	360	88%	76%	67%	55%

	CZ3	0:12	3:12	5:12	8:12
Azimuth	0	88%	76%	67%	56%
	15	88%	73%	63%	50%
	30	88%	72%	61%	48%
	45	88%	72%	62%	49%
	60	88%	74%	65%	52%
	75	88%	76%	68%	57%
	90	88%	79%	73%	64%
	105	88%	82%	77%	70%
	120	88%	85%	82%	77%
	135	88%	88%	87%	83%
	150	88%	91%	91%	89%
	165	88%	93%	94%	94%
	180	88%	95%	97%	97%
	195	88%	96%	98%	99%
	210	88%	96%	99%	100%
	225	88%	96%	98%	99%
	240	88%	95%	97%	97%
	255	88%	93%	94%	94%
	270	88%	91%	91%	89%
	285	88%	88%	87%	84%
	300	88%	85%	83%	78%
	315	88%	83%	78%	71%
	330	88%	80%	74%	65%
	345	88%	78%	70%	60%
	360	88%	76%	67%	56%

	CZ4	0:12	3:12	5:12	8:12
Azimuth	0	88%	76%	67%	55%
	15	88%	73%	62%	49%
	30	88%	72%	61%	47%
	45	88%	72%	61%	48%
	60	88%	74%	64%	52%
	75	88%	76%	68%	57%
	90	88%	79%	72%	63%
	105	88%	82%	77%	70%
	120	88%	85%	82%	76%
	135	88%	88%	87%	83%
	150	88%	91%	91%	89%
	165	88%	93%	94%	93%
	180	88%	95%	97%	97%
	195	88%	96%	98%	99%
	210	88%	96%	99%	100%
	225	88%	96%	98%	99%
	240	88%	95%	97%	97%
	255	88%	93%	94%	94%
	270	88%	91%	91%	89%
	285	88%	88%	87%	84%
	300	88%	85%	82%	78%
	315	88%	82%	78%	71%
	330	88%	80%	73%	65%
	345	88%	77%	70%	59%
	360	88%	76%	67%	55%

	CZ5	0:12	3:12	5:12	8:12
Azimuth	0	87%	75%	65%	53%
	15	87%	72%	61%	48%
	30	87%	71%	60%	46%
	45	87%	72%	61%	48%
	60	87%	73%	64%	52%
	75	87%	76%	68%	57%
	90	87%	79%	72%	64%
	105	87%	82%	77%	70%
	120	87%	85%	82%	77%
	135	87%	88%	87%	84%
	150	87%	91%	91%	89%
	165	87%	93%	95%	94%
	180	87%	95%	97%	97%
	195	87%	96%	98%	99%
	210	87%	96%	99%	100%
	225	87%	95%	98%	99%
	240	87%	94%	96%	96%
	255	87%	92%	93%	93%
	270	87%	90%	90%	88%
	285	87%	87%	86%	82%
	300	87%	84%	81%	76%
	315	87%	81%	76%	69%
	330	87%	78%	72%	63%
	345	87%	76%	68%	57%
	360	87%	75%	65%	53%

	CZ6	0:12	3:12	5:12	8:12
Azimuth	0	88%	77%	68%	56%
	15	88%	74%	64%	52%
	30	88%	73%	62%	51%
	45	88%	73%	63%	53%
	60	88%	75%	66%	56%
	75	88%	77%	69%	61%
	90	88%	80%	74%	67%
	105	88%	83%	78%	73%
	120	88%	86%	83%	79%
	135	88%	89%	88%	85%
	150	88%	92%	92%	90%
	165	88%	94%	95%	94%
	180	88%	95%	97%	97%
	195	88%	96%	99%	99%
	210	88%	96%	99%	100%
	225	88%	96%	98%	99%
	240	88%	95%	97%	97%
	255	88%	93%	94%	94%
	270	88%	91%	91%	90%
	285	88%	88%	87%	85%
	300	88%	86%	83%	79%
	315	88%	83%	78%	73%
	330	88%	80%	74%	67%
	345	88%	78%	70%	61%
	360	88%	77%	68%	56%

	CZ7	0:12	3:12	5:12	8:12
Azimuth	0	88%	75%	66%	54%
	15	88%	72%	62%	48%
	30	88%	71%	60%	46%
	45	88%	71%	61%	48%
	60	88%	73%	63%	51%
	75	88%	75%	67%	56%
	90	88%	78%	71%	62%
	105	88%	81%	76%	69%
	120	88%	84%	81%	76%
	135	88%	88%	86%	83%
	150	88%	90%	90%	88%
	165	88%	93%	94%	93%
	180	88%	94%	96%	97%
	195	88%	95%	98%	99%
	210	88%	96%	99%	100%
	225	88%	95%	98%	99%
	240	88%	94%	97%	97%
	255	88%	93%	94%	94%
	270	88%	90%	91%	89%
	285	88%	88%	87%	84%
	300	88%	85%	82%	78%
	315	88%	82%	78%	71%
	330	88%	79%	73%	65%
	345	88%	77%	69%	59%
	360	88%	75%	66%	54%

	CZ8	0:12	3:12	5:12	8:12
Azimuth	0	89%	77%	68%	56%
	15	89%	74%	64%	51%
	30	89%	73%	62%	49%
	45	89%	73%	63%	50%
	60	89%	75%	65%	53%
	75	89%	77%	69%	58%
	90	89%	80%	73%	64%
	105	89%	83%	78%	71%
	120	89%	86%	83%	77%
	135	89%	89%	87%	83%
	150	89%	91%	91%	89%
	165	89%	94%	95%	94%
	180	89%	95%	97%	97%
	195	89%	96%	99%	99%
	210	89%	96%	99%	100%
	225	89%	96%	99%	99%
	240	89%	95%	97%	97%
	255	89%	93%	95%	94%
	270	89%	91%	91%	89%
	285	89%	89%	87%	84%
	300	89%	86%	83%	78%
	315	89%	83%	79%	72%
	330	89%	81%	75%	66%
	345	89%	79%	71%	61%
	360	89%	77%	68%	56%

	CZ9	0:12	3:12	5:12	8:12
Azimuth	0	89%	76%	67%	56%
	15	89%	74%	63%	50%
	30	89%	73%	62%	49%
	45	89%	73%	63%	50%
	60	89%	75%	65%	53%
	75	89%	77%	69%	58%
	90	89%	80%	73%	64%
	105	89%	83%	78%	71%
	120	89%	86%	83%	77%
	135	89%	89%	87%	84%
	150	89%	91%	91%	89%
	165	89%	94%	95%	94%
	180	89%	95%	97%	97%
	195	89%	96%	99%	99%
	210	89%	96%	99%	100%
	225	89%	96%	98%	99%
	240	89%	95%	97%	97%
	255	89%	93%	94%	94%
	270	89%	91%	91%	89%
	285	89%	88%	87%	84%
	300	89%	86%	83%	78%
	315	89%	83%	78%	72%
	330	89%	80%	74%	66%
	345	89%	78%	70%	60%
	360	89%	76%	67%	56%

	CZ10	0:12	3:12	5:12	8:12
Azimuth	0	89%	77%	68%	56%
	15	89%	74%	64%	51%
	30	89%	73%	62%	49%
	45	89%	73%	63%	50%
	60	89%	75%	66%	54%
	75	89%	77%	69%	58%
	90	89%	80%	73%	64%
	105	89%	83%	78%	71%
	120	89%	86%	83%	77%
	135	89%	89%	87%	83%
	150	89%	91%	91%	89%
	165	89%	94%	95%	93%
	180	89%	95%	97%	97%
	195	89%	96%	99%	99%
	210	89%	96%	99%	100%
	225	89%	96%	99%	99%
	240	89%	95%	97%	97%
	255	89%	93%	95%	94%
	270	89%	91%	91%	90%
	285	89%	89%	88%	85%
	300	89%	86%	83%	79%
	315	89%	83%	79%	73%
	330	89%	81%	75%	66%
	345	89%	78%	71%	61%
	360	89%	77%	68%	56%

	CZ11	0:12	3:12	5:12	8:12
Azimuth	0	85%	73%	64%	52%
	15	85%	70%	60%	50%
	30	85%	69%	59%	50%
	45	85%	70%	60%	53%
	60	85%	72%	63%	57%
	75	85%	75%	67%	62%
	90	85%	78%	72%	68%
	105	85%	81%	77%	74%
	120	85%	84%	82%	80%
	135	85%	87%	87%	86%
	150	85%	90%	91%	91%
	165	85%	92%	94%	95%
	180	85%	94%	97%	98%
	195	85%	95%	98%	99%
	210	85%	95%	98%	100%
	225	85%	94%	97%	99%
	240	85%	93%	96%	97%
	255	85%	91%	93%	93%
	270	85%	89%	89%	89%
	285	85%	86%	85%	84%
	300	85%	83%	80%	78%
	315	85%	80%	75%	71%
	330	85%	77%	71%	64%
	345	85%	74%	67%	58%
	360	85%	73%	64%	52%

	CZ12	0:12	3:12	5:12	8:12
Azimuth	0	89%	77%	68%	56%
	15	89%	75%	65%	52%
	30	89%	74%	64%	51%
	45	89%	74%	65%	52%
	60	89%	76%	67%	56%
	75	89%	78%	71%	61%
	90	89%	81%	75%	67%
	105	89%	84%	79%	73%
	120	89%	87%	84%	79%
	135	89%	90%	88%	85%
	150	89%	92%	92%	90%
	165	89%	94%	95%	94%
	180	89%	95%	97%	97%
	195	89%	96%	99%	99%
	210	89%	97%	99%	100%
	225	89%	96%	98%	99%
	240	89%	95%	97%	97%
	255	89%	93%	94%	94%
	270	89%	91%	91%	90%
	285	89%	89%	87%	84%
	300	89%	86%	83%	79%
	315	89%	83%	79%	73%
	330	89%	81%	75%	66%
	345	89%	79%	71%	61%
	360	89%	77%	68%	56%

CZ13 Azimuth	0:12	3:12	5:12	8:12
0	91%	79%	70%	58%
15	91%	77%	67%	54%
30	91%	76%	66%	53%
45	91%	76%	67%	54%
60	91%	77%	69%	58%
75	91%	80%	72%	62%
90	91%	82%	76%	68%
105	91%	85%	80%	74%
120	91%	88%	85%	80%
135	91%	91%	89%	85%
150	91%	93%	93%	90%
165	91%	95%	96%	94%
180	91%	96%	98%	97%
195	91%	97%	99%	99%
210	91%	97%	100%	100%
225	91%	97%	99%	99%
240	91%	96%	98%	98%
255	91%	94%	95%	95%
270	91%	92%	92%	91%
285	91%	90%	89%	86%
300	91%	88%	85%	80%
315	91%	85%	81%	74%
330	91%	83%	77%	69%
345	91%	81%	73%	63%
360	91%	79%	70%	58%

CZ14 Azimuth	0:12	3:12	5:12	8:12
0	85%	73%	64%	52%
15	85%	70%	60%	47%
30	85%	69%	59%	46%
45	85%	70%	60%	48%
60	85%	72%	62%	51%
75	85%	74%	66%	57%
90	85%	77%	71%	63%
105	85%	81%	76%	70%
120	85%	84%	81%	76%
135	85%	87%	86%	83%
150	85%	90%	90%	89%
165	85%	92%	94%	93%
180	85%	94%	96%	97%
195	85%	95%	98%	99%
210	85%	95%	98%	100%
225	85%	95%	98%	99%
240	85%	94%	96%	97%
255	85%	92%	93%	94%
270	85%	89%	90%	89%
285	85%	87%	86%	83%
300	85%	84%	81%	77%
315	85%	81%	76%	70%
330	85%	78%	72%	64%
345	85%	75%	67%	57%
360	85%	73%	64%	52%

CZ15 Azimuth	0:12	3:12	5:12	8:12
0	88%	76%	68%	56%
15	88%	73%	64%	51%
30	88%	72%	62%	50%
45	88%	73%	63%	51%
60	88%	74%	65%	54%
75	88%	76%	69%	59%
90	88%	79%	73%	65%
105	88%	82%	78%	71%
120	88%	85%	82%	77%
135	88%	88%	87%	83%
150	88%	91%	91%	88%
165	88%	93%	94%	93%
180	88%	95%	97%	96%
195	88%	96%	98%	99%
210	88%	96%	99%	100%
225	88%	96%	99%	100%
240	88%	95%	97%	98%
255	88%	94%	95%	95%
270	88%	92%	92%	91%
285	88%	89%	88%	86%
300	88%	86%	84%	81%
315	88%	84%	80%	74%
330	88%	81%	75%	68%
345	88%	78%	71%	62%
360	88%	76%	68%	56%

CZ16 Azimuth	0:12	3:12	5:12	8:12
0	83%	70%	61%	49%
15	83%	68%	57%	44%
30	83%	67%	57%	43%
45	83%	68%	58%	46%
60	83%	70%	61%	50%
75	83%	73%	66%	56%
90	83%	77%	71%	63%
105	83%	80%	76%	70%
120	83%	84%	82%	78%
135	83%	87%	86%	84%
150	83%	90%	91%	90%
165	83%	92%	94%	95%
180	83%	93%	96%	98%
195	83%	94%	98%	100%
210	83%	94%	98%	100%
225	83%	93%	97%	99%
240	83%	92%	94%	96%
255	83%	89%	91%	91%
270	83%	87%	87%	86%
285	83%	84%	82%	80%
300	83%	80%	77%	73%
315	83%	77%	72%	66%
330	83%	74%	67%	59%
345	83%	72%	63%	53%
360	83%	70%	61%	49%

Figure 68: Solar Orientation Factors (SOF) for PV systems verses azimuth, tilt and climate zone

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12. Appendix 6 – Solar Water Heating Parametric Study Results

Figure 69: Annual SWH TDV savings vs. azimuth for a 5:12 tilt

	Azimuth																							
	0	15	30	45	60	75	90	105	120	135	150	165	180	195	210	225	240	255	270	285	300	315	330	345
CZ1	6,288	6,478	7,020	7,818	8,826	10,049	11,267	12,394	13,334	14,145	14,811	15,179	15,322	15,239	14,957	14,404	13,705	12,729	11,639	10,423	9,127	7,935	7,009	6,439
CZ2	9,288	9,522	10,259	11,350	12,690	14,103	15,563	16,763	17,775	18,507	19,063	19,421	19,559	19,443	19,087	18,540	17,806	16,902	15,744	14,460	13,037	11,657	10,470	9,626
CZ3	9,070	9,396	10,161	11,182	12,441	13,872	15,309	16,517	17,548	18,371	18,959	19,347	19,473	19,379	19,093	18,491	17,702	16,758	15,496	14,170	12,703	11,354	10,164	9,385
CZ4	9,694	9,975	10,774	11,846	13,183	14,635	16,043	17,220	18,224	18,972	19,523	19,854	19,948	19,782	19,447	18,874	18,094	17,151	15,980	14,650	13,200	11,817	10,667	9,907
CZ5	10,406	10,677	11,376	12,519	14,040	15,745	17,388	18,770	19,962	20,998	21,805	22,233	22,401	22,291	21,925	21,405	20,476	19,279	17,942	16,385	14,614	12,948	11,589	10,695
CZ6	10,352	10,537	11,217	12,232	13,557	14,966	16,404	17,647	18,736	19,670	20,262	20,666	20,912	20,788	20,423	19,839	19,080	18,008	16,784	15,417	13,981	12,580	11,332	10,630
CZ7	9,992	10,259	11,047	12,210	13,715	15,262	16,641	17,968	19,090	19,952	20,632	21,039	21,118	21,033	20,693	20,139	19,307	18,247	17,000	15,497	13,867	12,305	11,010	10,224
CZ8	11,308	11,486	12,169	13,216	14,638	16,200	17,579	18,869	20,050	20,946	21,607	22,002	22,129	22,095	21,818	21,318	20,577	19,484	18,238	16,810	15,273	13,757	12,469	11,590
CZ9	10,431	10,709	11,450	12,561	13,988	15,481	16,858	18,033	19,052	19,890	20,517	20,819	20,897	20,723	20,393	19,842	19,079	18,030	16,872	15,513	14,072	12,628	11,419	10,675
CZ10	10,568	10,807	11,467	12,552	14,002	15,461	16,808	18,057	19,152	20,026	20,610	20,961	21,092	20,917	20,631	20,066	19,329	18,285	17,078	15,784	14,280	12,857	11,631	10,819
CZ11	8,373	8,709	9,568	10,639	12,025	13,491	14,912	16,074	17,069	17,832	18,422	18,731	18,802	18,690	18,386	17,756	16,984	15,933	14,745	13,305	11,819	10,396	9,309	8,556
CZ12	9,897	10,280	11,054	12,214	13,532	14,952	16,294	17,422	18,325	19,054	19,509	19,822	19,844	19,668	19,415	18,897	18,128	17,191	16,147	14,914	13,558	12,245	11,039	10,208
CZ13	10,232	10,591	11,386	12,372	13,603	14,904	16,035	17,028	17,892	18,460	18,932	19,245	19,306	19,158	18,893	18,378	17,781	16,929	15,912	14,716	13,499	12,199	11,164	10,473
CZ14	11,620	12,001	12,892	14,263	15,990	17,796	19,426	20,978	22,140	23,096	23,907	24,285	24,461	24,329	24,070	23,455	22,402	21,216	19,784	18,011	16,043	14,233	12,705	11,805
CZ15	9,603	9,968	10,800	11,959	13,516	14,991	16,401	17,641	18,659	19,402	19,995	20,278	20,381	20,217	19,925	19,306	18,556	17,526	16,352	14,909	13,322	11,776	10,524	9,760

	Azimuth																							
	0	15	30	45	60	75	90	105	120	135	150	165	180	195	210	225	240	255	270	285	300	315	330	345
CZ1	41%	42%	46%	51%	58%	66%	74%	81%	87%	92%	97%	99%	100%	99%	98%	94%	89%	83%	76%	68%	60%	52%	46%	42%
CZ2	47%	49%	52%	58%	65%	72%	80%	86%	91%	95%	97%	99%	100%	99%	98%	95%	91%	86%	80%	74%	67%	60%	54%	49%
CZ3	47%	48%	52%	57%	64%	71%	79%	85%	90%	94%	97%	99%	100%	100%	98%	95%	91%	86%	80%	73%	65%	58%	52%	48%
CZ4	49%	50%	54%	59%	66%	73%	80%	86%	91%	95%	98%	100%	100%	99%	97%	95%	91%	86%	80%	73%	66%	59%	53%	50%
CZ5	46%	48%	51%	56%	63%	70%	78%	84%	89%	94%	97%	99%	100%	100%	98%	96%	91%	86%	80%	73%	65%	58%	52%	48%
CZ6	50%	50%	54%	58%	65%	72%	78%	84%	90%	94%	97%	99%	100%	99%	98%	95%	91%	86%	80%	74%	67%	60%	54%	51%
CZ7	47%	49%	52%	58%	65%	72%	79%	85%	90%	94%	98%	100%	100%	100%	98%	95%	91%	86%	80%	73%	66%	58%	52%	48%
CZ8	51%	52%	55%	60%	66%	73%	79%	85%	91%	95%	98%	99%	100%	100%	99%	96%	93%	88%	82%	76%	69%	62%	56%	52%
CZ9	50%	51%	55%	60%	67%	74%	81%	86%	91%	95%	98%	100%	100%	99%	98%	95%	91%	86%	81%	74%	67%	60%	55%	51%
CZ10	50%	51%	54%	60%	66%	73%	80%	86%	91%	95%	98%	99%	100%	99%	98%	95%	92%	87%	81%	75%	68%	61%	55%	51%
CZ11	45%	46%	51%	57%	64%	72%	79%	85%	91%	95%	98%	100%	100%	99%	98%	94%	90%	85%	78%	71%	63%	55%	50%	46%
CZ12	50%	52%	56%	62%	68%	75%	82%	88%	92%	96%	98%	100%	100%	99%	98%	95%	91%	87%	81%	75%	68%	62%	56%	51%
CZ13	53%	55%	59%	64%	70%	77%	83%	88%	93%	96%	98%	100%	100%	99%	98%	95%	92%	88%	82%	76%	70%	63%	58%	54%
CZ14	48%	49%	53%	58%	65%	73%	79%	86%	91%	94%	98%	99%	100%	99%	98%	96%	92%	87%	81%	74%	66%	58%	52%	48%
CZ15	47%	49%	53%	59%	66%	74%	80%	87%	92%	95%	98%	99%	100%	99%	98%	95%	91%	86%	80%	73%	65%	58%	52%	48%

Figure 70: Solar Orientation Factor vs. azimuth for system 1 at a 5:12 tilt

13. Appendix 7 – Survey of "Current Practice" Solar Performance in Existing Homes and Communities

13.1 Introduction

In order to characterize the current practice and performance of solar-ready and solar-oriented residential developments, it was necessary to collect and analyze data from a number of relevant residential developments. Housing data was collected for solar-ready, solar-oriented, and non-solar communities in California to determine the specific implementation of current practice and the potential for improvement for each residential category in both solar energy generation and building energy use. Building, roof, and PV orientation as well as additional specific design attributes were compared amongst solar-ready, solar-oriented, and non-solar homes in order to determine the feasibility and effectiveness of plausible solar-ready and solar-oriented measures/regulations to reduce overall building energy usage and maximize solar PV generation.

The variables affecting PV performance are roof tilt (pitch) and PV orientation, which is impacted by, but not necessarily driven by street layout and roof shape, orientation, and obstructions. Amongst surveyed solar developments, the average PV orientation deviation from optimal is 43 degrees, and the average PV performance is estimated to be 92.1% of optimal output. For surveyed non-solar communities, theoretical solar implementation would deviate from optimal PV orientation by 51 degrees, and achieve average 91.7% efficiency. The solar oriented community of Village Homes, however, orients 100% of panels optimally for average 98.7% efficiency. Solar and non-solar communities deviate from optimal PV orientation due to varying combinations of street layout and roof shape, orientation, and obstructions.

13.2 Methodology

The photovoltaic (PV) performance of the communities described in Sections 4.1.7 and 4.1.8 were evaluated by completing housing surveys to identify specific attributes and orientations of each home and applying annual PV output estimates to the data. Bing Maps and Google Maps were used to collect data for the specific lot orientation, roof orientation, roof area, roof complexity, roof pitch, and PV and SDWH size and orientation. The orientation of the lot, roof, and solar generation panels were estimated.

The PV orientation and tilt (roof pitch) were used to estimate solar energy output with the National Renewable Energy Laboratory's PV Watts V.2 performance estimator for grid-connected solar PV panels. The calculator determines the energy production and cost savings of PV systems using hourly performance simulations corrected for local temperature conditions. An overall DC to AC derating factor of 0.77 was used for the analysis. Note: the measure life cycle cost analyses used the orientation data obtained from the survey, but used PV performance data calculated using the CEC PV tool for each climate zone.

After attaining PV output data for each house in the development, the data was compiled to specify the average efficiency of each development as a percentage of maximum PV output. The relationship between orientation and solar output, the quantity of homes at each orientation, and the cumulative frequency of solar performance are used as analysis techniques to highlight desirable and non-desirable attributes of the neighborhood layout and home designs.

13.3 PV Performance in Current Practice: Solar Communities

"Solar communities" are communities which installed a large percentage of solar systems on homes during construction (verses retrofitted after construction). Note that the CASE authors were not always able to determine if specific solar oriented development strategies were incorporated into the planning phase as well.

13.3.1 Natomas, CA: Fallen Leaf

The 32 "Zero Net Energy" homes at Fallen Leaf were built by Treasure Homes to meet the requirements of the California Green Builder program[161]. Each home includes a 2.4kW DC photovoltaic integrated roofing system from BP Solar which, coupled with other energy efficient design features, produces almost as much electricity as it needs to power the house on an annual basis. 50% of the solar homes in Fallen Leaf oriented their photovoltaic systems to the south, achieving 99.9% efficiency. The other 50% of homes oriented the panels perpendicular to the roof spine, so panels on north-south oriented roofs performed at only 81-83% of optimal PV output. On average, these homes showed potential to gain an additional 410 kWh of annual energy generation with adjustments to the orientation of their PV panels.

Figure 71: The solar homes of Fallen Leaf employ different PV systems oriented to the south, east, and west

Image source: Google Maps © 2010 Google

[161] http://www.cagreenbuilder.org/

General Neighborhood Information							
Name:	Fallen Leaf	Location:	Natomas, CA	Climate Zone:	12	Date:	2008
Number of Single Family Homes:			32	Solar Oriented:		No	
Link:	http://www.bira.ws/projects/fallen-leaf.php						
Characteristics:	2.4 kW PV systems and energy efficiency measures						

Home Details	
Overall Home Efficiency:	30% reduction in cooling and 15% in heating from 2008 Title 24 standards
General Roof Types:	Gable, average 2.4 complexity
Other Notes:	PV panels installed on spacious south, east, and west roof faces

Solar Photovoltaic Energy Generation			
% of Homes with PV:	100%	Annual Energy Generation:	98,500 kWh
Typical PV Size:	2.4 kW	Average Neighborhood PV Efficiency:	91.0%

Solar Domestic Water Heating			
% of Homes with SWH:	0%	Collector Type:	N/A
Typical Collector Size:	N/A	Average SWH Generation Efficiency:	N/A

Figure 72: Fallen Leaf survey details

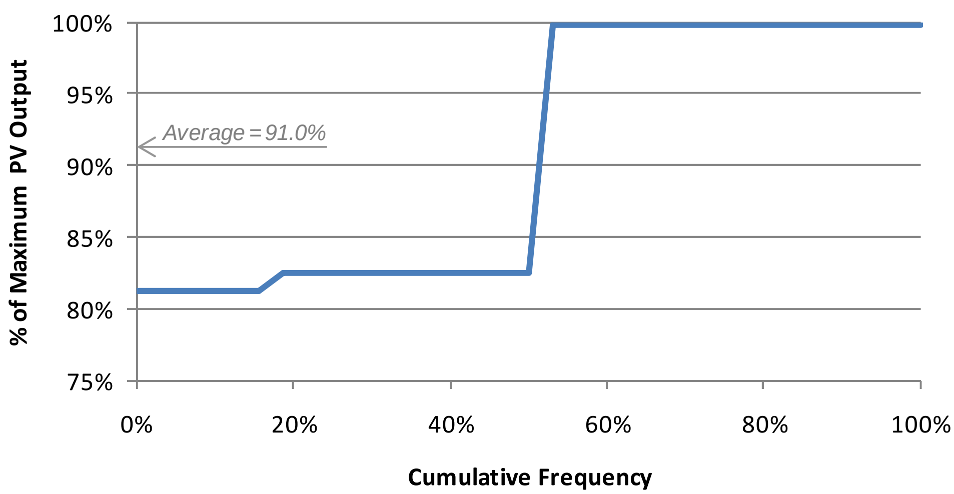


Figure 73: The cumulative frequency of PV performance in Fallen Leaf evaluated as the percentage of maximum photovoltaic output.

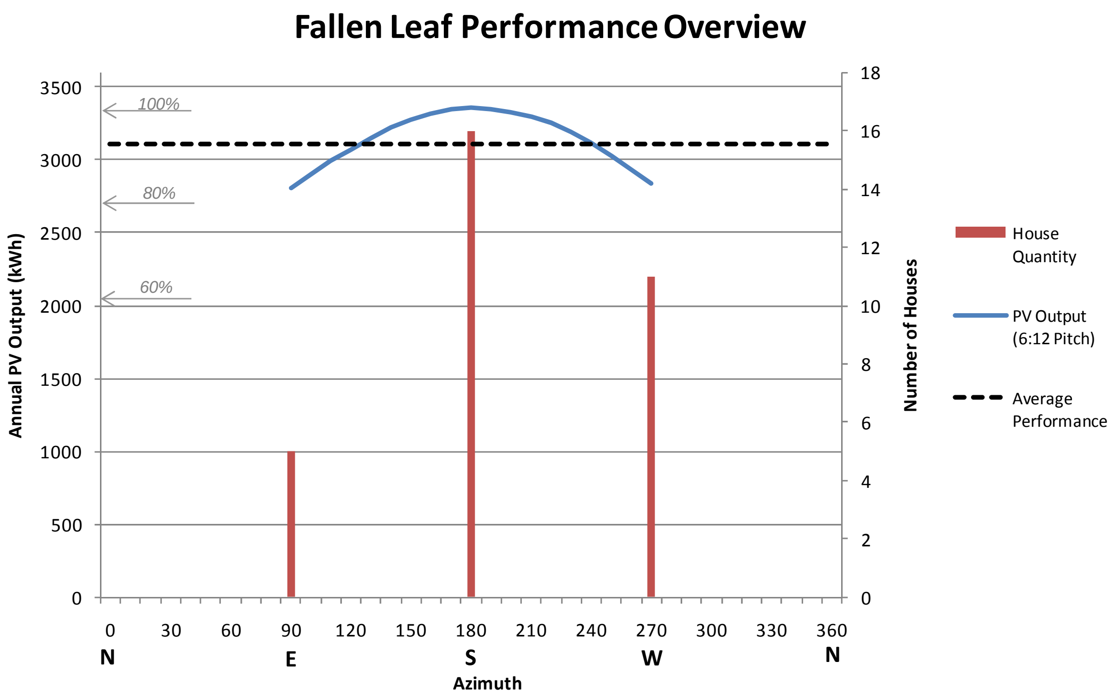


Figure 74: Fallen Leaf PV performance verses azimuth (Quantity of homes (red bars) overlaid with photovoltaic output against PV azimuth)

13.3.2 Rancho Cordova, CA: Premier Gardens

Figure 75: Premier Gardens with solar panels oriented to the south, east, or west.

Image source: Bing Maps © 2010 Microsoft Corporation

This 98 home community built by Premier Homes in Rancho Cordova combines mechanical and passive design features with 2.2 kW AC solar home power systems to save residents more than 60% of grid electricity use. The homes, without solar, would still use 22% less energy than those built to

2005 Title 24 standards. The solar panels are installed only on spacious roof faces and are oriented south for every home for which the roof shape allows. Because streets are aligned north-south and east-west, roof orientation and shape are the limiting factors in PV performance. Almost 60% of homes in Premier Gardens perform within 1% of optimal PV efficiency. The remainders perform at about 83-84% efficiency and at a 90 degree deviation from optimal orientation, leaving an annual average of 220 kWh of unused solar energy to be gained per home.

General Neighborhood Information							
Name:	Premier Gardens	Location:	Rancho Cordova, CA	Climate Zone:	12	Date:	2006
Number of Single Family Homes:			98	Solar Oriented:		No	
Link:	http://www.bira.ws/projects/premier-gardens.php						
Characteristics:	2.2 kW PV systems and energy efficiency measures						

Home Details	
Overall Home Efficiency:	Use 22% less energy than those built to 2005 Title 24 standards
General Roof Types:	Primarily gable, vary in complexity
Other Notes:	PV panels installed on spacious south, east, and west roof faces

Solar Photovoltaic Energy Generation			
% of Homes with PV:	100%	Annual Energy Generation:	272,800 kWh
Typical PV Size:	2.2 kW	Average Neighborhood PV Efficiency:	92.8%

Solar Domestic Water Heating			
% of Homes with SWH:	0%	Collector Type:	N/A
Typical Collector Size:	N/A	Average SWH Generation Efficiency:	N/A

Figure 76: Premier Gardens survey details

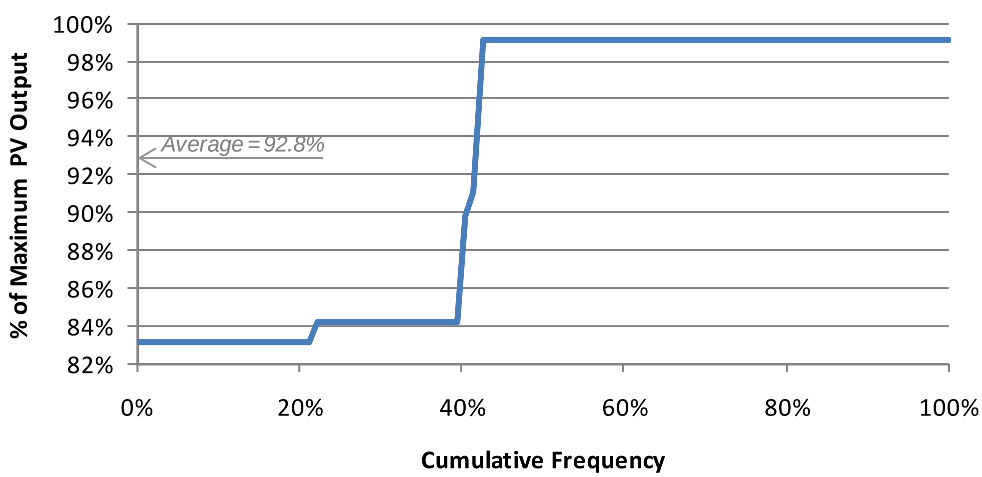


Figure 77: The cumulative frequency of PV performance in Premier Gardens evaluated as the percentage of maximum photovoltaic output.

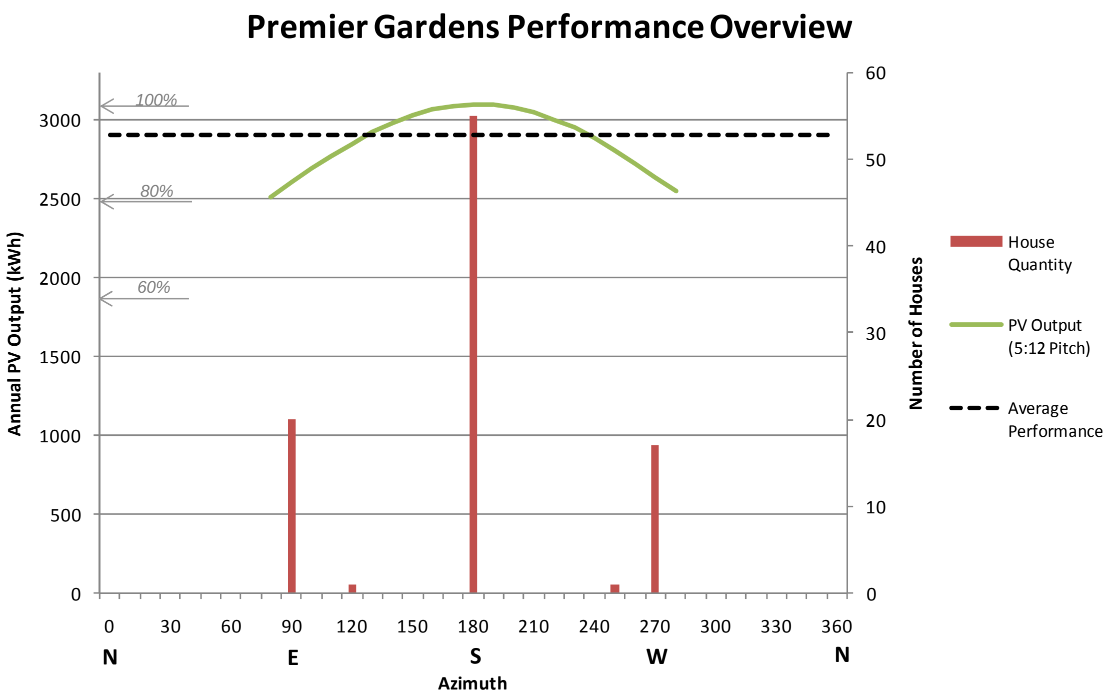


Figure 78: Premier Gardens' PV performance verses azimuth (Quantity of homes (red bars) overlaid with photovoltaic output against PV azimuth)

13.3.3 Watsonville, CA: Vista Montaña

Figure 79: Vista Montaña solar homes are installed with PV systems that vary in size, shape, and orientation. No solar panels face the lot entrance and street.

Image source: Bing Maps © 2010 Microsoft Corporation

Summary

In 2005 in Watsonville, CA, Clarum Homes built 257 residences, of which 177 were single-family homes, to use nearly zero net energy. All homes have a solar PV system powering between 1.2 and 2.4 kW, and implement a range of energy efficiency measures such as radiant roof and wall barriers, high-efficiency windows, tankless water heaters, sealed ducts, and fluorescent light bulbs to reduce household energy use by 60-90%. Almost all of the panels are oriented approximately south, east, and west, but *none* are oriented to face the street. For each of 38 homes (22%) with lots that face approximately south, 14%-31% of potential solar generation is remised for aesthetic purposes. One house is a particular outlier in that its PV panels are oriented within 15 degrees of north. A total of 41,200 kWh of solar energy, averaging 240 kWh per house, is left unharnessed due to the orientation of the solar panels.

General Neighborhood Information							
Name:	Vista Montana	Location:	Watsonville, CA	Climate Zone:	3	Date:	2005
Number of Single Family Homes:			177	Solar Oriented:		No	
Link:	http://www.bira.ws/projects/vista-montana.php						
Characteristics:		1.2 to 2.4 kW PV systems and efficiency measures					

Home Details	
Overall Home Efficiency:	Designed to save 60-90% in grid energy usage
General Roof Types:	Hip, average 2.2 complexity
Other Notes:	PV panels installed only on roof faces oriented away from street

Solar Photovoltaic Energy Generation			
% of Homes with PV:	100%	Annual Energy Generation:	382,200 kWh
Typical PV Size:	1.2-2.4 kW	Average Neighborhood PV Efficiency:	90.3%

Solar Domestic Water Heating			
% of Homes with SWH:	0%	Collector Type:	N/A
Typical Collector Size:	N/A	Average SWH Generation Efficiency:	N/A

Figure 80: Vista Montana survey details

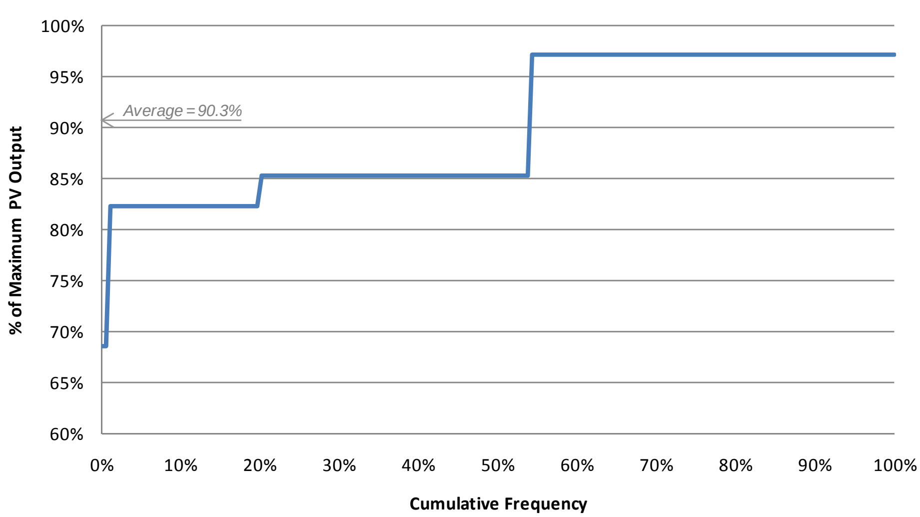


Figure 81: The cumulative frequency of PV performance in Vista Montaña evaluated as the percentage of maximum photovoltaic output.

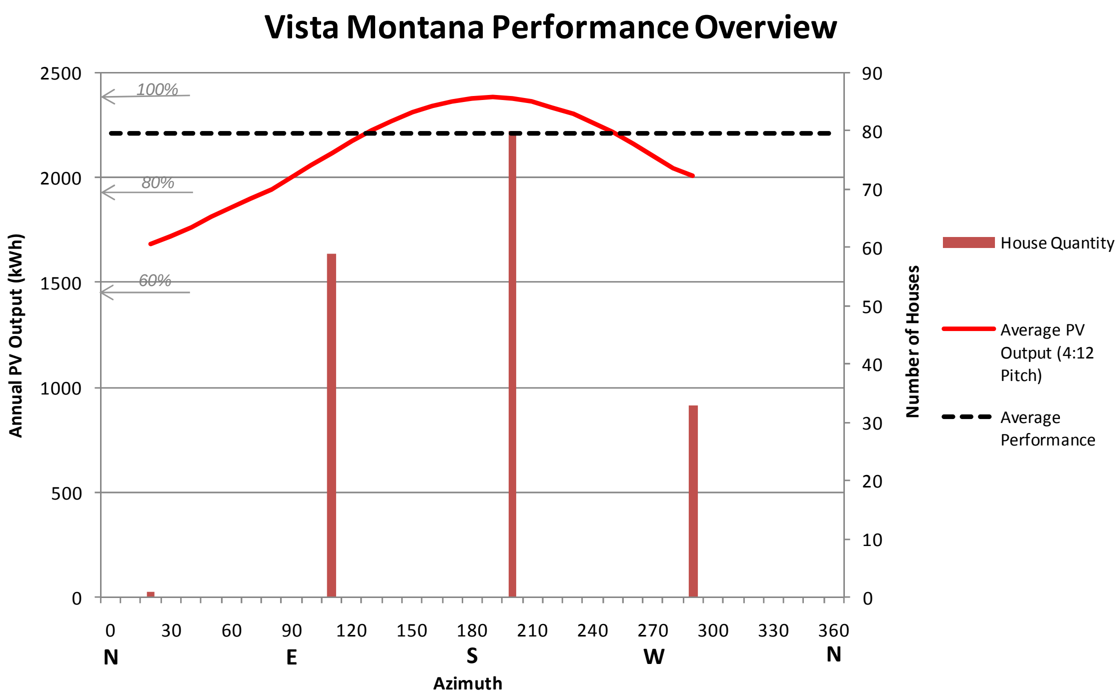


Figure 82: Vista Montana PV performance verses azimuth (Quantity of homes (red bars) overlaid with photovoltaic output against PV azimuth)

13.3.4 Pleasanton, CA: Avignon

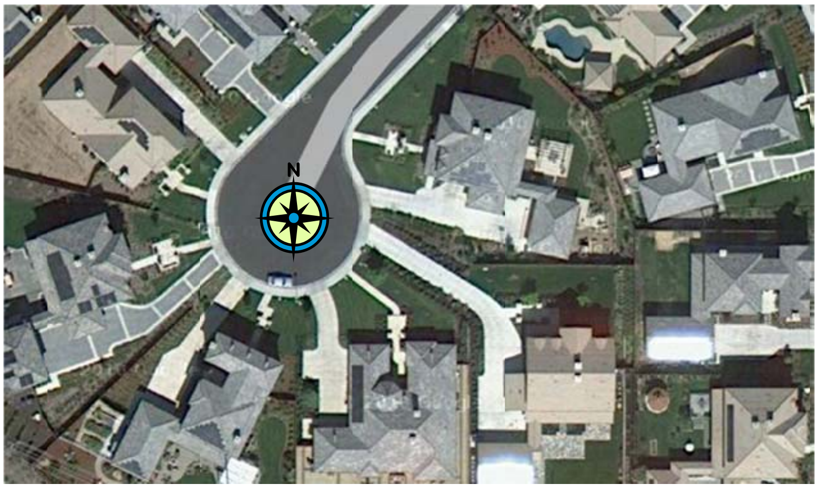


Figure 83: Estate homes in Avignon use large PV systems without orienting the neighborhood for solar design.

Image source: Google Maps © 2010 Google

Summary

Centex Homes' Avignon development consists of 32 larger estate homes containing 3.5 kW PV systems designed to reduce total energy bills by 70%. They are designed to draw no more than 1 kW of electricity during peak times, and include energy efficiency measures that allow the homes to exceed California's 2005 Title 24 requirements by at least 15%. While the layout is not designed for solar generation, the average PV orientation deviates only 39 degrees from optimal for 94% efficiency. Avignon's panels still leave an annual average of 300 kWh of energy unharnessed. Both the neighborhood layout and roof shape/orientation negatively contribute to photovoltaic performance.

General Neighborhood Information							
Name:	Avignon	Location:	Pleasanton, CA	Climate Zone:	12	Date:	2006
Number of Single Family Homes:			30	Solar Oriented:		No	
Link:	http://www.bira.ws/projects/avignon.php						
Characteristics:		3.5 kW PV systems and efficiency measures					

Home Details	
Overall Home Efficiency:	Exceeds Title 24 code by 15-25% and meets Building America standards
General Roof Types:	Primarily hip, some gable, average 3.1 complexity
Other Notes:	No uniformity in housing orientations, PV typically southward

Solar Photovoltaic Energy Generation			
% of Homes with PV:	100%	Annual Energy Generation:	142,400 kWh
Typical PV Size:	3.5 kW	Average Neighborhood PV Efficiency:	94.0%

Solar Domestic Water Heating			
% of Homes with SWH:	20%	Collector Type:	Pool heaters
Typical Collector Size:	400 ft^2	Average SWH Generation Efficiency:	**

Figure 84: Avignon survey details

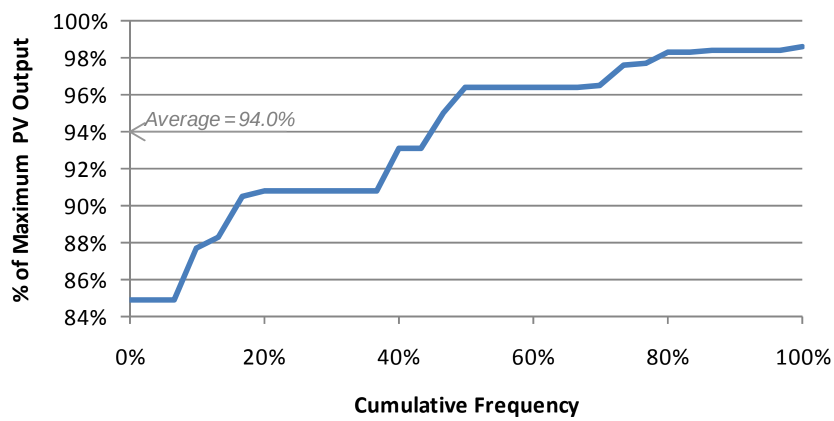


Figure 85: The cumulative frequency of PV performance in Avignon evaluated as the percentage of maximum photovoltaic output.

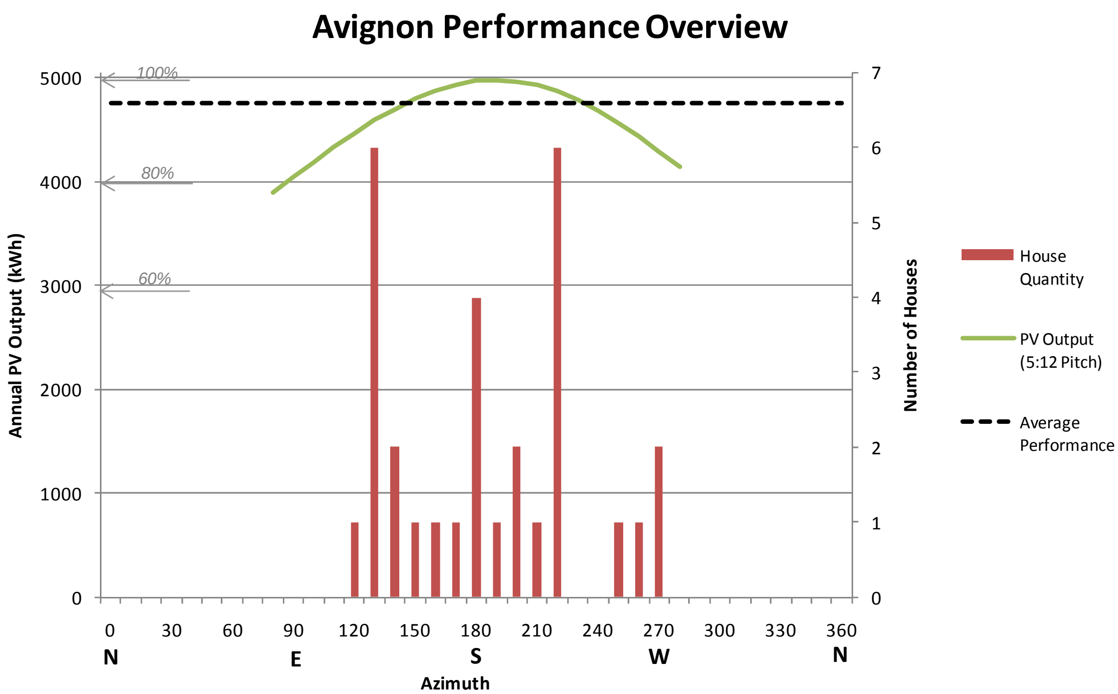


Figure 86: Avignon PV performance verses azimuth (Quantity of homes (red bars) overlaid with photovoltaic output against PV azimuth)

13.3.5 Redding, CA: Sonata

Figure 87: The solar homes of Sonata under construction

Image source: Bing Maps © 2010 Microsoft Corporation

Summary

Seastar Communities built and designed the 84 single-family home development of Sonata to exceed 2005 Title 24 energy cooling standards by 50% and current energy efficiency practice by over 20%.

Home designs implement a range of efficiency measures and include a 2 kW solar electric home power system to allow owners to save around 50% on utilities. Due to the housing collapse, however, Seastar was forced to put the development up for auction in 2008. The street layout does not orient homes with any uniformity, yet the solar panels are oriented towards south when the roof shape and orientation allows. The average PV orientation deviation from optimal is 49 degrees. With an average 91% PV efficiency, homes showed the potential to gain 250 kWh of energy annually on average by means of effective PV orientation.

General Neighborhood Information							
Name:	Sonata	Location:	Redding, CA	Climate Zone:	11	Date:	2006
Number of Single Family Homes:			15 (incomplete)	Solar Oriented:		No	
Link:	http://www.bira.ws/projects/sonata.php						
Characteristics:		2 kW PV systems and efficiency measures					

Home Details	
Overall Home Efficiency:	Exceeds Title 24 cooling energy code by 50%
General Roof Types:	Hip, complex
Other Notes:	No uniformity in housing orientations, PV typically faces southward

Solar Photovoltaic Energy Generation			
% of Homes with PV:	100%	Annual Energy Generation:	38,200 kWh
Typical PV Size:	2 kW	Average Neighborhood PV Efficiency:	90.9%

Solar Domestic Water Heating			
% of Homes with SWH:	0	Collector Type:	N/A
Typical Collector Size:	N/A	Average SWH Generation Efficiency:	N/A

Figure 88: Sonata survey details

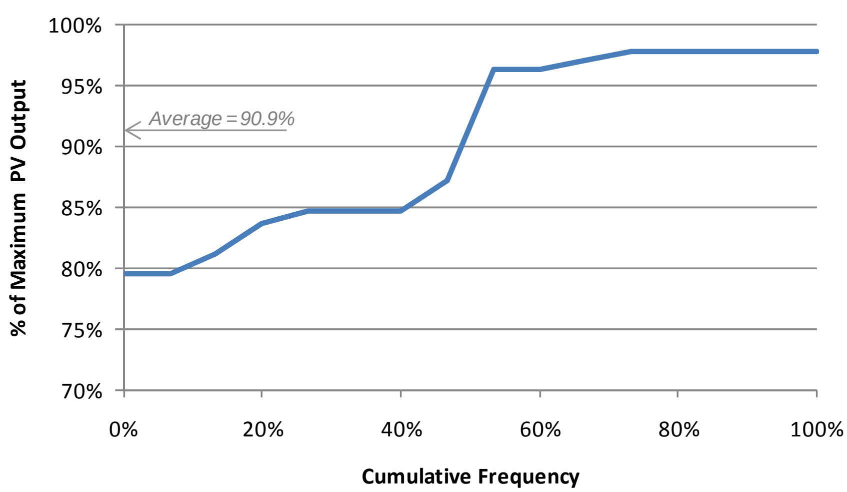


Figure 89: The cumulative frequency of PV performance in Sonata evaluated as the percentage of maximum photovoltaic output.

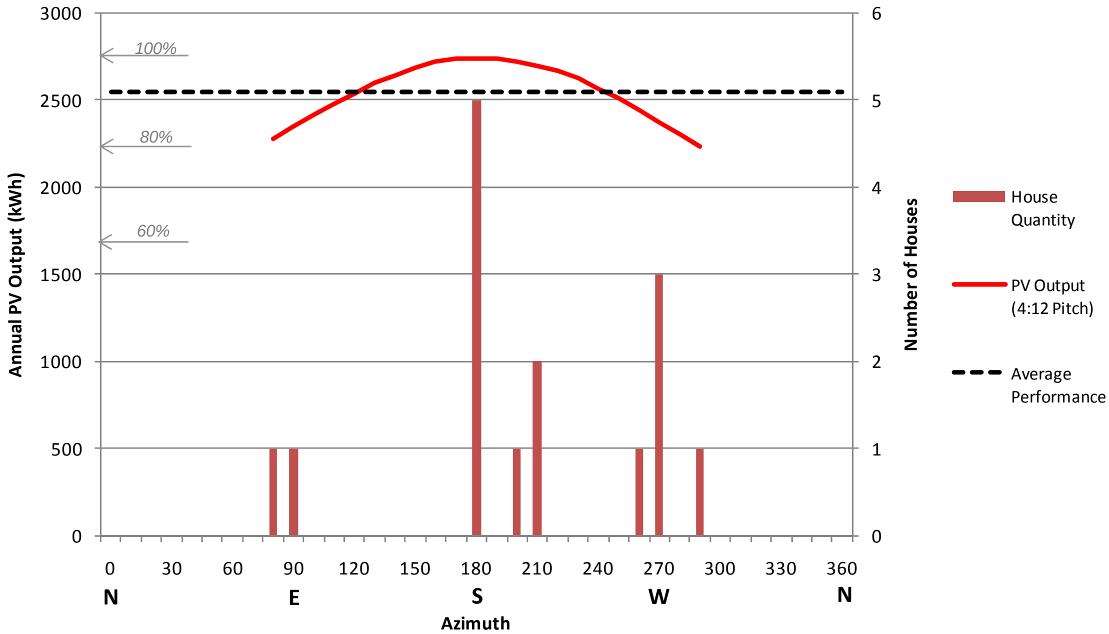


Figure 90: Sonata PV performance verses azimuth (Quantity of homes (red bars) overlaid with photovoltaic output against PV azimuth)

13.3.6 Roseville, CA: Premier Oaks

Figure 91: Premier Oaks neighborhood

Image source: Bing Maps © 2010 Microsoft Corporation

Summary

Premier Homes' second standard ZNE community, Premier Oaks, is built upon a single north-south oriented street with cul-de-sacs on either end. Each house is designed to save 60% of all utilities costs using energy efficiency features including Energy Star appliances and a 2 kW AC solar electric home power system. The north-south neighborhood layout generally allows the solar panels to be oriented to the south, so the average PV orientation deviation from optimal is only 19 degrees and this development performs best of the non-solar-oriented communities. Of the worst 9 performing homes, 4-5 residences have simply remised the opportunity to optimize PV despite that their roof shape/orientation appears to allow for southern orientation. An average of 110 kWh of energy remains to be gained annually by orienting PV panels southwards.

General Neighborhood Information							
Name:	Premier Oaks	Location:	Roseville, CA	Climate Zone:	12	Date:	2006
Number of Single Family Homes:			47	Solar Oriented:		No	
Link:	http://www.bira.ws/projects/premier-oaks.php						
Characteristics:		2 kW PV systems and efficiency measures					

Home Details	
Overall Home Efficiency:	Designed to save 60% of utilities costs
General Roof Types:	Primarily hip, complex, some gable
Other Notes:	One street, oriented north-south

Solar Photovoltaic Energy Generation			
% of Homes with PV:	100%	Annual Energy Generation:	127,300 kWh
Typical PV Size:	2 kW	Average Neighborhood PV Efficiency:	96.1%

Solar Domestic Water Heating			
% of Homes with SWH:	0	Collector Type:	N/A
Typical Collector Size:	N/A	Average SWH Generation Efficiency:	N/A

Figure 92: Premier Oaks survey details

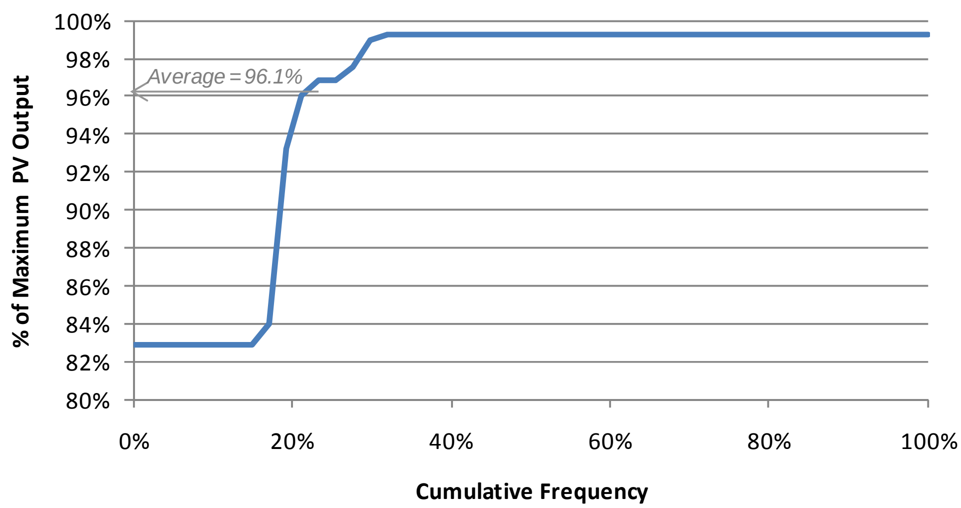


Figure 93: The cumulative frequency of PV performance in Premier Oaks evaluated as the percentage of maximum photovoltaic output.

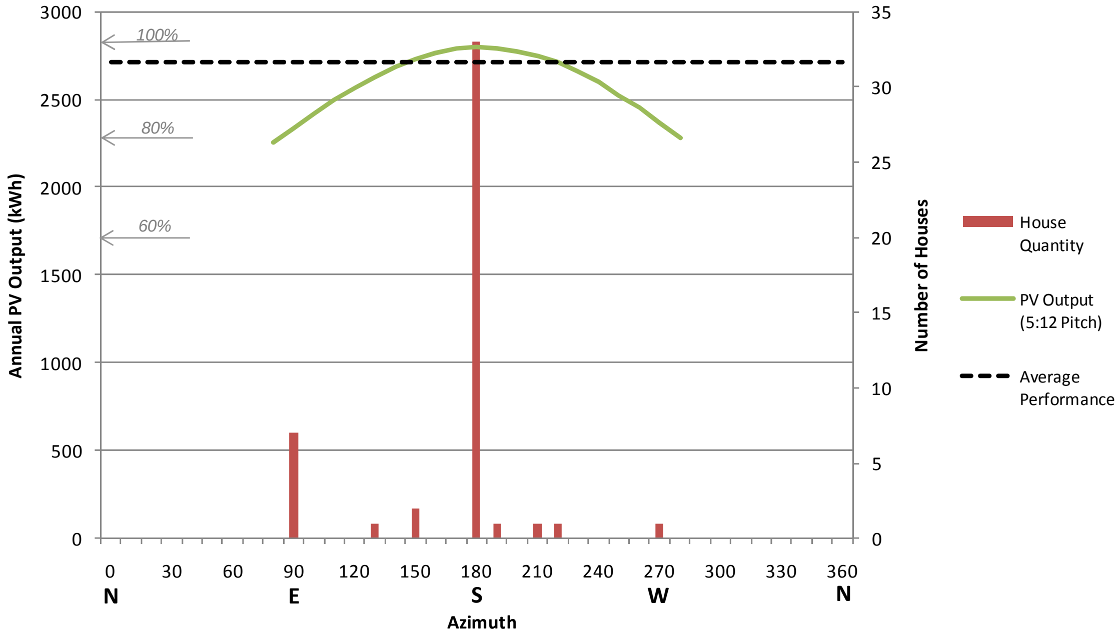


Figure94: Premier Oaks PV performance verses azimuth (Quantity of homes (red bars) overlaid with photovoltaic output against PV azimuth)

13.3.7 San Diego, CA: Tiempo

Figure 95: Tiempo neighborhood

Image source: Bing Maps © 2010 Microsoft Corporation

Summary

Shea Homes built the solar neighborhoods Tiempo and San Angelo, totaling 306 homes, in Scripps Highlands of San Diego in 2001, of which Tiempo comprises 287 homes. The homes are built to exceed 2001 Title 24 standards by 38%, allowing homeowners to reduce their overall utilities costs by 30% to 50%. In addition, Shea provided solar hot water heaters to each home in Tiempo and 1.2-2.4

kW solar electric systems to 41% of homes in the development. 9% of homes are outfitted with pool water heaters of varying size. The development is primarily curvilinear, displaying a relatively wide range of lot and PV orientations and limiting PV output. Roof shape, orientation, and complexity often require split PV systems and play a role in reducing solar energy generation potential, yet Tiempo's average PV orientation deviation from optimal by only 33 degrees to make it the second best performing development without solar orientation in this report. An average of only 100 kWh per home of solar electricity is not unharnessed annually.

General Neighborhood Information							
Name:	Tiempo	Location:	San Diego, CA	Climate Zone:	7	Date:	2001
Number of Single Family Homes:			287	Solar Oriented:		No	
Link:	http://www.toolbase.org/PDF/CaseStudies/ZEH_NRELfarhar2.pdf						
Characteristics:		1.2-2.4 kW PV systems and efficiency measures					

Home Details	
Overall Home Efficiency:	Designed to exceed 2001 Title 24 standards by 38%
General Roof Types:	Primarily hip, complex, some gable
Other Notes:	Curvilinear neighborhood orientation, SDWH standard

Solar Photovoltaic Energy Generation			
% of Homes with PV:	41%	Annual Energy Generation:	236,200 kWh
Typical PV Size:	1.2-2.4 kW	Average Neighborhood PV Efficiency:	95.0%

Solar Domestic Water Heating			
% of Homes with SWH:	100%	Collector Type:	Flat panel
Typical Collector Size:	40 sqft.	Average SWH Generation Efficiency:	**

Figure 96: Tiempo survey details

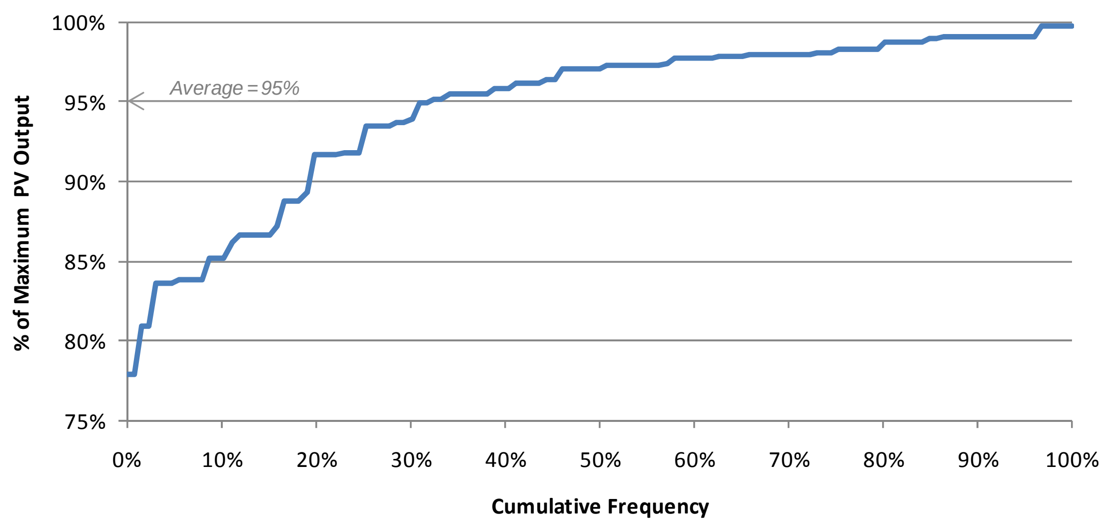


Figure 97: The cumulative frequency of PV performance in Tiempo evaluated as the percentage of maximum photovoltaic output.

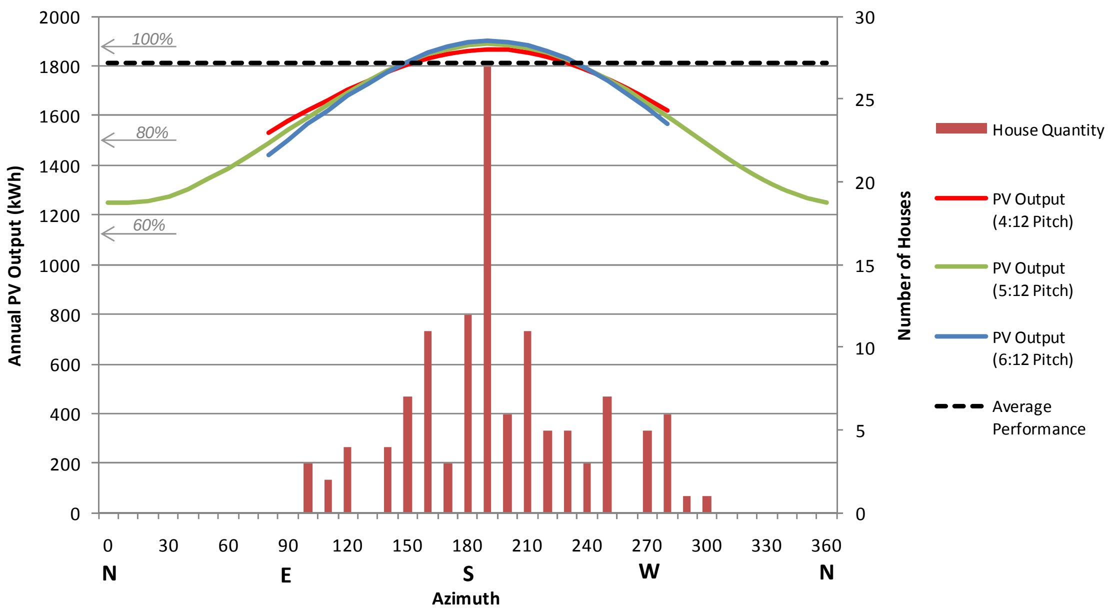


Figure 98: Tiempo PV performance verses azimuth (Quantity of homes (red bars) overlaid with photovoltaic output against PV azimuth)

13.3.8 Rocklin, CA: Carsten Crossings

Figure 99: Solar homes in Carsten Crossings

Image source: Google Maps © 2010 Google

Summary

Built by Grupe, the 144 homes in the Carsten Crossings neighborhood are built with 2.4 kW solar roof tile electric power systems and designed with additional efficiency measures to exceed Title 24 standards by 36%. A lack of recent photographs limited the survey and analysis to only 53 of the 144 total houses in the neighborhood. 58% of PV panels were oriented south, and 32% were oriented west for an average collector efficiency of 93%. Homes are limited in PV efficiency by roof shape, orientation, and complexity. On some houses, panels are shaded to a small degree from protrusions in the complex roof shape. On average, houses leave 240 kWh of unharnessed solar energy annually due to PV orientation.

General Neighborhood Information							
Name:	Carsten Crossings	Location:	Rocklin, CA	Climate Zone:	12	Date:	2008
Number of Single Family Homes:			144	Solar Oriented:		No	
Link:	http://www.pvdatabase.org/urban_view_details.php?ID=19						
Characteristics:	2.4 kW PV systems and efficiency measures						

Home Details	
Overall Home Efficiency:	Exceed 2008 Title 24 Standards by 36%
General Roof Types:	Hip, gable, low complexity
Other Notes:	Neighborhood oriented in a loop

Solar Photovoltaic Energy Generation			
% of Homes with PV:	100%	Annual Energy Generation:	453,000 kWh
Typical PV Size:	2.4 kW	Average Neighborhood PV Efficiency:	93.0%

Solar Domestic Water Heating			
% of Homes with SWH:	0%	Collector Type:	N/A
Typical Collector Size:	N/A	Average SWH Generation Efficiency:	N/A

Figure 100: Carsten Crossings survey details

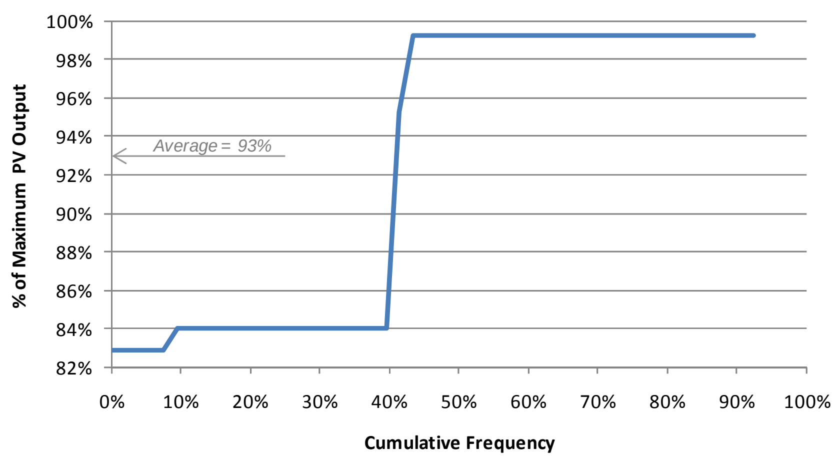


Figure 101: The cumulative frequency of PV performance in Carsten Crossings evaluated as the percentage of maximum photovoltaic output.

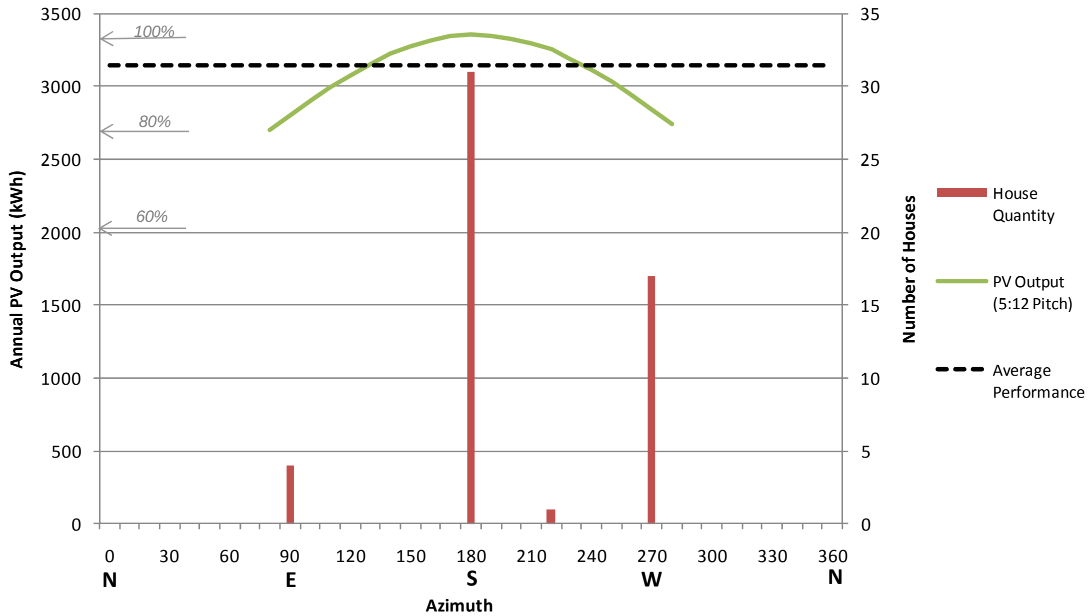


Figure 102: Carsten Crossings PV performance verses azimuth (Quantity of homes (red bars) overlaid with photovoltaic output against PV azimuth)

13.3.9 Ladera Ranch, CA: The Terramor Developments

Figure 103: Three solar communities in Terramor, Ladera Ranch

Image source: Google Maps © 2010 Google

Of 1,156 total homes, over 450 of the houses in the village of Terramor have PV for electric energy systems installed. Constructed by 10 different builders, the community has a variety of sustainable features that make its houses on average 20% more energy and water efficient than comparable conventional homes. The developments of Terramor average a 48 degree PV orientation from optimal, and perform just below average amongst surveyed neighborhoods. PV performance analyses were conducted for each major builder separately, and are discussed in the following sections.

General Neighborhood Information							
Name:	Tarleton	Location:	Ladera Ranch, CA	Climate Zone:	6	Date:	2004
Number of Single Family Homes:			1156	Solar Oriented:		No	
Link:	http://www.laderaranch.com						
Characteristics:		PV systems and efficiency measures					
Home Details							
Overall Home Efficiency:		**					
General Roof Types:		Gable, hip, and complex					
Other Notes:		Follows a variety of grid and curvilinear street layouts					
Solar Photovoltaic Energy Generation							
% of Homes with PV:	40.3%	Annual Energy Generation:		961,600 kWh			
Typical PV Size:	1.0-2.4 kW	Average Neighborhood PV Efficiency:		91.3%			
Solar Domestic Water Heating							
% of Homes with SWH:	0.3%	Collector Type:	Pool heaters				
Typical Collector Size:	200 sqft.	Average SWH Generation Efficiency:		**			

Figure 104: Tarleton survey details

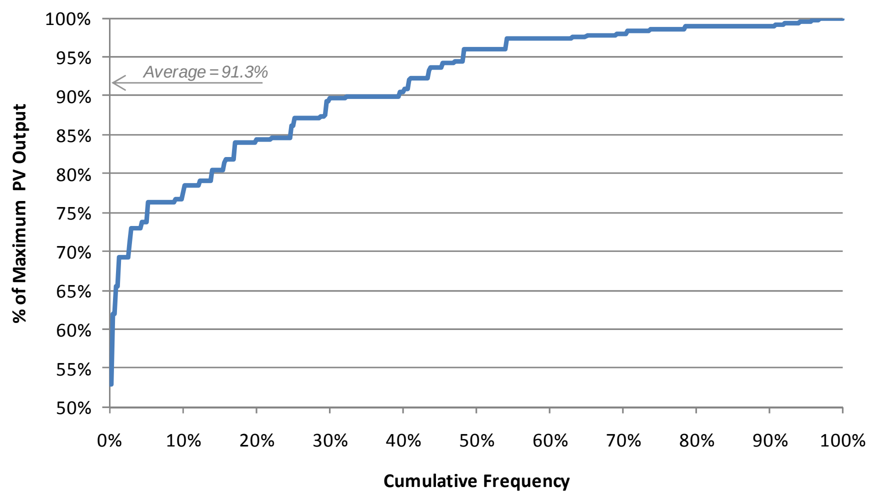


Figure 105: The cumulative frequency of PV performance in Terramor evaluated as the percentage of maximum photovoltaic output.

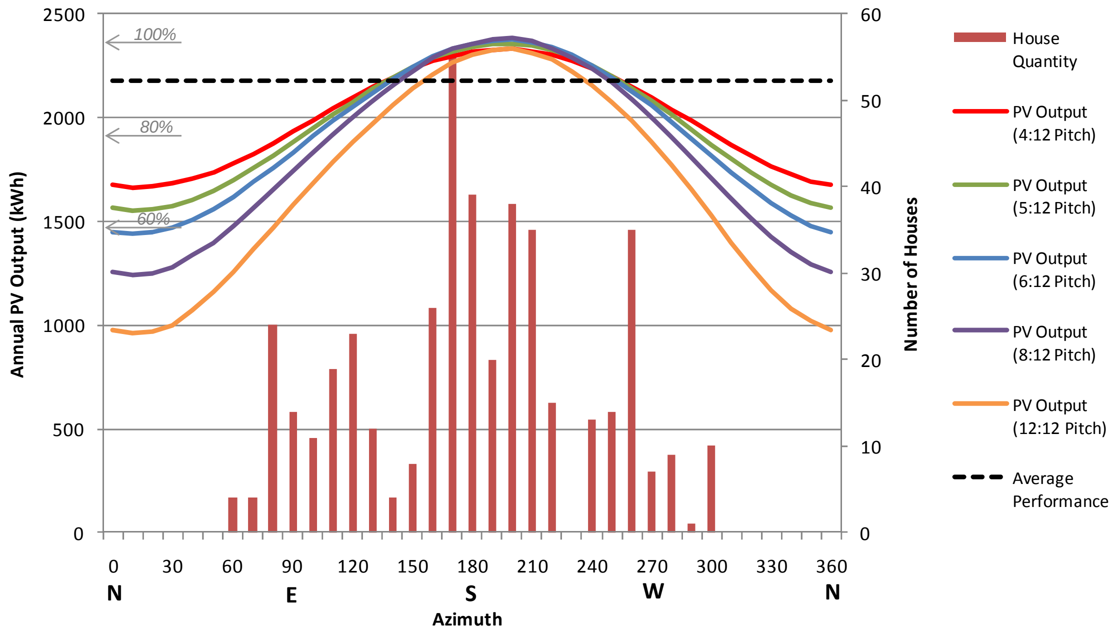
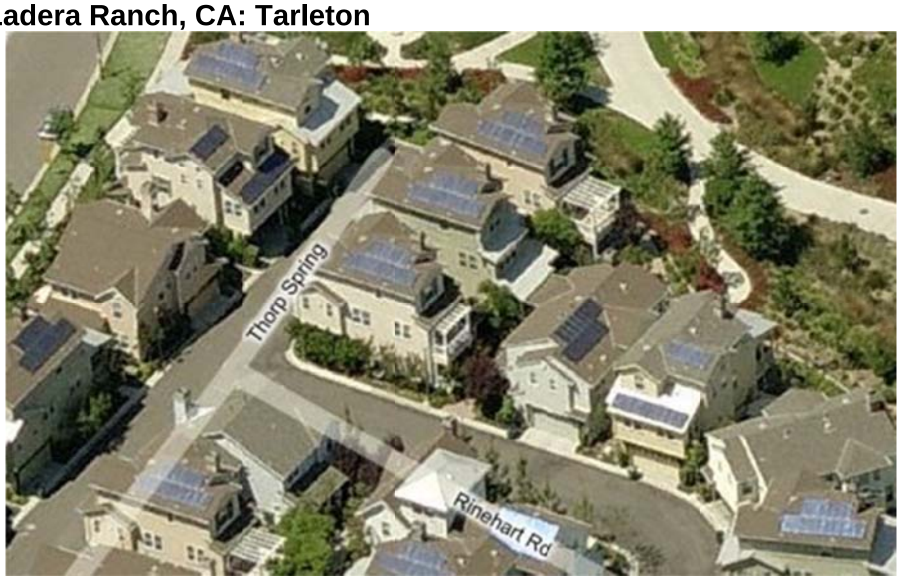


Figure 106: Terramor PV performance verses azimuth (Quantity of homes (red bars) overlaid with photovoltaic output against PV azimuth)

13.3.10 Ladera Ranch, CA: Tarleton



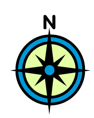


Figure 107: The solar houses of Tarleton are shown above, built by DR Horton

Image source: Bing Maps © 2010 Microsoft Corporation

Summary

Built by DR Horton, the Tarleton development of the Terramor neighborhood has a relatively curvilinear layout that does not orient streets for solar access. Despite that 60% of homes orient solar panels within 30 degrees of a 180 degree azimuth, Tarleton performs poorly overall in panel orientation due to limitations in the street layout, roof orientations, and steep roof pitches. PV output is significantly more sensitive to orientation when steep roof pitches are involved, so panels oriented east perform at approximately 75% rather than 83% for a 5:12 roof pitch. It was also observed that on more complex homes, protrusions in the roof shape subjected some solar panels to shading at certain parts of the day, further decreasing performance. Amongst Tarleton's solar homes, it is estimated that an average of 220 kWh of solar energy is left unharnessed annually due to the orientation of solar panels.

General Neighborhood Information							
Name:	Tarleton	Location:	Ladera Ranch, CA	Climate Zone:	6	Date:	2004
Number of Single Family Homes:			142	Solar Oriented:		No	
Link:	http://www.laderaranch.com						
Characteristics:		1.6 kW PV systems and efficiency measures					

Home Details	
Overall Home Efficiency:	**
General Roof Types:	Gable, complex
Other Notes:	Generally follows a "loops and lollipops" style street layout

Solar Photovoltaic Energy Generation			
% of Homes with PV:	53%	Annual Energy Generation:	162,600 kWh
Typical PV Size:	1.6 kW	Average Neighborhood PV Efficiency:	90.6%

Solar Domestic Water Heating			
% of Homes with SWH:	0%	Collector Type:	N/A
Typical Collector Size:	N/A	Average SWH Generation Efficiency:	N/A

Figure 108: Tarleton survey details

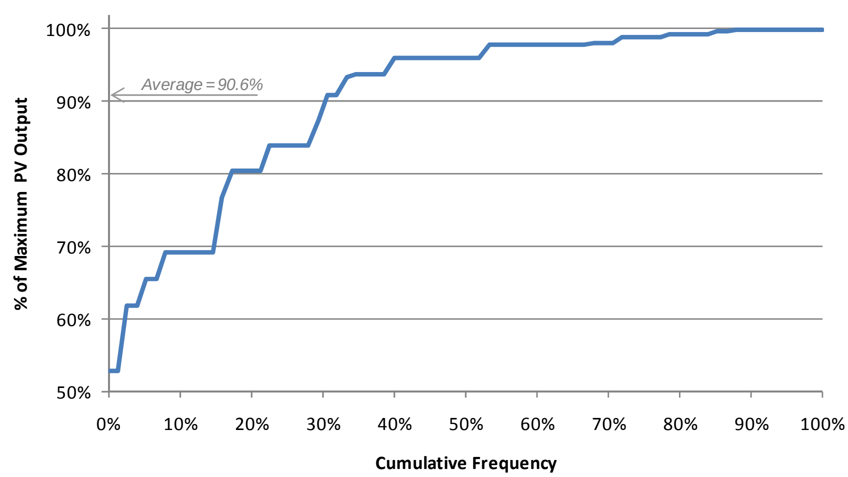


Figure 109: The cumulative frequency of PV performance in Terramor's Tarleton development evaluated as the percentage of maximum photovoltaic output.

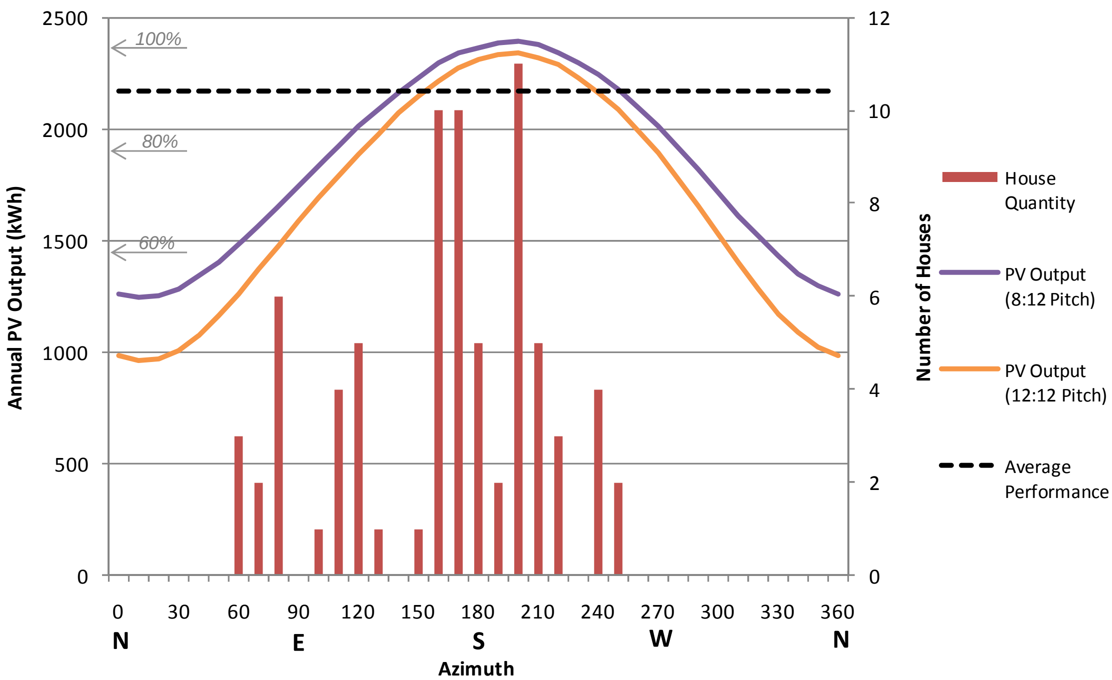


Figure 110: Tarleton PV performance verses azimuth (Quantity of homes (red bars) overlaid with photovoltaic output against PV azimuth)

13.3.11 Ladera Ranch, CA: Arborage

Figure 111: The solar houses of Arborage, built by Richmond American

Image source: Bing Maps © 2010 Microsoft Corporation

Summary

Built by Richmond American Homes, Terramor's Arborage development orients 40% of its solar panels directly south, yet achieves below average performance due to east and west oriented panels and steep roof pitches. Street layouts and roof shape/orientation are both limiting factors in panel orientation. It was observed that some panels were subject to minimal shading from chimneys, which lowers PV performance beyond the scope of this analysis. Approximately 150 kWh of energy is estimated to be lost annually due to PV orientation per solar house in this community.

General Neighborhood Information							
Name:	Arborage	Location:	Ladera Ranch, CA	Climate Zone:	6	Date:	2004
Number of Single Family Homes:			104	Solar Oriented:		No	
Link:	http://www.laderaranch.com						
Characteristics:		1.2 kW PV systems and efficiency measures					
Home Details							
Overall Home Efficiency:		**					
General Roof Types:		Gable, complex					
Other Notes:		Generally follows a "lollipops on a stick" style street layout					
Solar Photovoltaic Energy Generation							
% of Homes with PV:		28%	Annual Energy Generation:		65,600 kWh		
Typical PV Size:		1.2 kW	Average Neighborhood PV Efficiency:		91.4%		
Solar Domestic Water Heating							
% of Homes with SWH:		0%	Collector Type:		N/A		
Typical Collector Size:		N/A	Average SWH Generation Efficiency:		N/A		

Figure 112: Arborage survey details

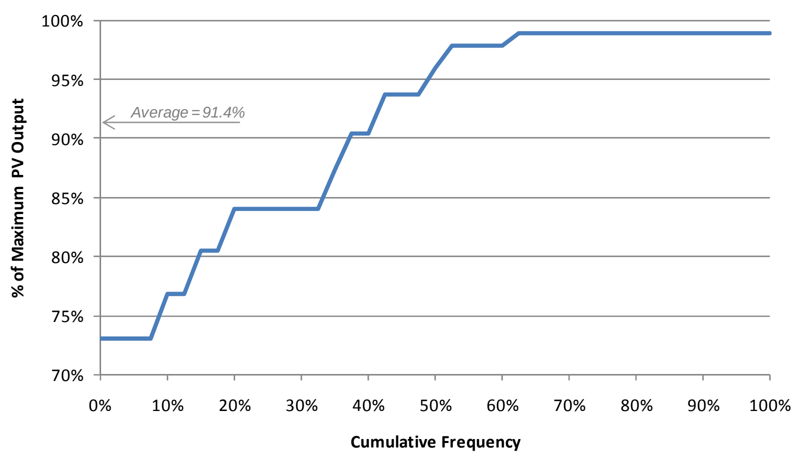


Figure 113: The cumulative frequency of PV performance in Terramor's Arborage development evaluated as the percentage of maximum photovoltaic output.

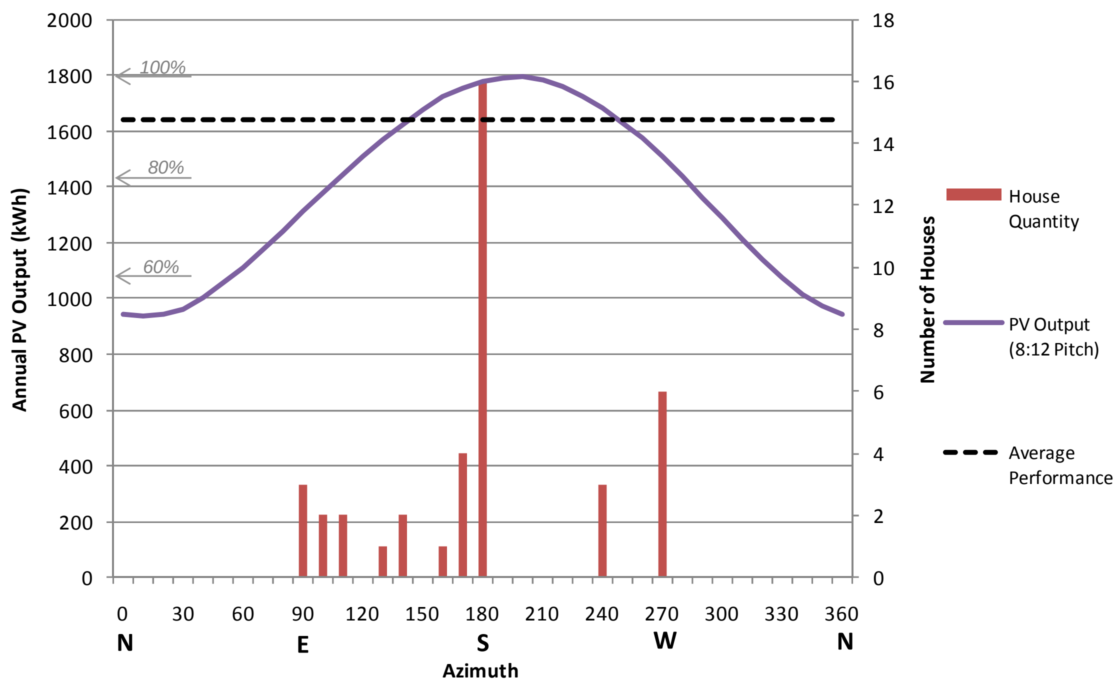


Figure 114: Arborage PV performance verses azimuth (Quantity of homes (red bars) overlaid with photovoltaic output against PV azimuth)

13.3.12 Ladera Ranch, CA: Claiborne

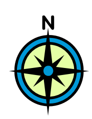


Figure 115: The solar houses of Claiborne, built by Pulte Homes

Image source: Bing Maps © 2010 Microsoft Corporation

Built by Pulte Homes, Terramor’s Claiborne development is laid out approximately as a grid angled slightly east of south. Of a flatter roof pitch, the solar homes of this development perform with less sensitivity to orientation than the homes of Tarleton or Arborage, and therefore achieve a higher average efficiency despite that Claiborne displays a wide 52 degree average distribution of PV orientation from optimal. As can be observed in Figure 115, shading from protrusions in roof shapes will decrease the performance of some solar panels at certain times of day. For each solar home in the development, an average of 150 kWh of solar electricity is unharnessed due to orientation.

General Neighborhood Information							
Name:	Claiborne	Location:	Ladera Ranch, CA	Climate Zone:	6	Date:	2004
Number of Single Family Homes:			74	Solar Oriented:		No	
Link:	http://www.laderaranch.com						
Characteristics:		1.2 kW PV systems and efficiency measures					
Home Details							
Overall Home Efficiency:		**					
General Roof Types:		Hip, gable, and complex					
Other Notes:		Follows a trapezoidal loop street layout					
Solar Photovoltaic Energy Generation							
% of Homes with PV:		97%	Annual Energy Generation:		118,700 kWh		
Typical PV Size:		1.2 kW	Average Neighborhood PV Efficiency:		91.9%		
Solar Domestic Water Heating							
% of Homes with SWH:		0%	Collector Type:		N/A		
Typical Collector Size:		N/A	Average SWH Generation Efficiency:		N/A		

Figure 116: Claiborne survey details

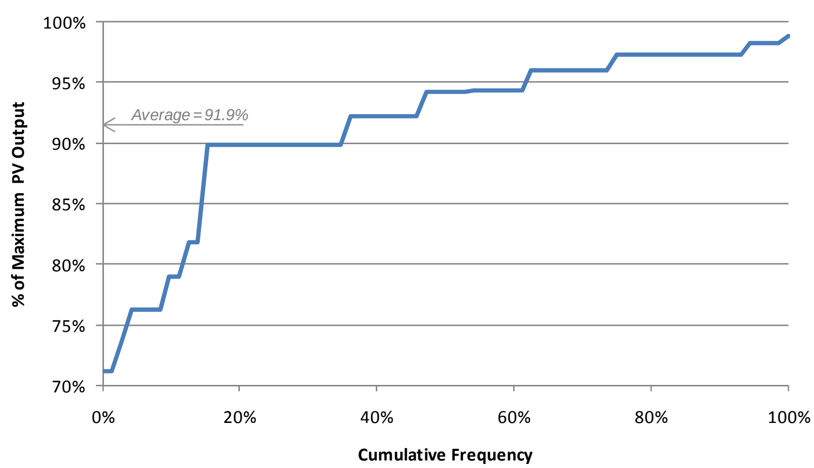


Figure 117: The cumulative frequency of PV performance in Terramor's Claiborne development evaluated as the percentage of maximum photovoltaic output.

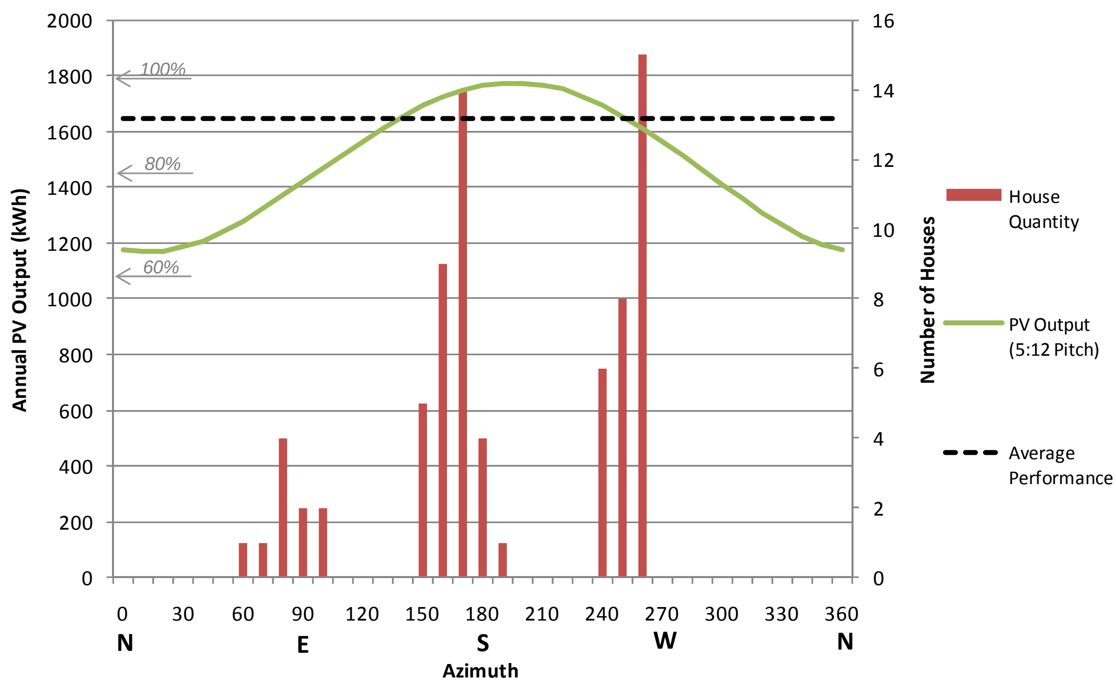


Figure 118: Claiborne PV performance verses azimuth (Quantity of homes (red bars) overlaid with photovoltaic output against PV azimuth)

13.3.13 Ladera Ranch, CA: Sedona

Figure 119: The solar houses of Sedona (a part of Terramor), built by Shea Homes

Image source: Bing Maps © 2010 Microsoft Corporation

Built by Shea Homes, the Sedona development of Terramor does not trend significantly toward south-facing PV and averages a 48 degree PV orientation deviation from optimal. With only half of lot orientations within 15 degrees of NE-SW or NW-SE, the street layout is somewhat responsible for PV orientation losses. In addition, the large 2.4 kW panels require spacious roof surfaces, so roof shape and orientation are limiting factors in PV performance. Minimal shading from steep protrusions in roof shape and chimneys further decreases performance in some homes. 300 kWh of solar energy is remised annually due to PV orientation.

General Neighborhood Information							
Name:	Sedona	Location:	Ladera Ranch, CA	Climate Zone:	6	Date:	2004
Number of Single Family Homes:			79	Solar Oriented:		No	
Link:	http://www.laderaranch.com						
Characteristics:	2.4 kW PV systems and efficiency measures						

Home Details	
Overall Home Efficiency:	**
General Roof Types:	Gable, hip, high complexity
Other Notes:	Generally follows a “lollipops on a stick” style street layout

Solar Photovoltaic Energy Generation			
% of Homes with PV:	100%	Annual Energy Generation:	274,600 kWh
Typical PV Size:	2.4 kW	Average Neighborhood PV Efficiency:	91.6%

Solar Domestic Water Heating			
% of Homes with SWH:	6.8%	Collector Type:	Pool heaters
Typical Collector Size:	200 sqft.	Average SWH Generation Efficiency:	**

Figure 120: Sedona survey details

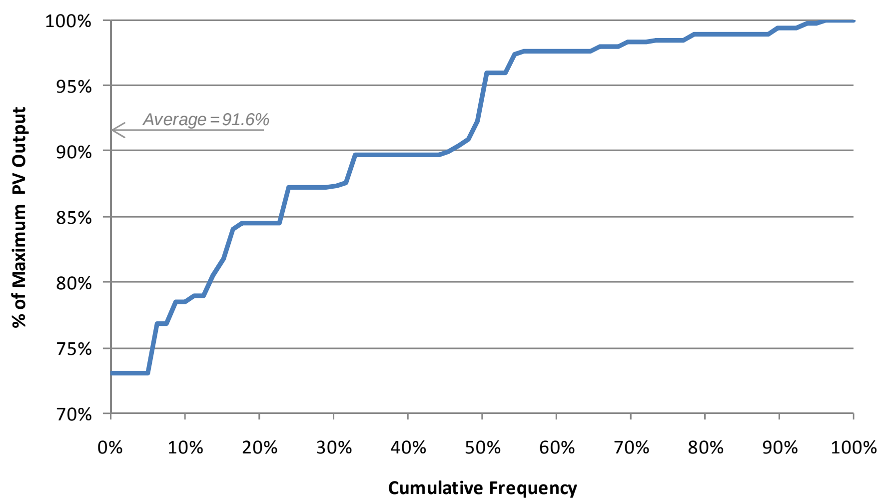


Figure 121: The cumulative frequency of PV performance in Terramor’s Sedona development evaluated as the percentage of maximum photovoltaic output.

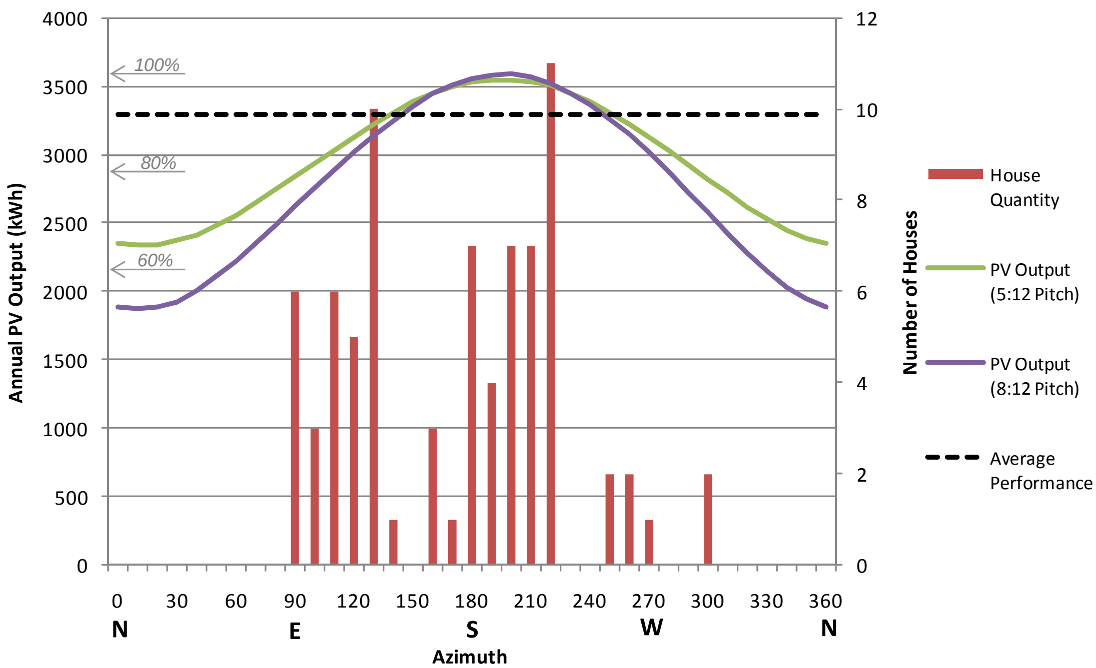


Figure 122: Sedona PV performance verses azimuth (Quantity of homes (red bars) overlaid with photovoltaic output against PV azimuth)

13.3.14 Ladera Ranch, CA: Walden Park

Figure 123: The solar houses of Walden Park (a part of Terramor), built by W. Lyon

Image source: Bing Maps © 2010 Microsoft Corporation

The layout of Walden Parks, built by W. Lyon, follows a more uniform grid than the other developments in Terramor, yet half of the grid is offset 20-30 degrees from north-south orientation. Amongst surveyed solar developments, Walden Parks has an average 43 degree PV orientation deviation from optimal slightly above average overall efficiency. Roof shape and orientation are primarily responsible for PV orientation losses, but in some cases homes seemed to remise the opportunity to orient panels southwards. On average, 110 kWh of solar electricity generation per house annually remains to be gained by optimizing the orientation of PV collectors.

General Neighborhood Information							
Name:	Walden Park	Location:	Ladera Ranch, CA	Climate Zone:	6	Date:	2004
Number of Single Family Homes:			109	Solar Oriented:		No	
Link:	http://www.laderaranch.com						
Characteristics:		1 kW PV systems and efficiency measures					

Home Details	
Overall Home Efficiency:	**
General Roof Types:	Gable, high complexity
Other Notes:	Generally follows a fragmented parallel street layout

Solar Photovoltaic Energy Generation			
% of Homes with PV:	100%	Annual Energy Generation:	151,100 kWh
Typical PV Size:	1 kW	Average Neighborhood PV Efficiency:	92.8%

Solar Domestic Water Heating			
% of Homes with SWH:	0%	Collector Type:	N/A
Typical Collector Size:	N/A	Average SWH Generation Efficiency:	N/A

Figure 124: Walden Park survey details

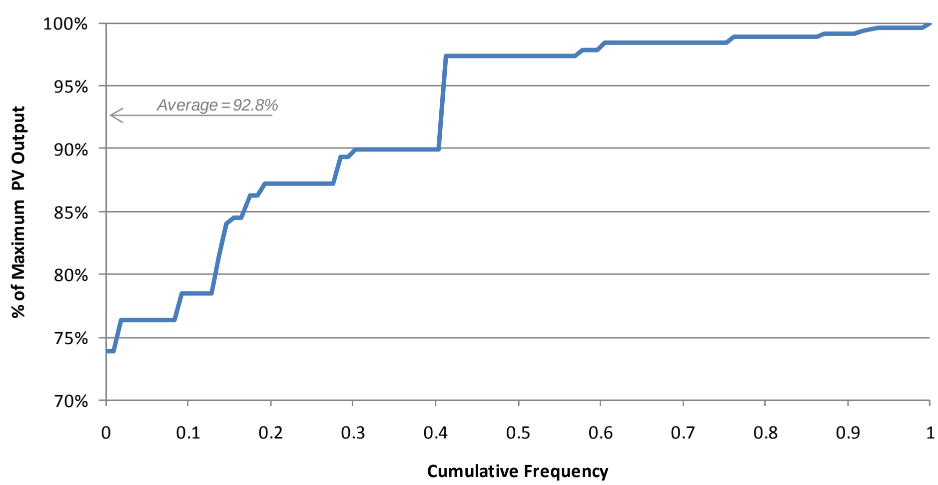


Figure 125: The cumulative frequency of PV performance in Terramor's Walden Park development evaluated as the percentage of maximum photovoltaic output.

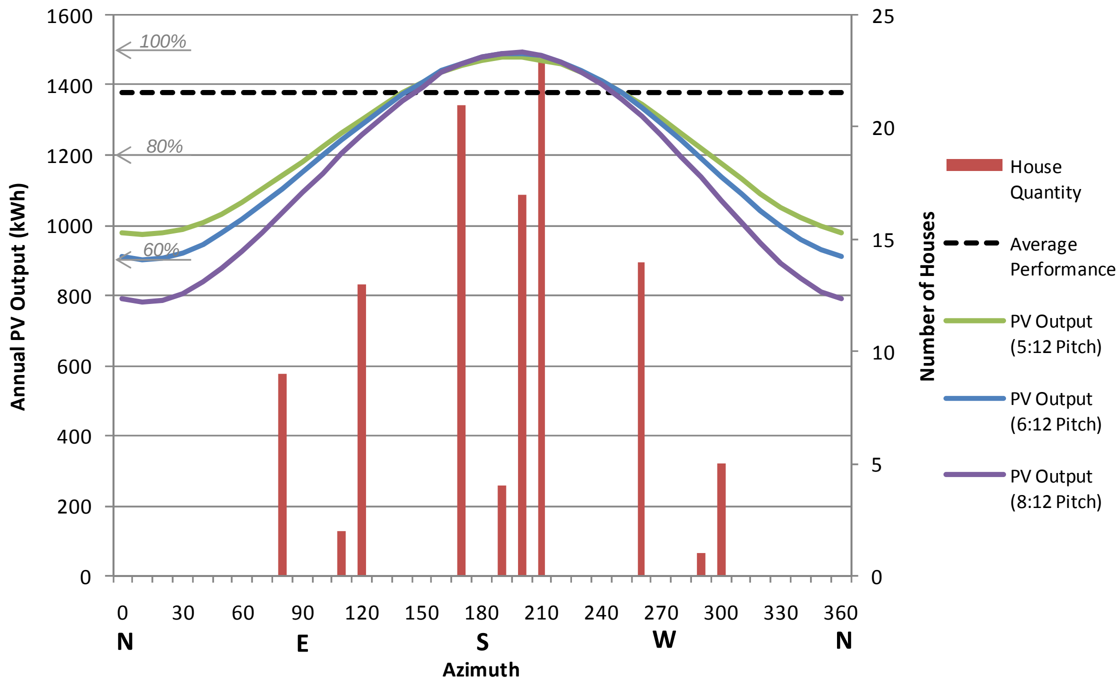


Figure 126: Walden Park PV performance verses azimuth (Quantity of homes (red bars) overlaid with photovoltaic output against PV azimuth)

13.3.15 Ladera Ranch, CA: Mosiac

Figure 127: The solar houses of Mosiac (a part of Terramor), built by K. Hovnanian

Image source: Bing Maps © 2010 Microsoft Corporation

Terramor's Mosiac development, built by K. Hovnanian, orients its cul-de-sacs primarily on an east-west axis, providing a street layout that allows for a large number of south-facing PV collectors. A significant number face west, however, due to limitations in roof shape and orientation. With an average PV orientation of 48 degrees from optimal, Mosiac achieves 91.6% efficiency. Minimal shading is noticeable from some roof protrusions and chimneys, and should to a certain extent reduce this estimate. Each house on average annually leaves 300 kWh of solar energy uncollected due to the orientation of its PV systems.

General Neighborhood Information							
Name:	Mosiac	Location:	Ladera Ranch, CA	Climate Zone:	6	Date:	2004
Number of Single Family Homes:			89	Solar Oriented:		No	
Link:	http://www.laderaranch.com						
Characteristics:		2.4 kW PV systems and efficiency measures					
Home Details							
Overall Home Efficiency:		**					
General Roof Types:		Gable, complex					
Other Notes:		Generally follows a "lollipops on a stick" style street layout					
Solar Photovoltaic Energy Generation							
% of Homes with PV:		58%	Annual Energy Generation:		144,600 kWh		
Typical PV Size:		2.4 kW	Average Neighborhood PV Efficiency:		91.6%		
Solar Domestic Water Heating							
% of Homes with SWH:		0%	Collector Type:		N/A		
Typical Collector Size:		N/A	Average SWH Generation Efficiency:		N/A		

Figure 128: Mosaic survey details

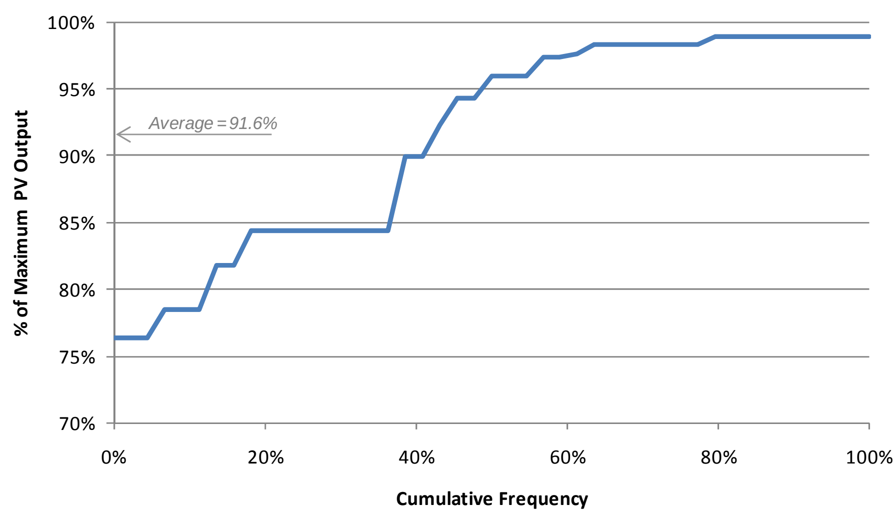


Figure 129: The cumulative frequency of PV performance in Terramor's Mosiac development evaluated as the percentage of maximum photovoltaic output.

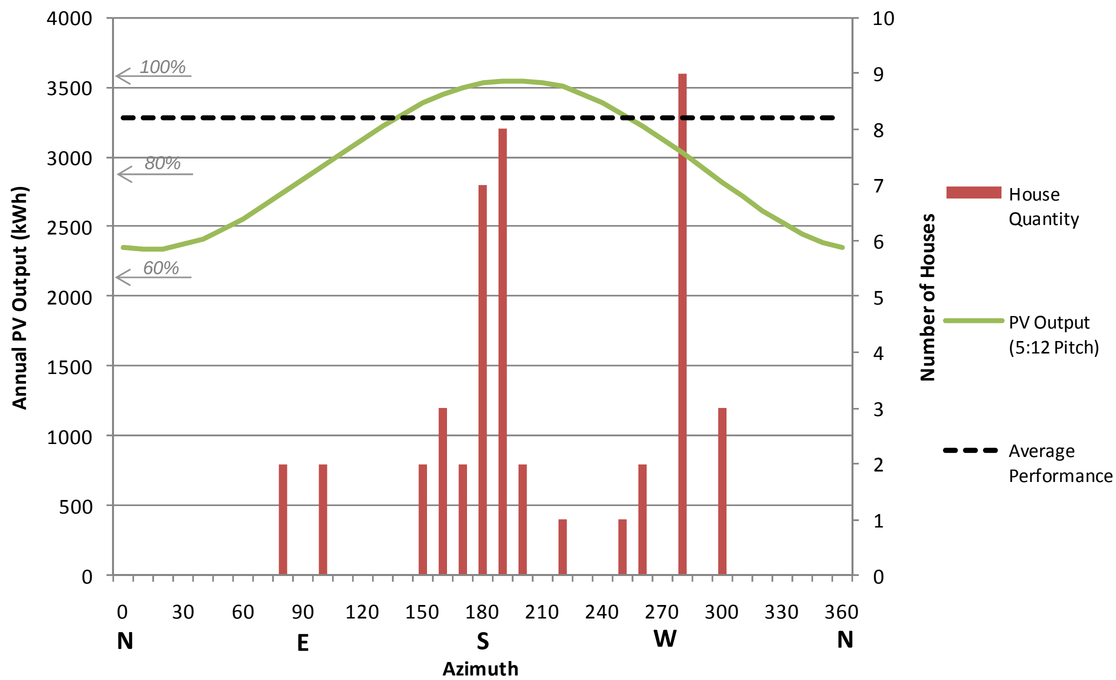


Figure 130: Mosaic PV performance verses azimuth (Quantity of homes (red bars) overlaid with photovoltaic output against PV azimuth)

13.3.16 Ladera Ranch, CA: Evergreen

Figure 131: The solar houses of Evergreen, built by Pardee Homes

Image source: Bing Maps © 2010 Microsoft Corporation

Built by Pardee Homes, Terramor's Evergreen development performs worst of the surveyed solar communities with an average PV orientation of 72 degrees from optimal and an average PV performance of 86%. While most cul-de-sacs are primarily aligned along an east-west axis, a small number of collectors are oriented to face south because roof faces are limited and roof spines are typically oriented perpendicular to the street. On average, these solar houses annually leave 410 kWh of unharnessed solar energy due to PV orientation.

General Neighborhood Information							
Name:	Evergreen	Location:	Ladera Ranch, CA	Climate Zone:	6	Date:	2004
Number of Single Family Homes:			77	Solar Oriented:		No	
Link:	http://www.laderaranch.com						
Characteristics:		1.2-2.4 kW PV systems and efficiency measures					

Home Details	
Overall Home Efficiency:	**
General Roof Types:	Gable, hip, high complexity
Other Notes:	Generally follows a "lollipops on a stick" style street layout

Solar Photovoltaic Energy Generation			
% of Homes with PV:	30%	Annual Energy Generation:	59,700 kWh
Typical PV Size:	1.2-2.4 kW	Average Neighborhood PV Efficiency:	86.2%

Solar Domestic Water Heating			
% of Homes with SWH:	0%	Collector Type:	N/A
Typical Collector Size:	N/A	Average SWH Generation Efficiency:	N/A

Figure 132: Evergreen survey details

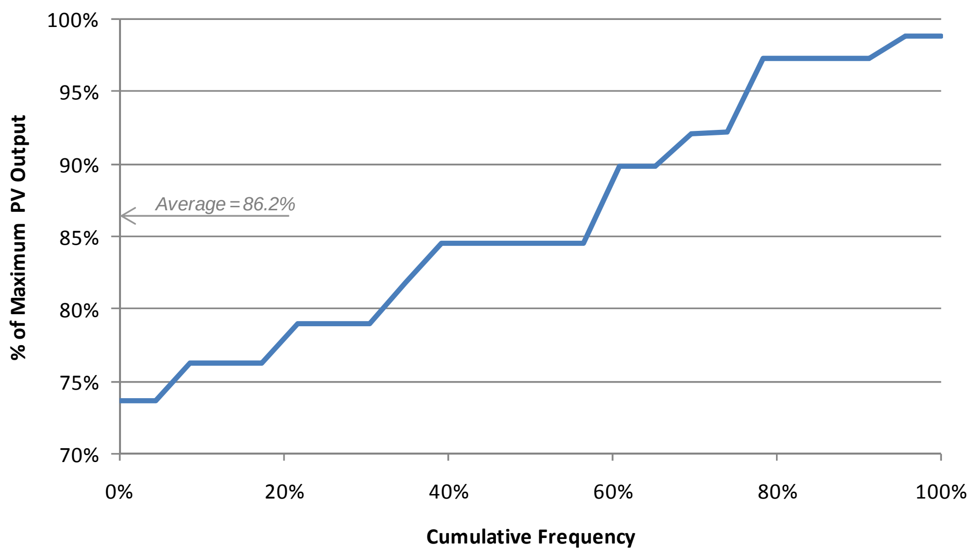


Figure 133: The cumulative frequency of PV performance in Terramor's Evergreen development evaluated as the percentage of maximum photovoltaic output.

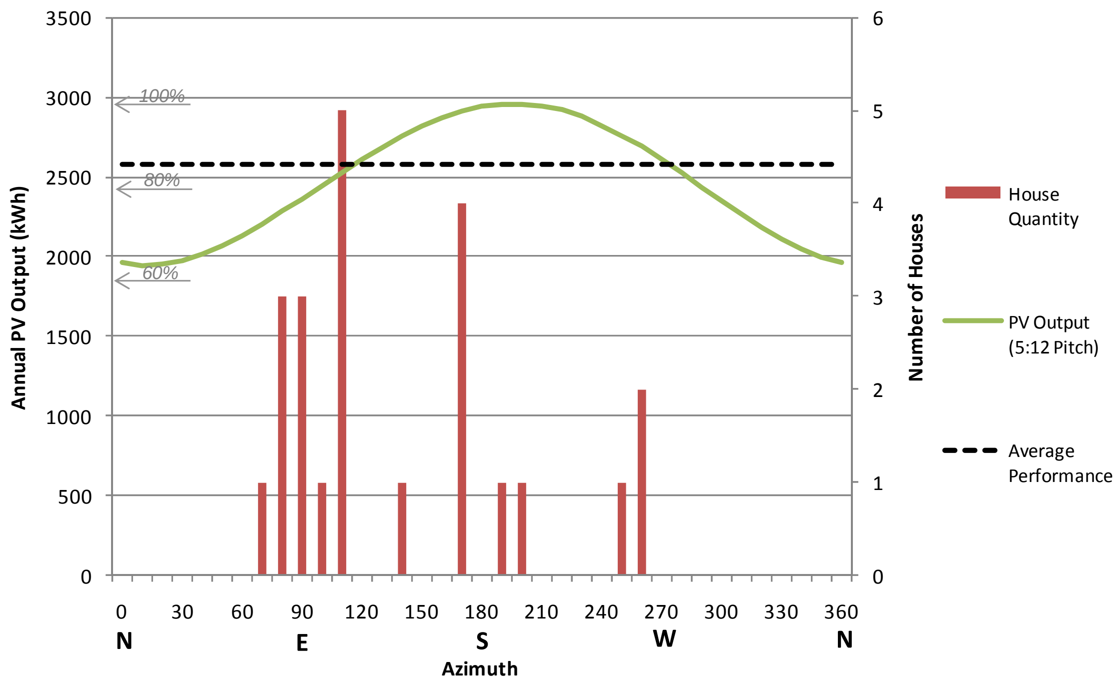


Figure 134: Evergreen PV performance verses azimuth (Quantity of homes (red bars) overlaid with photovoltaic output against PV azimuth)

13.4 PV Performance in Current Practice: Conventional Non-Solar Communities

In order to distinguish the specific solar design attributes of the preceding neighborhoods, theoretical PV performance analyses were conducted for three non-solar communities in California Climate Zones 6, 7, and 12 and the results were used for comparison. The theoretical analysis assumes that for each home, solar collector panels are placed on the most efficient roof surface with a sufficient unobstructed roof area. The size of the PV system was determined to be either 1.2 or 2.4 kW assuming that 100 ft^2 are required for each 1.2 kW system. Neighborhood layout, complexity in roof shape, chimneys, and vents were typical factors limiting theoretical PV orientation. Qualitative observations of the solar neighborhoods evaluated in the previous section indicate some planning for roof obstructions in solar homes yet little to no planning in street and roof orientation. The following sections provide quantitative analysis for baseline conventional homes to provide a foundation for such a hypothesis.

13.4.1 Ladera Ranch, CA

Figure 135: The non-solar community adjacent to Terramor in Ladera Ranch, CA.

Image source: Bing Maps © 2010 Microsoft Corporation

A section of 87 homes, comprising about 10% of the full non-solar community, was used for this analysis to generalize the theoretical PV output. Only 79 homes, however, were potentially compatible for solar panels due to roof complexity and obstructions. The theoretical PV performance of Ladera Ranch's non-solar community is characterized by a wide spread of feasible orientations that perform, on average, with only 0.2% less efficiency than Ladera Ranch's solar communities of Terramor.

The average PV orientation deviation of the non-solar neighborhood is 53 degrees – about 5 degrees further from optimal orientation than the solar developments. However, the average roof pitch is about 4 degrees steeper in the Terramor developments, which decreases performance at wide azimuths. In the analysis of neighborhood layout design, the comparison shown in Figure 137 shows that a significantly larger percentage of Terramor's lots were oriented within 5 degrees of optimal azimuth, yet a clear trend in street orientation is difficult to discern. General observations about the Ladera Ranch neighborhood indicated that the placement of vents and chimneys, in particular, were often the most important factor for the feasibility and efficiency of solar generation in the existing non-solar development. This indicates a possibility that design for solar efficiency at the level of roof design and neighborhood layout was applied to some extent in some of the solar communities of Terramor, but the difference in PV performance suggests that the effort was relatively insignificant.

General Neighborhood Information							
Name:	Ladera Ranch	Location:	Ladera Ranch, CA	Climate Zone:	6	Date:	2004
Number of Single Family Homes:			87 sampled	Solar Oriented:		No	
Link:	http://www.laderaranch.com						
Characteristics:	No solar systems installed						

Home Details	
Overall Home Efficiency:	Conventional
General Roof Types:	Gable, hip, average complexity
Other Notes:	Generally follows a "loops and lollipops" style street layout

Solar Photovoltaic Energy Generation (theoretical)			
% of Homes with PV:	91%	Annual Energy Generation:	129,000 kWh
Typical PV Size:	1.2 kW	Average Neighborhood PV Efficiency:	91.1%

Solar Domestic Water Heating			
% of Homes with SWH:	0%	Collector Type:	N/A
Typical Collector Size:	N/A	Average SWH Generation Efficiency:	N/A

Figure 136: Ladera Ranch survey details

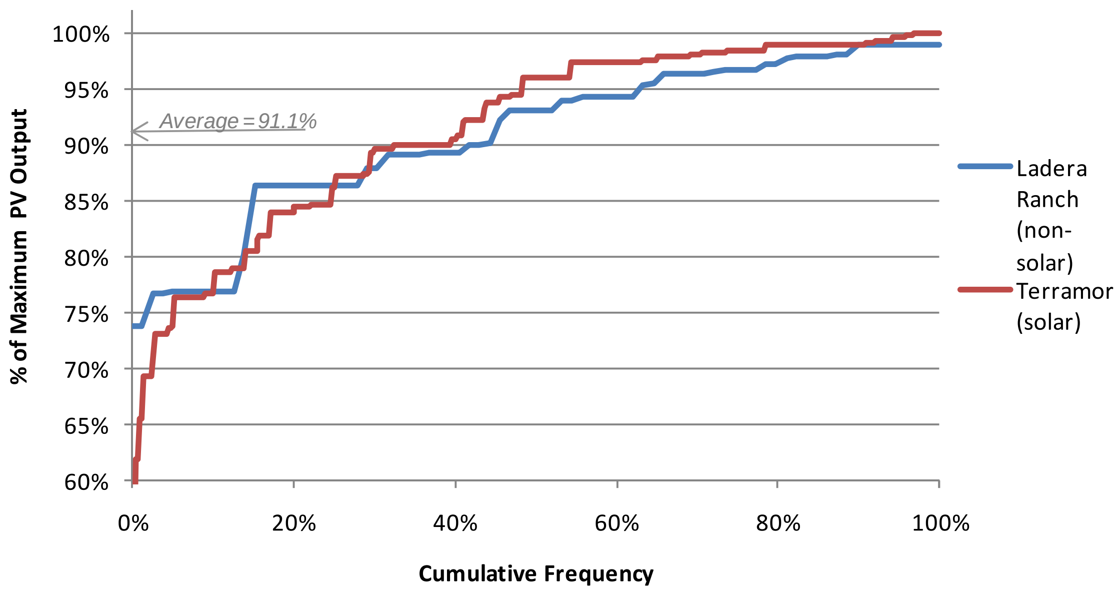


Figure 137: Comparison of Terramor and Ladera Ranch PV performance verses azimuth (Quantity of homes (red bars) overlaid with photovoltaic output against PV azimuth)

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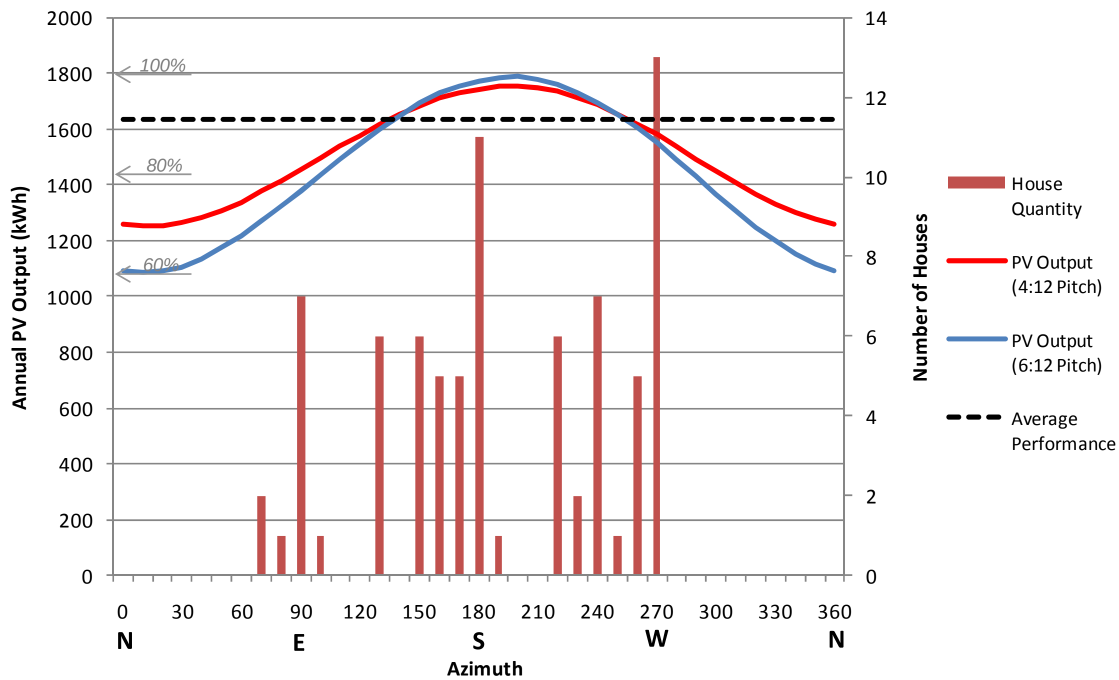


Figure 138: Quantity of homes (red bars) overlaid with theoretical photovoltaic output against PV azimuth.

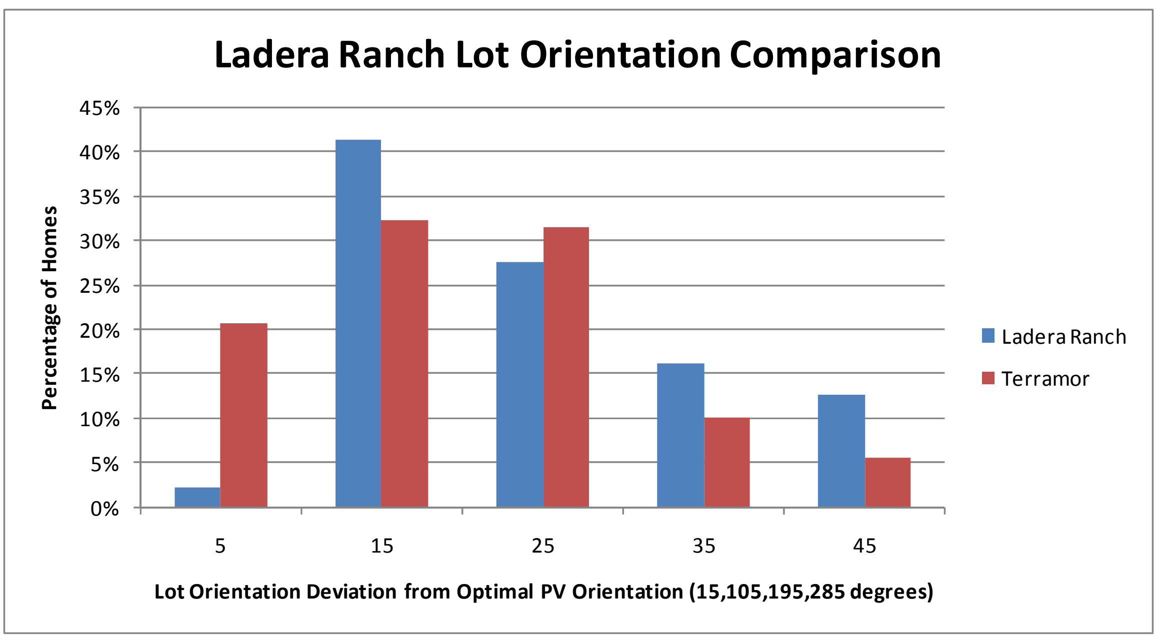


Figure 139: Analysis of neighborhood street layout by lot orientation deviation from optimal PV orientation. Because homes may orient solar panels within the four principle directions, the deviation from optimal lot orientation is within 0 and 45 degrees.

13.4.2 San Diego, CA: Scripps Highlands

Figure 140: The non-solar community adjacent to Tiempo in Scripps Highlands of San Diego

Image source: Bing Maps © 2010 Microsoft Corporation

A section of about 50% of the full non-solar Scripps Highlands community was used for this analysis to generalize the theoretical PV output. The performance of the non-solar community is characterized by a very wide spread of feasible PV orientations that, on average, perform approximately 3% worse than the solar community of Tiempo. The average deviation from optimal PV orientation is 51 degrees in the non-solar community, whereas in Tiempo the average deviation is only 33 degrees.

Analysis of neighborhood layout design, shown in Figure 144, indicates that little to no specific design for solar access was applied to the street layout of Tiempo, which oriented approximately the same fraction of roof faces toward the optimal PV output of 190 degrees. The largest factors contributing to low performance in the non-solar neighborhood were roof shape and orientation. Many rooftops in the Scripps Highlands community were designed with only one feasible face for PV collectors and were not oriented for solar access. In some cases, there were also possibilities for the shading of panels from the roof chimney, yet significantly fewer roof obstructions existed in Scripps than for the Ladera Ranch community. It is important to note that only 41% of Tiempo homes were installed with PV. The analysis may indicate that some design for optimal solar efficiency in roof shape and orientation was applied to homes in Tiempo. Yet, compared to the overall body of solar neighborhoods, the PV performance of this non-solar neighborhood is fairly consistent.

General Neighborhood Information							
Name:	Scripps Highlands	Location:	San Diego, CA	Climate Zone:	7	Date:	2001
Number of Single Family Homes:			96 sampled	Solar Oriented:		No	
Link:	http://www.laderaranch.com						
Characteristics:	No solar systems installed						

Home Details	
Overall Home Efficiency:	Conventional
General Roof Types:	Gable, hip, complex
Other Notes:	Generally follows a “loops and lollipops” style street layout

Solar Photovoltaic Energy Generation (theoretical)			
% of Homes with PV:	100%	Annual Energy Generation:	181,100 kWh
Typical PV Size:	1.2-2.4 kW	Average Neighborhood PV Efficiency:	91.6%

Solar Domestic Water Heating			
% of Homes with SWH:	0%	Collector Type:	N/A
Typical Collector Size:	N/A	Average SWH Generation Efficiency:	N/A

Figure 141: Scripps Highlands survey details

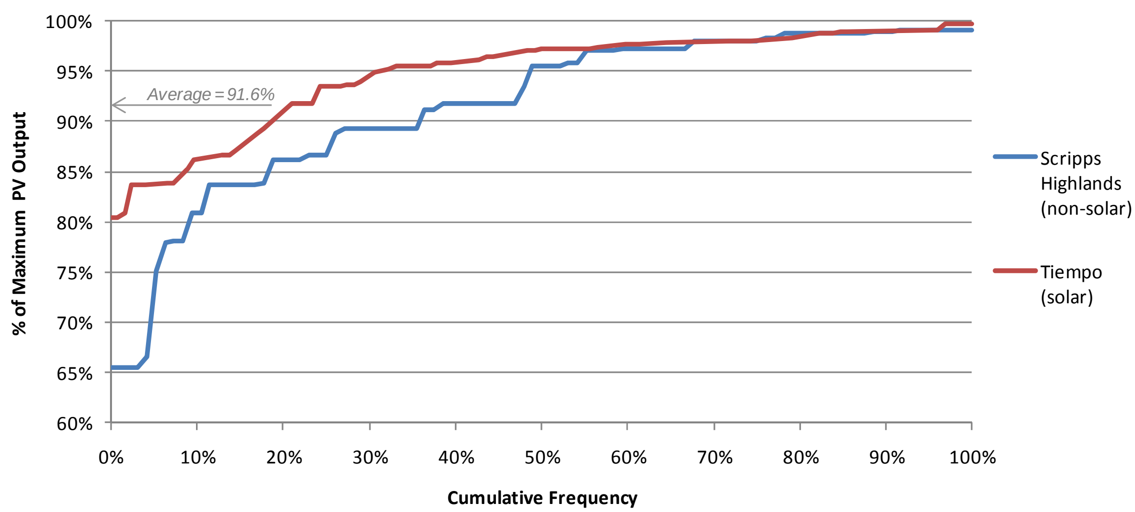


Figure 142: Comparison of Tiempo and Scripps Highlands PV performance verses azimuth (Quantity of homes (red bars) overlaid with photovoltaic output against PV azimuth)

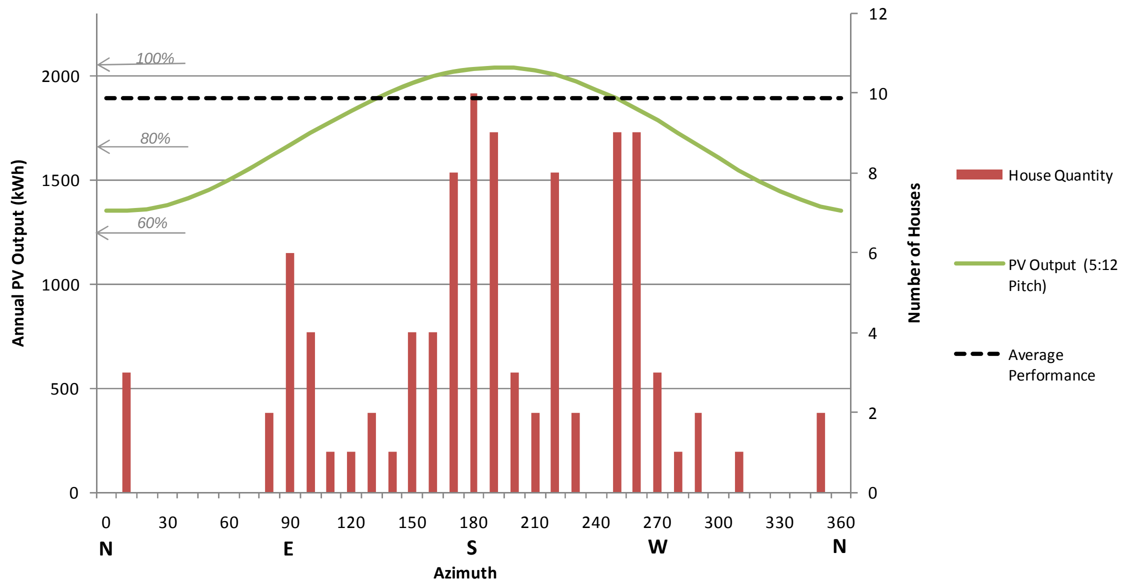


Figure 143: Scripps Highlands non-solar community predicted PV performance (Quantity of homes (red bars) overlaid with theoretical photovoltaic output against PV azimuth)

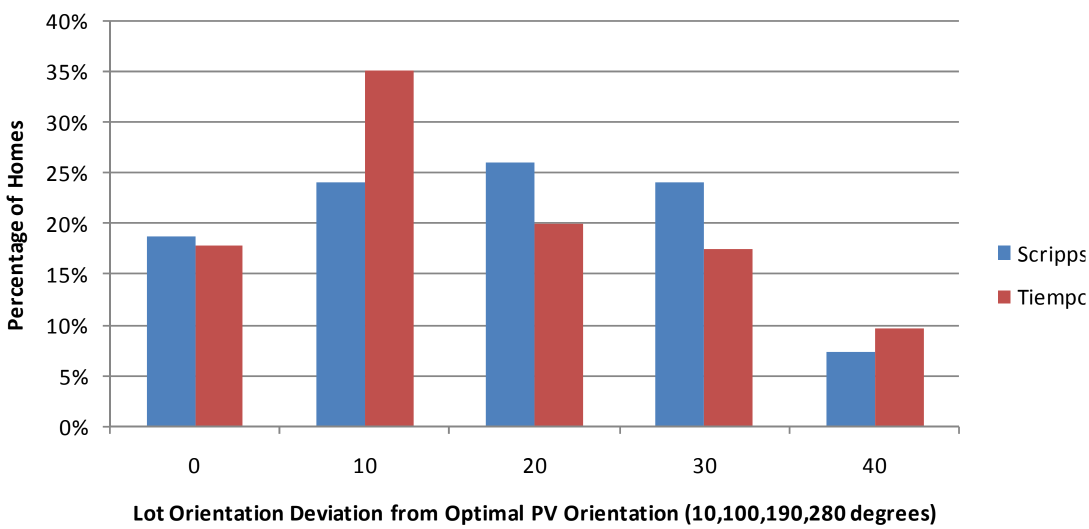


Figure 144: Analysis of neighborhood street layout by lot orientation deviation from optimal PV orientation. Because homes may orient solar panels within the four principle directions, the deviation from optimal lot orientation is within 0 and 45 degrees.

13.4.3 Non-Solar Community Adjacent to Fallen Leaf in Natomas

Figure 145: The non-solar community adjacent to Fallen Leaf in Natomas

Image source: Bing Maps © 2010 Microsoft Corporation

A section of approximately 30-40% of the full non-solar community in Natomas was used for this analysis to generate theoretical PV output. The theoretical performance of the community is characterized by a relatively wide spread of feasible orientations that trend to the south, west, and east. This trend is a function of the street layout, as most lots are oriented in one of the four principle directions. This is consistent with the street layout of Natomas' solar community, Fallen Leaf. On average, the non-solar homes perform with approximately 1% greater efficiency than Fallen Leaf, which achieves only 91.0% efficiency.

Analysis of the neighborhood layout, shown in Figure 149, shows that while both communities were oriented well for solar access, Fallen Leaf oriented 100% of lots with potential for optimal solar access. However, because half of roof spines in Fallen Leaf were oriented parallel to the optimal PV azimuth, the neighborhood layout was not effectively utilized for solar generation. The difference in overall PV performance between the solar and non-solar neighborhood indicates that design for optimal solar efficiency in regard to roof shape and orientation was not applied to the solar community of Fallen Leaf.

General Neighborhood Information							
Name:	Natomas	Location:	Natomas, CA	Climate Zone:	7	Date:	2001
Number of Single Family Homes:			114 sampled	Solar Oriented:		No	
Link:	http://www.laderaranch.com						
Characteristics:	No solar systems installed						
Home Details							
Overall Home Efficiency:	Conventional						
General Roof Types:	Gable, hip, low complexity						
Other Notes:	Curvilinear with a "loops and lollipops" style street layout						
Solar Photovoltaic Energy Generation (theoretical)							
% of Homes with PV:	100%	Annual Energy Generation:		247,300 kWh			
Typical PV Size:	1.2-2.4 kW	Average Neighborhood PV Efficiency:		92.0%			
Solar Domestic Water Heating							
% of Homes with SWH:	0%	Collector Type:	N/A				
Typical Collector Size:	N/A	Average SWH Generation Efficiency:		N/A			

Figure 146: Natomas survey details

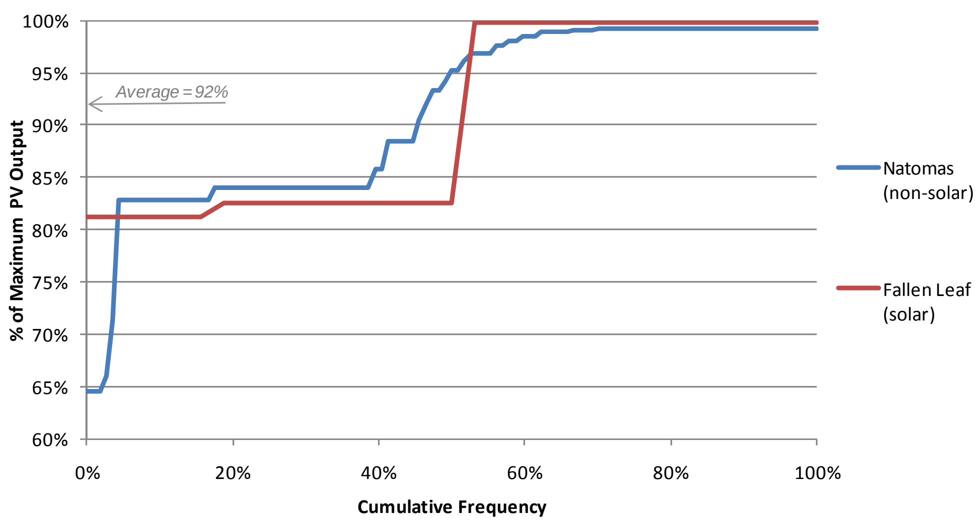


Figure 147: Comparison of Fallen Leaf and adjacent neighborhood PV performance verses azimuth (Quantity of homes (red bars) overlaid with photovoltaic output against PV azimuth)

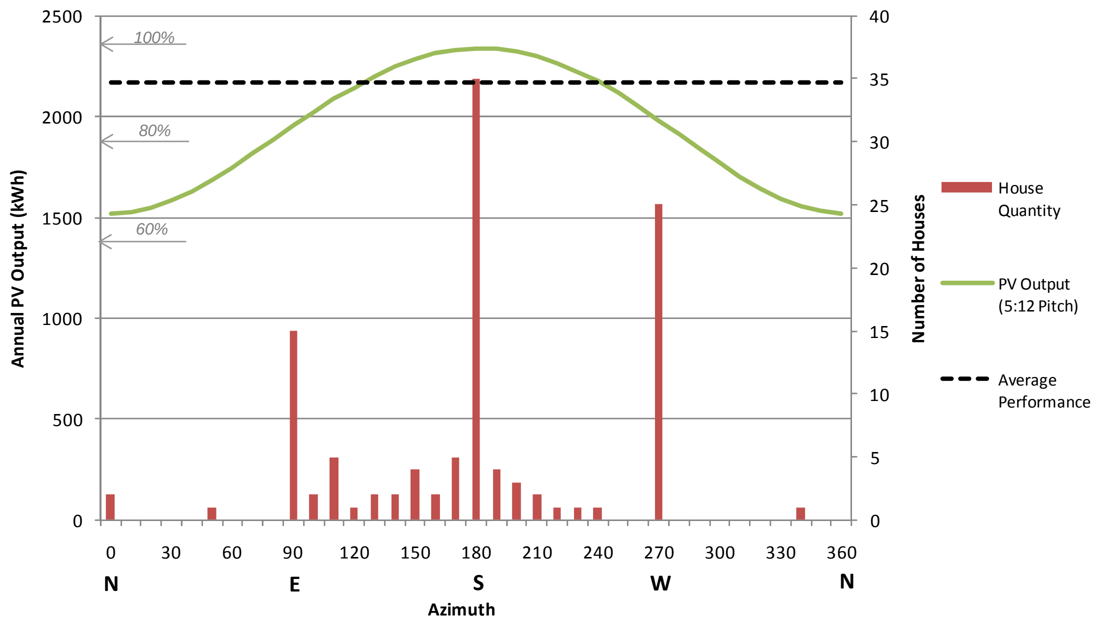


Figure 148: Natomas PV performance verses azimuth (quantity of homes (red bars) overlaid with theoretical photovoltaic output against PV azimuth)

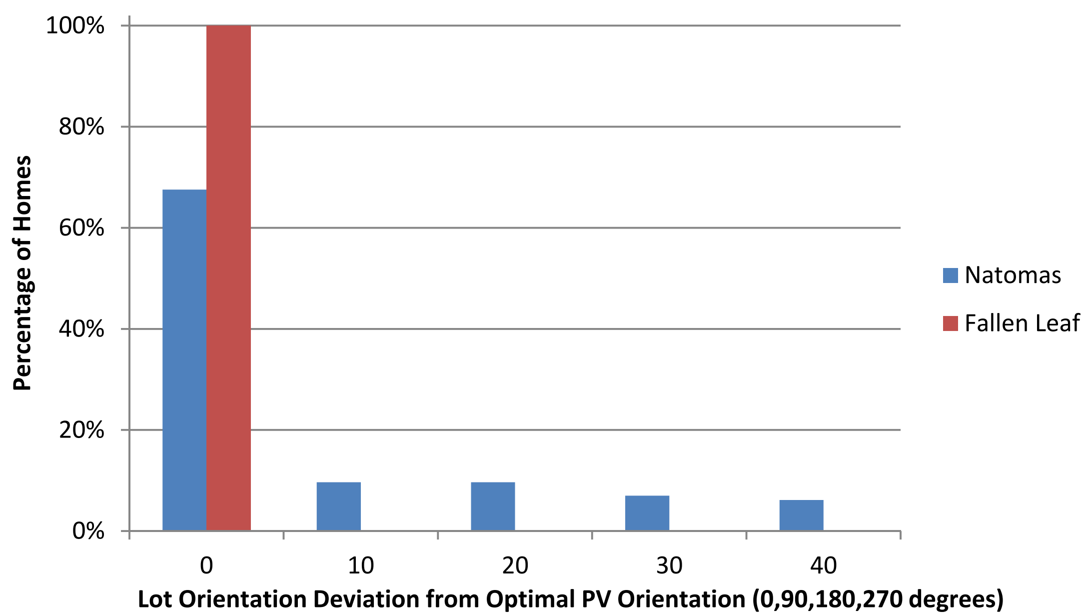


Figure 149: Analysis of neighborhood street layout by lot orientation deviation from optimal PV orientation. Because homes may orient solar panels within the four principle directions, the deviation from optimal lot orientation is within 0 and 45 degrees.

13.4.4 Overall Comparison between Solar and Non-Solar PV Performance

The theoretical PV performance of the non-solar communities in this section is fairly consistent overall with the estimated performance of the solar communities in Section 9.4. The average efficiency of theoretical solar collectors placed upon existing non-solar roof surfaces is 91.7%, while the average efficiency of currently implemented solar collectors is 92.1%. A comparison of the cumulative frequency of PV performance in solar and non-solar neighborhoods is shown below in Figure 150.

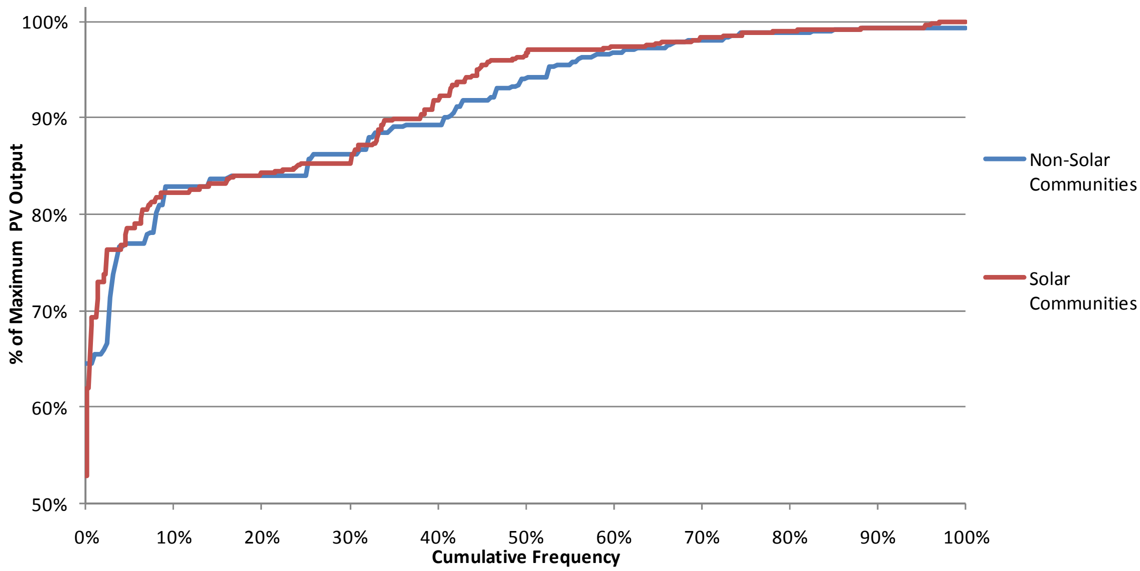


Figure 150: The cumulative frequency of PV performance in the surveyed non-solar communities evaluated as the percentage of maximum photovoltaic output and compared to the overall performance of the solar communities.

While the average solar performance remains relatively constant between solar and non-solar communities, the average deviation from optimal PV orientation is 50.8 degrees amongst the non-solar communities and only 43.3 degrees amongst the solar communities. There are a number of factors influencing this discrepancy. In many cases, roof obstructions, especially in Ladera Ranch's conventional non-solar community, limited the roof faces to which theoretical solar panels could be placed. In most of the neighborhoods in which all homes were built for solar energy generation, however, rooftops remained relatively clear to provide a spacious surface for solar panel installment. While oftentimes relatively inefficient roof surfaces were chosen for PV in these solar communities, the implemented roof face was very rarely oriented within 80 degrees of north. Amongst the non-solar communities, however, spacious roof faces are not a priority, so for some houses the only feasible PV orientation was approximately north.

The options for feasible PV roof surfaces are also inherently limited by the shape of the rooftop. Rooftops typically provide two (gable) or four (hip) potential directions for the orientation of solar collectors. However, roofs of greater complexity may limit the selection to one or even zero potential PV orientations, as was noted in the non-solar Scripps Highlands and Ladera Ranch developments. While the effects of roof shape on PV performance are mutually dependent upon the roof orientation, simpler roofs that allow more faces for solar generation are more efficient in larger-scale developments with uniform home design.

Depending on the roof shape and street alignment, a particular roof orientation is typically desirable for each residential home. Roof spines are generally aligned in one of two orientations: parallel or perpendicular to the street. For gable roof shapes, the roof spine should be oriented perpendicular to the optimal PV azimuth to ensure panel efficiency. For more complex roof shapes, fewer or greater options may be available for solar access. Roof orientations were the most influential factor decreasing performance in solar homes.

The layout of the street also affects a home's potential for solar energy generation. Because roof faces are generally oriented in the four principle directions relative to the street, certain street alignments have potential to allow for greater solar energy generation than others. Specifically, if the roof orientation is assumed to be tailored to the street layout, then optimal PV efficiency may be reached only for streets oriented in 90 degree intervals from the optimal PV azimuth. Below, Figure 151 compares the deviation of lots from these optimal azimuths between solar and non-solar communities. The data does not indicate a trend that solar communities designed street layouts for solar optimization.

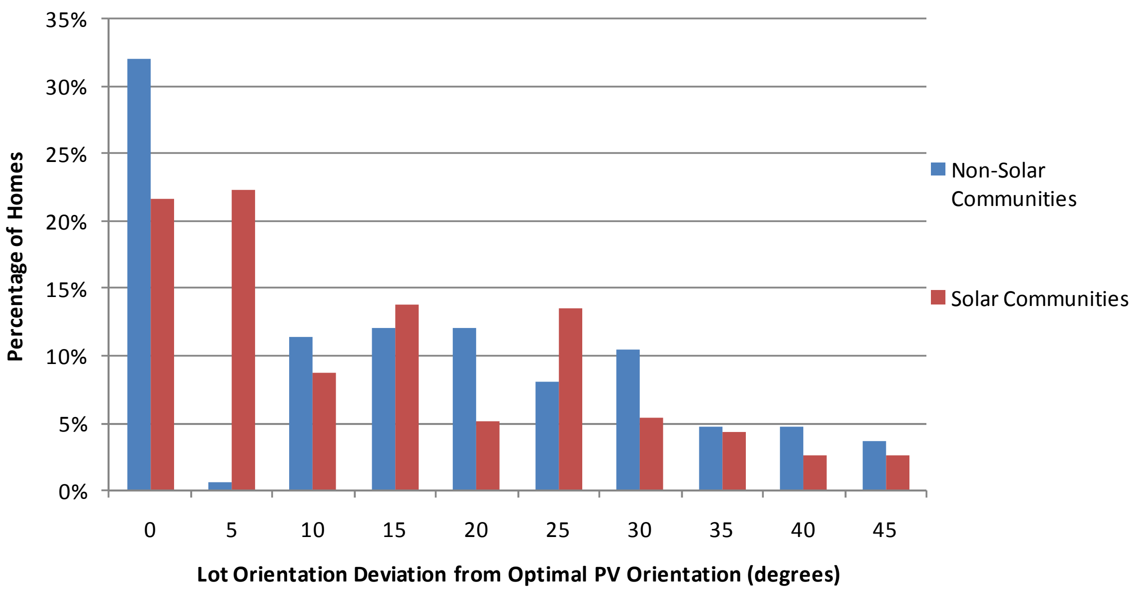


Figure 151: Analysis of neighborhood street layout by lot orientation deviation from optimal PV orientation. Because homes may orient solar panels within the four principle directions, the deviation from optimal lot orientation is within 0 and 45 degrees.

The average roof tilt is slightly lower within the non-solar communities than within the solar communities, which helps explain why the average performance is consistent despite differences in PV orientation. Roof tilt is an important design factor influencing optimal PV generation. Optimal tilt, as a general rule of thumb, is at an angle equal to the latitude of the site location; however, PV that is not oriented optimally performs more effectively at lower roof pitches. Therefore, while homes in both solar and non-solar neighborhoods deviated rather significantly from optimal orientation, those designed with lower roof tilts performed with greater efficiency overall.

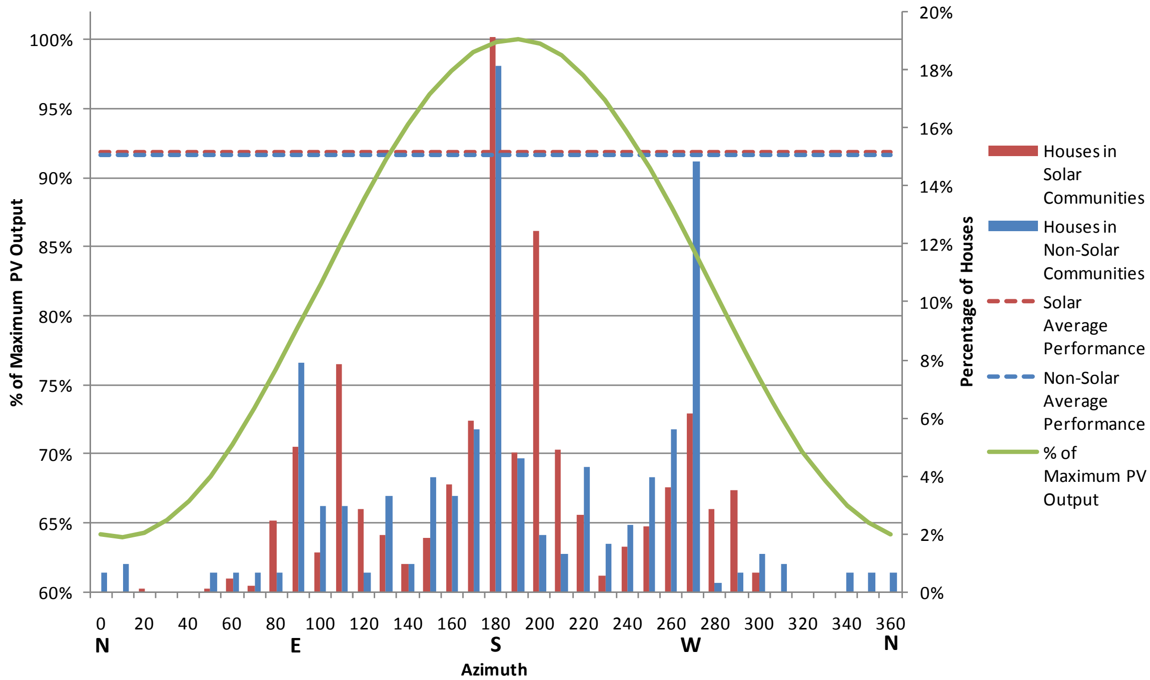


Figure 152: Percentage of homes in solar and non-solar communities overlaid with percent of maximum photovoltaic output against PV azimuth.

While certain aspects of solar design in street layout and roof shape, orientation, tilt, and obstructions were applied to some solar communities in the survey, none effectively utilized all of these factors for optimal solar production. Some solar homes even needlessly remised the opportunity to install PV on the most efficient roof face. While some elements of solar design were evident in the existing solar developments, overall these communities performed on the same level as theoretical implementation in non-solar communities, with orientation accounting for 7% of the losses in maximum PV output.

13.5 PV Performance of a Solar Oriented Neighborhood

13.5.1 Davis, CA: Village Homes

Figure 153: Village Homes solar oriented development in Davis, showing homes oriented north-south rather than perpendicular to the street

Image source: Bing Maps © 2010 Microsoft Corporation

Village Homes is a 70-acre subdivision located in Davis, California designed to encourage the conservation of energy and natural resources. All streets trend east-west and all lots are oriented north-south, allowing the houses with passive solar designs to efficiently utilize solar energy. Despite the variations in roof design, all roof spines are oriented east-west to include at least one spacious southern face. Village Homes was the only completed residential neighborhood identified in California that intentionally oriented all lots north-south specifically to enhance both passive and active solar performance in homes.

40 of 196 home owners in this development have installed photovoltaic solar generation panels or solar water heaters on roofs which are oriented directly to the south. On average, solar panels in this neighborhood perform 6-7% more efficiently than solar panels in other “green” solar communities. Due to the standardized orientation of lots in this neighborhood, the efficiency of the PV systems were only dependent upon the pitch of the roof, ranging from approximately 14 degrees (3:12) to 27 degrees (6:12). No houses reached lower than 96% efficiency due to the orientation of the Village Homes lots. While only a portion of home owners implemented PV systems, there is great potential for solar PV electricity generation for every occupant in this development.

General Neighborhood Information							
Name:	Village Homes	Location:	Davis, CA	Climate Zone:	12	Date:	1975
Number of Single Family Homes:			196	Solar Oriented:		Yes	
Link:	http://www.villagehomesdavis.org/public/about						
Characteristics:	A range of PV and SWH systems and energy-efficient lot orientation						

Home Details	
Overall Home Efficiency:	Oriented to reduce total heating/cooling loads
General Roof Types:	Hip and gable, varying in complexity
Other Notes:	PV and SWH panels installed only on southern roof faces

Solar Photovoltaic Energy Generation			
% of Homes with PV:	20.4%	Annual Energy Generation:	58,300 kWh
Typical PV Size:	0.5-3.5 kW	Average Neighborhood PV Efficiency:	98.7%

Solar Domestic Water Heating			
% of Homes with SWH:	2%	Collector Type:	Flat panel
Typical Collector Size:	150 sqft.	Average SWH Generation Efficiency:	**

Figure 154: Village Homes survey details

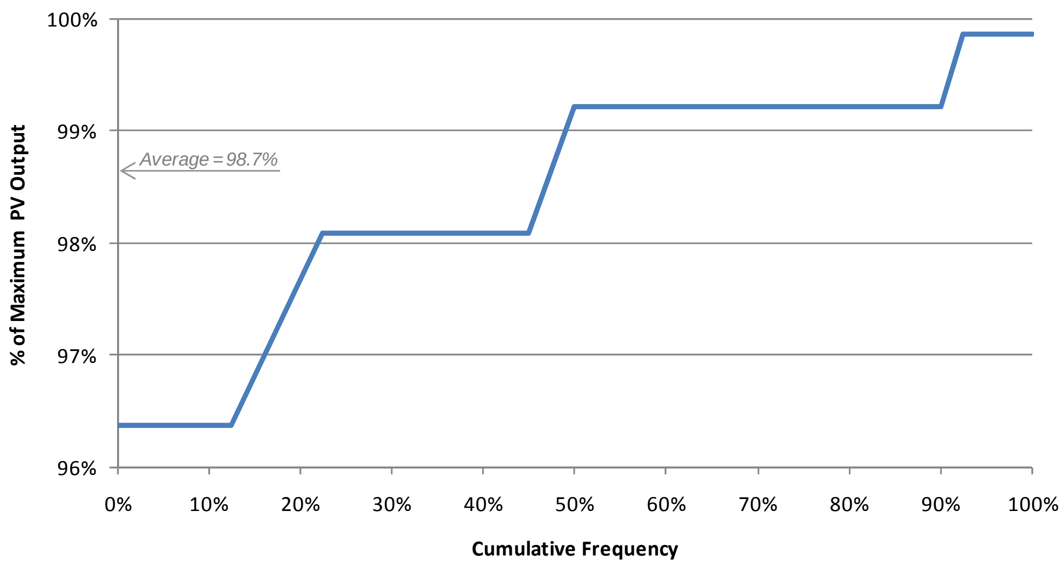


Figure155: The cumulative frequency of PV performance in Village Homes evaluated as the percent of maximum photovoltaic output. Due to the solar orientation of residences, output is a function of only roof tilt.

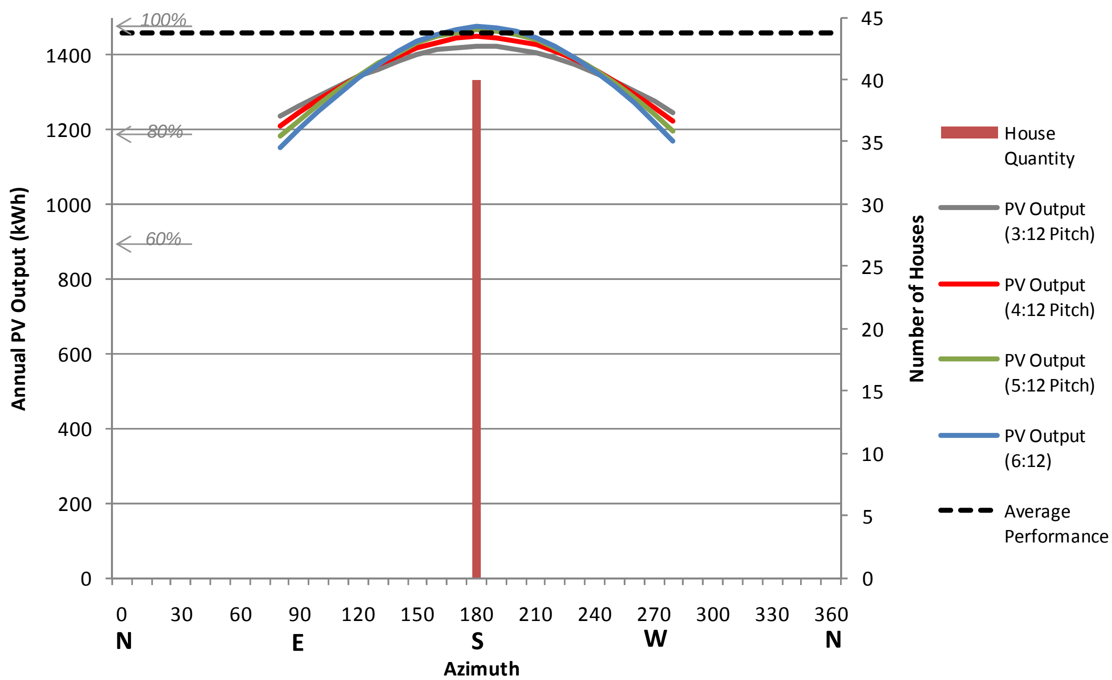


Figure 156: Village Homes PV performance verses azimuth (quantity of homes (red bar) overlaid with photovoltaic output against PV azimuth)

13.5.2 Claremont, CA: Meadowoods Neighborhood

Meadowoods is a 140 acre parcel with 92 single family homes. The neighborhood was specifically designed as a solar oriented development with a variety of solar oriented features, including east/west street orientation to provide all homes with good southern exposure, minimal windows on the east and west facing walls, clerestory windows for daylighting, and some solar water heating systems. Houses range in size from 1,400 ft^2 to 2,800 ft^2. The streets were also specifically designed with narrower widths to minimize urban heat island impacts. Other sustainability design features include low impact development stormwater design and onsite infiltration in a central park, interconnecting streets with walking and bike paths to promote walkability, and "outdoor living" features. House sizes were intermingled, and overall neighborhood densities were designed to transition into densities of neighboring developments. This neighborhood was designed by the Claremont Environmental Design Group (CEDG)[162]. This solar oriented neighborhood was identified too late to be included in the analytical study, but general background is provided here due to the limited number of true "solar oriented developments" that included solar orientation from the planning phase that were identified.

[162] http://www.cedg-design.com

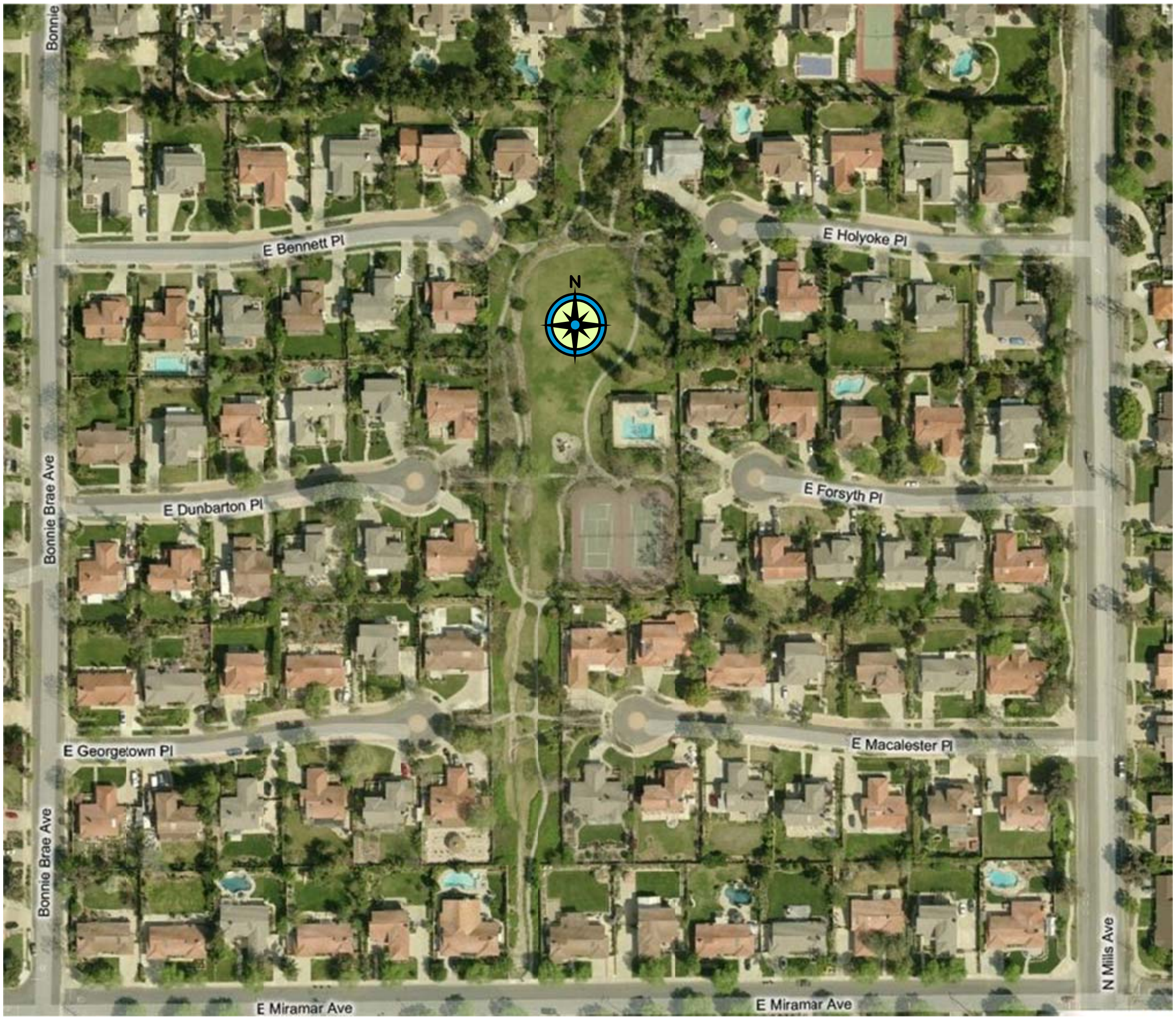


Figure 157: Meadowoods solar oriented neighborhood

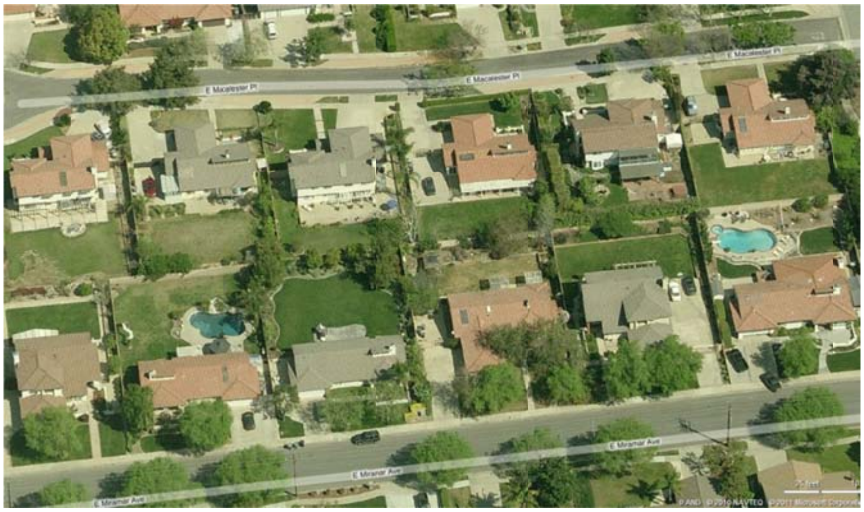


Figure 158: Meadowoods homes with clerestory windows and solar water heating

Figure 159: Meadowoods home with clerestory and roof integrated solar water heating system

Image source: Google Maps © 2010 Google

General Neighborhood Information							
Name:	Meadowoods	Location:	Claremont, CA	Climate Zone:	9	Date:	1987
Number of Single Family Homes:			92	Solar Oriented:		Yes	
Link:	http://www.cedg-design.com						
Characteristics:	Solar oriented streets for southern solar exposure for every home, homes have minimal east and west glazing, southern glazing designed to be shaded in summer but allow winter heat gains, clerestory windows for daylighting and natural ventilation, north/south natural ventilation, reduced street widths for reduced urban heat island impacts, low impact design stormwater system.						

Home Details	
Overall Home Efficiency:	Oriented to reduce total heating/cooling loads, minimal east/west facing windows, clerestories with operable windows for natural ventilation
General Roof Types:	Hip and gable, varying in complexity, almost all homes have south facing roof space for solar systems
Other Notes:	Roof integrated SWH systems designed, only some installed, approximately 4’x10’

Solar Photovoltaic Energy Generation			
% of Homes with PV:	6.5%	Annual Energy Generation:	Not calculated[163]
Typical PV Size:	0.5-3.5 kW	Average Neighborhood PV Efficiency:	98.7%

Solar Domestic Water Heating			
% of Homes with SWH:	30%	Collector Type:	Flat panel, ~ 4’x10’
Typical Collector Size:	150 sqft.	Average SWH Generation Efficiency:	**

Figure 160: Meadowoods survey details

[163] This neighborhood was not identified in time to be included in the analytic analysis, but neighborhood details are included.

14. Appendix 8 – Solar Zone Roof Calculations

A parametric was conducted to determine the amount of roof area available for solar zones, as a function of roof shape, house area, fire setback distances, roof tile, house rotation, and other parameters. The solar zone areas were calculated based on variable input data for key parameters. These parameters were adjusted to explore how the available roof area changed. Three primary house/roof shapes were analyzed: a rectangular home, an L-shaped home, and a T-shaped home. For each of these, the analysis was conducted for both a gabled and hip roof configuration, for a total of six different primary roof configurations, as shown in the following figure. The yellow areas indicate potential solar zone area after fire clearances are accounted for.

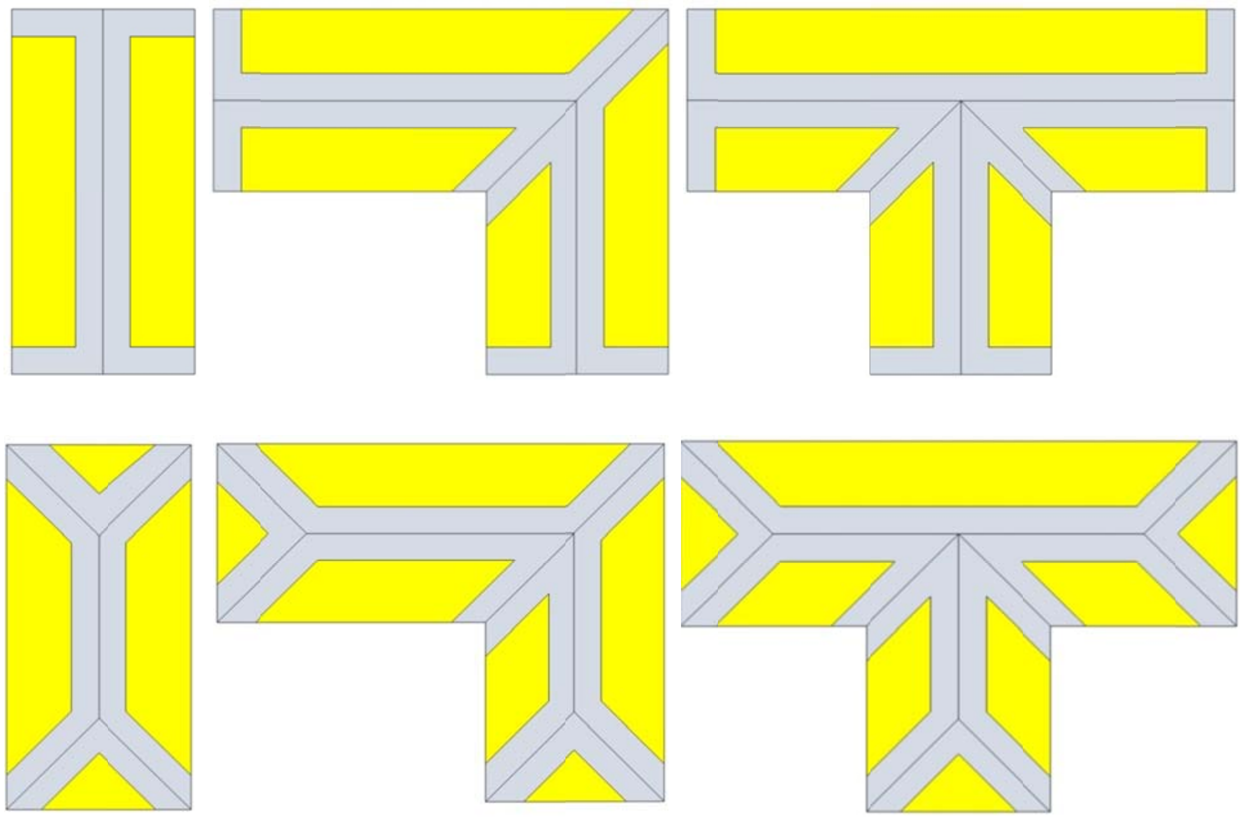
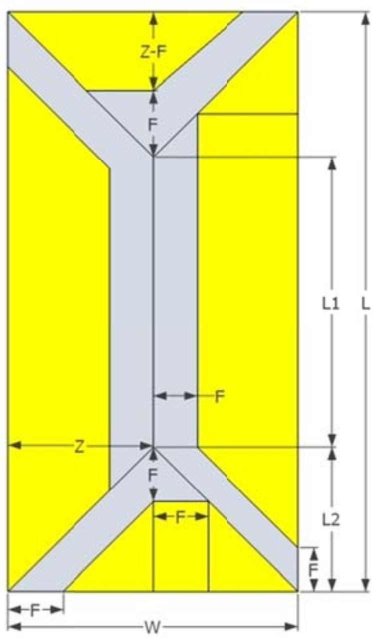
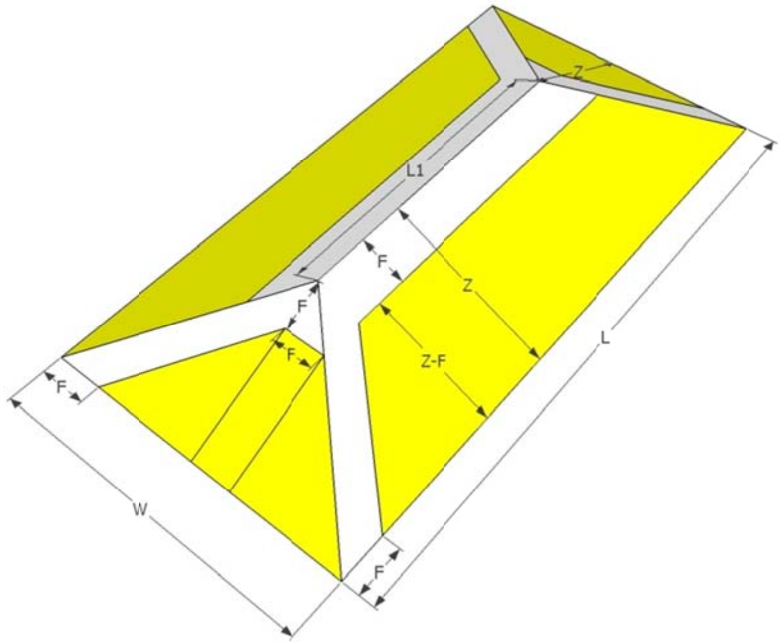


Figure 161: Primary roof shapes and configurations analyzed





Example calculations are provided for an L-shaped building with a gabled roof. Calculations for other roof shapes are similar.

The basic roof dimensions and nomenclature are defined in the following figure.

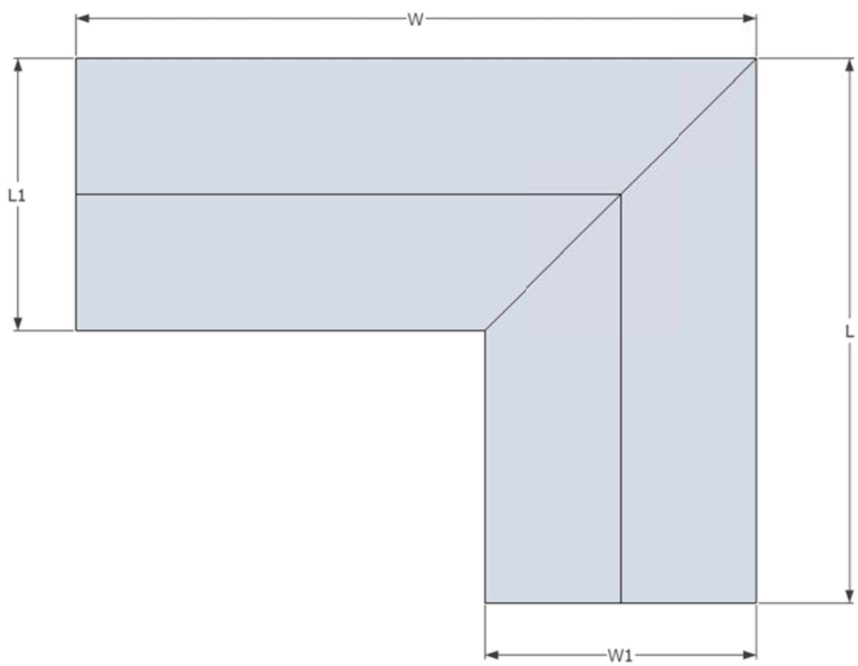


Figure 162: Roof dimension nomenclature for an L-shaped building

This analysis accounts for the roof overhang (OH). The underlying building dimensions are defined in the following figure.

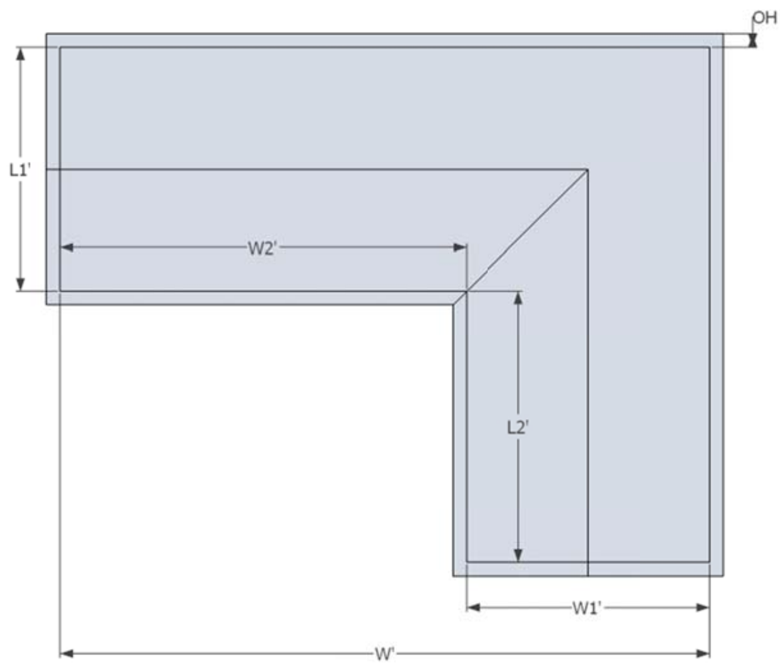


Figure 163: Building footprint nomenclature for an L-shaped building

The following key variables are used as inputs for this analysis:

A_{house} = House Area (sqft)

AR = Aspect Ratio, L'/W', where L' = length of the house (perpendicular to street), and W = width of the house (parallel to street).

S = Number of Stories

P = Roof Pitch (P:12)

F = Fire Setback for solar systems (ft)

OH = Roof Overhang (ft)

$L_{\%} = L_1'/L'$

$W_{\%} = W_1'/W'$

The house area for an L-shaped building is calculated as:

$A_{house} = [(L'*W') - (W_2'*L_2')]*S$ **[EQ 1]**

Substitute in $L_2' = (1-L_{\%})*L'$ and $W_2' = (1-W_{\%})*W'$, rearrange and solve for L' as a function of W' and input values:

$L' = A_{house}/S/(W_{\%}+L_{\%} - W_{\%}*L_{\%}) / W'$ **[EQ 2]**

The aspect ratio is defines as AR = L'/W'. Rearranging and solving for L:

$L' = W'*AR$ **[EQ 3]**

Substituting equation 3 into equation 2, and solving for W':

$W' = \text{sqrt}(A_{house} /(S*AR*(L_{\%}+W_{\%} - L_{\%}*W_{\%}))$ **[EQ 4]**

Note that L' can now be solved substituting equation 4 into equation 3, and roof dimensions can be calculated by the following equations:

$W = W' + 2*OH$ **[EQ 5]**

$W_1 = W_1' + 2*OH$ **[EQ 6]**

$W_2 = W - W_1$ **[EQ 7]**

$L = L' + 2*OH$ **[EQ 8]**

$L_1 = L_1' + 2*OH$ **[EQ 9]**

$L_2 = L - L_1$ **[EQ 10]**

The following figure shows the potential solar zones for an L-shaped building with a gabled roof. Also shown are roof gable cross sections, and nomenclature.

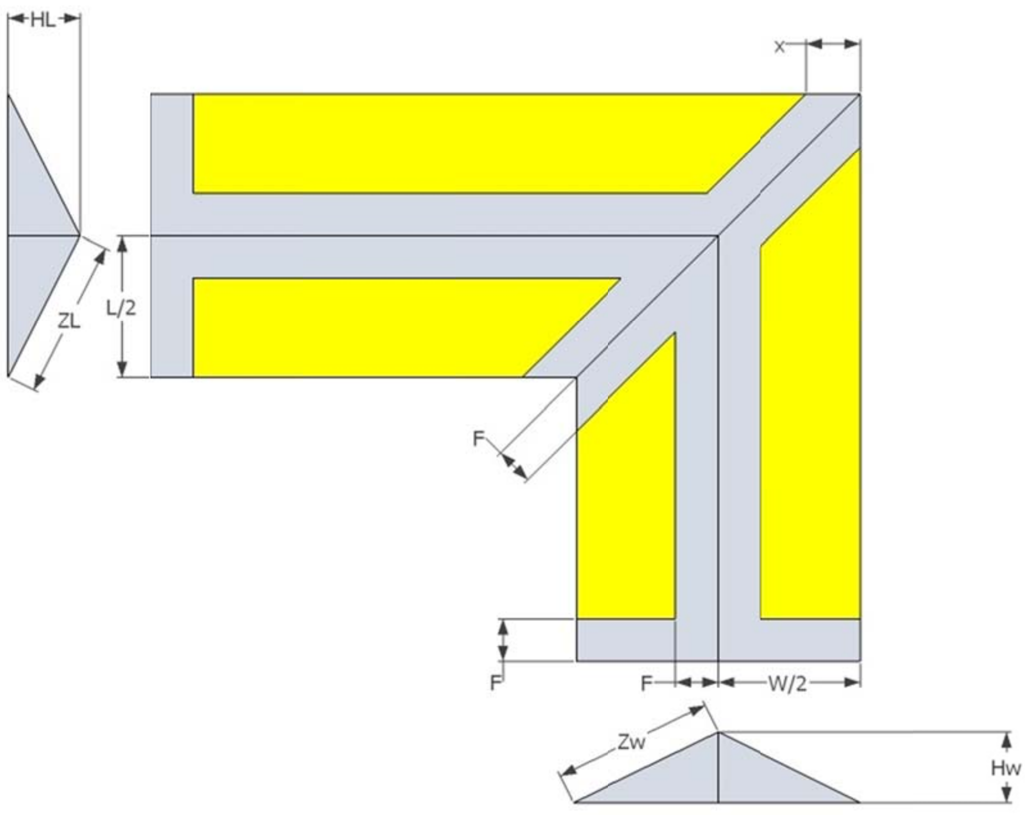


Figure 164: Solar zones and roof cross-sections for an L-shaped roof

The roof tilt (θ) is determined by the following formula:

$$\theta = \text{Atan}(P/12)$$

The roof height of the front facing roof section (H_w), and the roof height of the side facing roof section (H_L) can be determined via the following formulas:

$$H_w = (W_1/2)*\text{Tan}(\theta)$$

$$H_L = (L_1/2)*\text{Tan}(\theta)$$

The distance from roof eave to roof ridge (Z_w and Z_L) is given by the following general formula.

$$Z = H/\text{Sin}(\theta)$$

F is the fire setback, or perpendicular distance from the roof edge, roof ridge, and roof valley. For the roof valley, x is defined as the distance from the valley to start of the solar zone, parallel to the roof edge, as illustrated by the following figure.

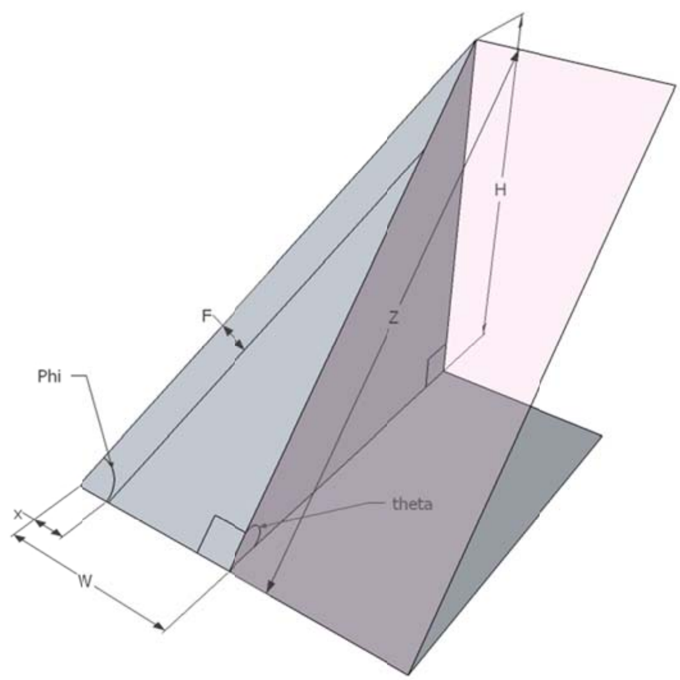


Figure 165: Fire setback geometry

If there is a solar system installed on both sides of the valley, then the distance x is defined by the following equation,

$$x = (F)/\text{Sin}(\phi)$$

and ϕ can be found through application of the law of cosines,

$$\phi = \text{Acos}[W/\text{sqrt}(W^2+Z^2)]$$

Note that if there is no solar system installed on the other side of the valley, then the solar system can about the valley and x = 0.

The solar zone areas are defined below.

$A_{sz,front} = (W_2\text{-X-F})*(Z_L\text{-F}) + ½* (Z_L\text{-F})*((Z_L\text{-F}) /(\text{Tan}(\phi))$

$A_{sz,back} = (\text{W-X-F})*(Z_L\text{-F}) - ½* (Z_L\text{-F})*((Z_L\text{-F}) /(\text{Tan}(\phi))$

$A_{left} = (L_2\text{-X-F})*(Z_w\text{-F}) + ½* (Z_w\text{-F})*((Z_w\text{-F}) /(\text{Tan}(\phi))$

$A_{right} = (\text{L-X-F})*(Z_w\text{-F}) - ½* (Z_w\text{-F})*((Z_w\text{-F}) /(\text{Tan}(\phi))$

The following figure shows an L-shaped building with a hip roof, with the solar zones highlighted in yellow. Calculations are nearly identical to the L-shaped building with a gable roof, with the exception of the hip roof sections. Note that there are now two different roof sections with solar zones facing front and left.

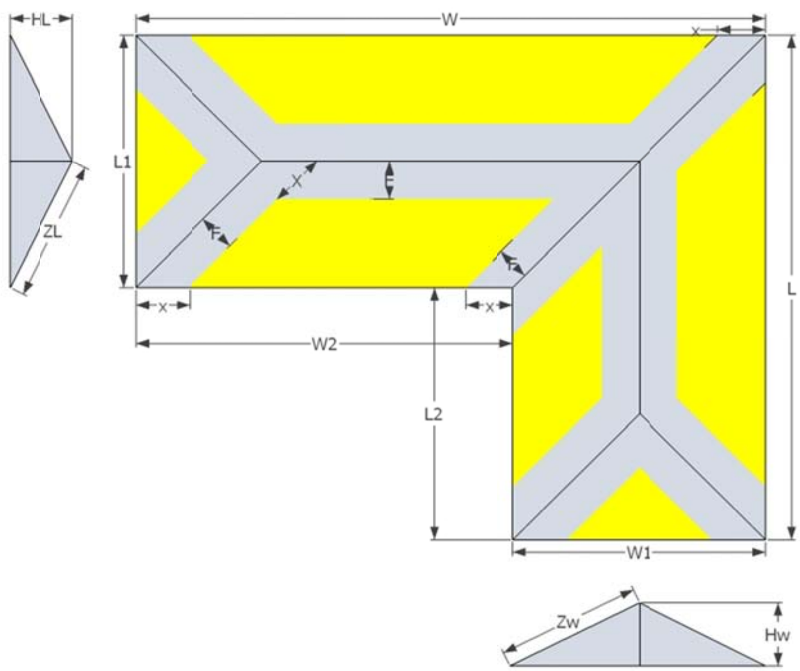


Figure 166: Potential solar zones for an L-shaped building with hip roofs

The geometry and solar zones for a T-shaped building with a gabled roof is summarized in Figure 167, and for a gabled roof in Figure 168. Note that T-shaped roof requires a new variable to define the location of the "T" relative to the width. This is defined as: $T_{\%} = W_2/(W-W_1)$ = location of the T, Ranging from 0 (T fully left) to 1 (T fully right)

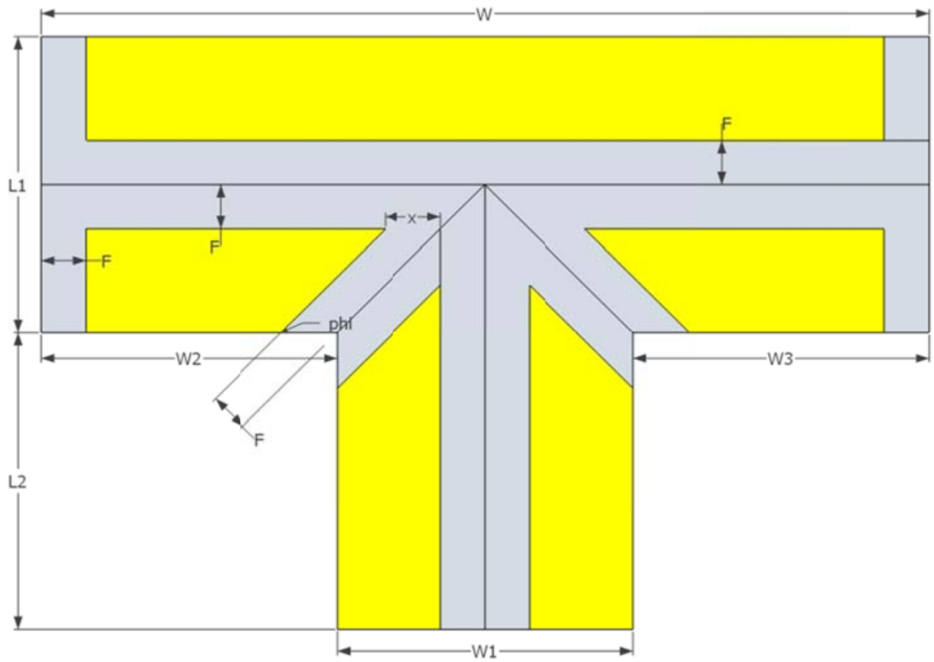


Figure 167: Potential solar zones for a T-shaped building with a gabled roof

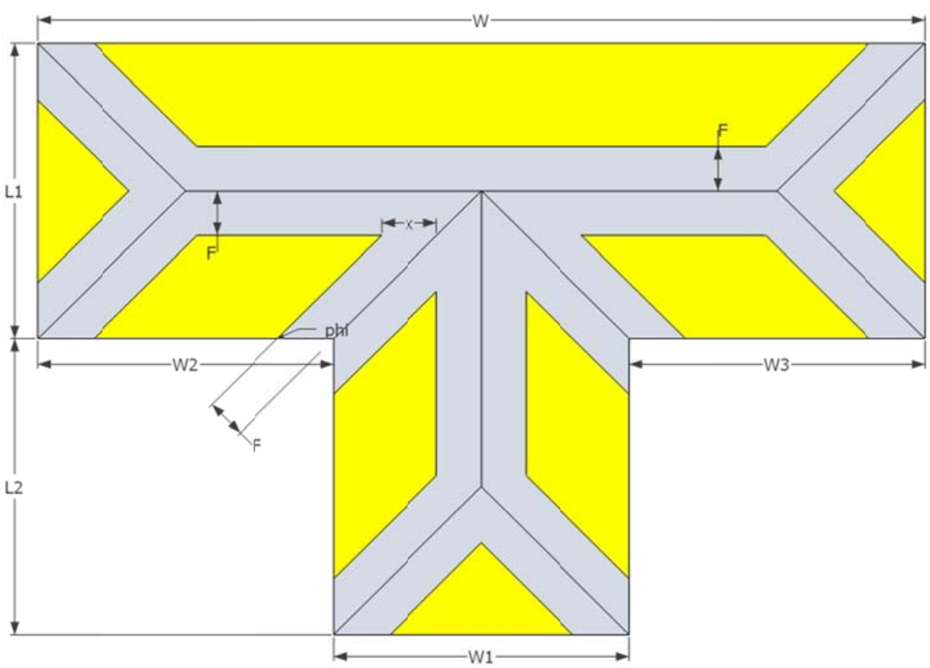


Figure 168: Potential solar zones for a T-shaped building with a hip roof

15. Appendix 9 - Solar Ready Homes Cost Effectiveness Supporting Data

15.1 Per System Energy Savings Details

The following graphs provide details on weighted average (by climate zone and azimuth) PV and SWH system performance and savings. Refer to section 4.5.5 for context and discussion.

Figure 169 summarizes the basecase 3.6 kW_{DC} PV system generation by climate zone. Rows 1 through 36 show PV generation for each climate zone and azimuth multiplied by the fraction of systems at each azimuth (Figure 47, black line). Row 37 shows the average PV system generation for each climate zone (weighted average for all azimuths, sum of rows 1 - 36). Row 38 shows the fraction of single family new home starts in 2014 by climate zone (based on CEC housing start projections). Row 39 shows the statewide weighted average per-system PV generation for all climate zones. Figure 170 shows similar data for the SWH system.

Figure 171 and Figure 172 shows similar data, but with poorly oriented systems re-oriented to minimally comply (i.e., azimuths < 150^o reoriented to 150^o, and azimuths > 270^o reoriented to 270^o) with the proposed solar oriented home solar zone orientation requirements. Statewide weighted average savings are 5,479 $kBTU_{TDV}$ (4.1%) per PV system, and 768 $kBTU_{TDV}$ (4.3%) per SWH system.

Reorienting poorly oriented systems to the optimal orientation (210^o for PV and 180^o for SWH), as shown in Figure 173 and Figure 174, results in system savings of 8,711 $kBTU_{TDV}$ (6.5%). 1,116 $kBTU_{TDV}$ (6.2%) for PV and SWH, respectively.

Azimuth	Climate Zone															
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
0	121	121	138	121	153	138	138	138	138	138	121	121	121	121	121	121
10	176	180	201	180	221	201	201	200	201	201	180	181	182	182	182	182
15	58	60	67	60	73	67	67	66	67	67	60	61	61	61	61	61
50	123	133	142	136	151	140	141	137	140	141	133	135	136	139	135	135
60	382	420	442	429	471	436	441	427	436	437	419	424	427	441	423	423
70	399	442	462	452	492	455	461	444	454	455	441	443	446	465	441	441
80	1,882	2,091	2,176	2,142	2,320	2,136	2,175	2,087	2,136	2,139	2,087	2,089	2,095	2,210	2,075	2,075
90	5,477	6,107	6,337	6,265	6,756	6,199	6,337	6,058	6,203	6,209	6,097	6,070	6,075	6,468	6,021	6,021
100	1,759	1,966	2,035	2,019	2,171	1,985	2,036	1,940	1,988	1,989	1,963	1,944	1,941	2,086	1,926	1,926
105	4,615	5,161	5,338	5,302	5,696	5,200	5,342	5,084	5,210	5,210	5,153	5,091	5,078	5,479	5,042	5,042
110	2,398	2,684	2,774	2,758	2,961	2,699	2,777	2,639	2,705	2,704	2,679	2,641	2,632	2,851	2,615	2,615
120	2,583	2,893	2,987	2,975	3,190	2,899	2,992	2,837	2,908	2,906	2,888	2,834	2,819	3,076	2,805	2,805
130	2,597	2,910	3,002	2,994	3,208	2,907	3,009	2,848	2,918	2,916	2,903	2,838	2,819	3,096	2,810	2,810
140	1,165	1,305	1,346	1,343	1,439	1,301	1,350	1,275	1,307	1,305	1,301	1,268	1,258	1,390	1,257	1,257
150	2,863	3,208	3,305	3,301	3,535	3,190	3,319	3,130	3,206	3,203	3,196	3,106	3,077	3,416	3,081	3,081
160	4,549	5,096	5,249	5,245	5,613	5,059	5,275	4,967	5,088	5,083	5,074	4,920	4,870	5,429	4,888	4,888
170	7,455	8,350	8,597	8,593	9,191	8,276	8,647	8,132	8,328	8,321	8,305	8,040	7,954	8,897	8,003	8,003
180	24,612	27,566	28,367	28,365	30,311	27,278	28,556	26,825	27,467	27,448	27,383	26,480	26,191	29,371	26,415	26,415
190	6,277	7,031	7,231	7,233	7,721	6,947	7,285	6,837	6,999	6,997	6,974	6,741	6,667	7,490	6,740	6,740
195	8,005	8,966	9,219	9,223	9,838	8,853	9,292	8,717	8,922	8,921	8,887	8,589	8,495	9,551	8,599	8,599
200	5,320	5,958	6,125	6,128	6,533	5,880	6,176	5,791	5,927	5,928	5,901	5,703	5,642	6,347	5,717	5,717
210	5,433	6,087	6,254	6,259	6,662	5,999	6,310	5,913	6,051	6,054	6,017	5,819	5,760	6,481	5,849	5,849
220	4,015	4,499	4,620	4,625	4,914	4,430	4,665	4,370	4,470	4,475	4,439	4,298	4,257	4,789	4,331	4,331
225	100	112	115	115	122	110	116	109	111	112	111	107	106	119	108	108
230	997	1,117	1,147	1,148	1,218	1,099	1,158	1,085	1,110	1,111	1,100	1,067	1,057	1,188	1,078	1,078
240	2,265	2,540	2,606	2,610	2,762	2,497	2,633	2,467	2,522	2,528	2,494	2,424	2,406	2,699	2,455	2,455
250	3,390	3,803	3,901	3,906	4,126	3,736	3,942	3,694	3,775	3,787	3,724	3,629	3,608	4,036	3,683	3,683
260	5,118	5,745	5,893	5,898	6,221	5,642	5,953	5,585	5,704	5,725	5,609	5,484	5,460	6,086	5,574	5,574
270	9,971	11,198	11,488	11,492	12,105	10,997	11,599	10,898	11,125	11,172	10,894	10,694	10,667	11,834	10,877	10,877
280	1,432	1,609	1,652	1,651	1,738	1,581	1,666	1,569	1,600	1,608	1,560	1,538	1,537	1,695	1,563	1,563
285	2,903	3,263	3,352	3,347	3,523	3,208	3,378	3,185	3,247	3,263	3,156	3,119	3,121	3,431	3,169	3,169
290	432	485	499	498	524	478	502	475	484	486	469	464	465	509	471	471
300	913	1,026	1,058	1,052	1,110	1,012	1,062	1,008	1,025	1,031	986	982	986	1,071	993	993
310	238	268	277	274	291	265	277	264	269	270	256	257	258	278	258	258
340	137	153	162	157	171	154	159	156	157	157	144	147	148	153	141	141
350	130	144	155	148	165	148	150	149	150	150	135	139	140	142	129	129
System Avg	**120,293**	**134,696**	**138,715**	**138,444**	**147,693**	**133,599**	**139,591**	**131,508**	**134,548**	**134,645**	**133,236**	**129,886**	**128,964**	**143,078**	**130,036**	**130,036**
% of Homes by CZ (2014)	***0.80%***	***2.48%***	***2.58%***	***5.67%***	***1.10%***	***2.51%***	***4.55%***	***4.15%***	***4.79%***	***18.67%***	***6.81%***	***20.63%***	***14.59%***	***3.46%***	***4.06%***	***3.16%***
State-Wide Wghtd Avg.	**133,112**															

Figure 169: PV system basecase energy generation (TDV/year/system)

	Climate Zone															
Azimuth	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**
0	10	14	14	15	16	16	15	17	16	16	13	15	15	17	14	
10	15	22	21	23	24	24	23	26	24	24	20	23	24	27	22	
15	5	7	7	8	8	8	8	9	8	8	7	8	8	9	8	
50	13	18	18	19	20	20	20	21	20	20	17	20	20	23	19	
60	41	59	58	61	65	62	63	68	64	64	56	63	63	74	62	
70	44	63	62	65	70	66	67	72	69	68	60	66	66	78	66	
80	215	300	295	310	334	318	322	341	327	326	286	316	313	375	317	
90	643	881	869	909	985	933	947	1,000	956	957	844	923	911	1,103	930	
100	210	284	281	293	319	301	306	322	308	308	273	296	291	356	300	
105	556	746	738	769	839	791	804	845	807	808	718	776	762	935	786	
110	291	388	384	399	437	411	418	439	419	420	374	403	394	486	408	
120	316	417	413	428	472	442	450	472	449	451	402	431	421	522	439	
130	319	417	414	428	473	443	451	472	449	451	403	430	419	523	438	
140	143	186	185	191	212	198	201	210	200	201	180	191	186	233	195	
150	351	453	451	464	517	482	490	513	486	489	438	463	451	568	475	
160	555	713	710	729	815	759	771	807	764	769	689	727	706	894	746	
170	902	1,155	1,150	1,180	1,322	1,230	1,250	1,309	1,236	1,245	1,115	1,176	1,142	1,448	1,208	
180	2,944	3,765	3,750	3,841	4,316	4,012	4,075	4,273	4,025	4,060	3,631	3,828	3,715	4,723	3,932	
190	741	947	943	965	1,087	1,010	1,025	1,076	1,012	1,021	912	962	934	1,188	988	
195	937	1,199	1,194	1,221	1,376	1,278	1,297	1,363	1,280	1,293	1,153	1,217	1,182	1,504	1,250	
200	617	790	787	805	907	843	856	900	844	853	759	802	779	992	824	
210	619	794	791	808	912	848	860	906	848	857	761	806	784	997	827	
220	447	577	574	586	662	616	624	659	616	623	551	586	570	724	600	
225	11	14	14	14	16	15	15	16	15	15	14	14	14	18	15	
230	108	141	140	143	161	150	152	161	150	152	134	143	139	176	146	
240	240	313	311	318	359	334	338	360	334	339	297	319	311	393	325	
250	348	459	455	466	525	490	495	529	490	497	433	468	458	575	476	
260	508	678	670	687	774	724	731	783	725	735	636	693	680	849	701	
270	955	1,289	1,272	1,307	1,469	1,379	1,388	1,496	1,382	1,402	1,204	1,323	1,303	1,613	1,333	
280	132	181	178	183	205	193	194	211	194	197	168	186	184	226	186	
285	262	362	356	367	410	387	389	422	389	395	334	373	370	452	373	
290	38	53	52	54	60	57	57	62	57	58	49	55	55	66	55	
300	77	110	107	111	123	118	117	129	118	120	100	114	114	136	112	
310	19	28	27	28	31	30	30	33	30	31	25	29	29	35	29	
340	10	15	15	15	17	17	16	18	17	17	13	16	16	18	15	
350	9	14	14	15	16	16	15	17	16	16	13	15	15	17	14	
System Avg	**13,653**	**17,852**	**17,718**	**18,225**	**20,354**	**19,019**	**19,279**	**20,359**	**19,144**	**19,307**	**17,079**	**18,275**	**17,845**	**22,372**	**18,636**	**-**
% of Homes by CZ (2014)	**0.80%**	**2.48%**	**2.58%**	**5.67%**	**1.10%**	**2.51%**	**4.55%**	**4.15%**	**4.79%**	**18.67%**	**6.81%**	**20.63%**	**14.59%**	**3.46%**	**4.06%**	**3.16%**
State-Wide Wghtd Avg.	**18,053**															

Figure 170: SWH system basecase energy generation (TDV/year)

Azimuth	Climate Zone															
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
150	185	207	213	213	228	206	214	202	207	207	206	200	199	220	199	199
150	277	310	320	319	342	309	321	303	310	310	309	301	298	331	298	298
150	92	103	107	106	114	103	107	101	103	103	103	100	99	110	99	99
150	185	207	213	213	228	206	214	202	207	207	206	200	199	220	199	199
150	554	621	640	639	684	617	642	606	621	620	619	601	596	661	596	596
150	554	621	640	639	684	617	642	606	621	620	619	601	596	661	596	596
150	2,493	2,794	2,879	2,875	3,079	2,779	2,891	2,726	2,793	2,790	2,784	2,705	2,680	2,975	2,684	2,684
150	6,926	7,760	7,996	7,987	8,552	7,718	8,030	7,572	7,758	7,749	7,733	7,514	7,445	8,265	7,455	7,455
150	2,124	2,380	2,452	2,449	2,622	2,367	2,462	2,322	2,379	2,376	2,371	2,304	2,283	2,535	2,286	2,286
150	5,449	6,105	6,291	6,283	6,727	6,072	6,317	5,957	6,103	6,096	6,083	5,911	5,856	6,502	5,864	5,864
150	2,771	3,104	3,199	3,195	3,421	3,087	3,212	3,029	3,103	3,100	3,093	3,006	2,978	3,306	2,982	2,982
150	2,863	3,208	3,305	3,301	3,535	3,190	3,319	3,130	3,206	3,203	3,196	3,106	3,077	3,416	3,081	3,081
150	2,771	3,104	3,199	3,195	3,421	3,087	3,212	3,029	3,103	3,100	3,093	3,006	2,978	3,306	2,982	2,982
150	1,201	1,345	1,386	1,384	1,482	1,338	1,392	1,312	1,345	1,343	1,340	1,302	1,290	1,433	1,292	1,292
150	2,863	3,208	3,305	3,301	3,535	3,190	3,319	3,130	3,206	3,203	3,196	3,106	3,077	3,416	3,081	3,081
160	4,549	5,096	5,249	5,245	5,613	5,059	5,275	4,967	5,088	5,083	5,074	4,920	4,870	5,429	4,888	4,888
170	7,455	8,350	8,597	8,593	9,191	8,276	8,647	8,132	8,328	8,321	8,305	8,040	7,954	8,897	8,003	8,003
180	24,612	27,566	28,367	28,365	30,311	27,278	28,556	26,825	27,467	27,448	27,383	26,480	26,191	29,371	26,415	26,415
190	6,277	7,031	7,231	7,233	7,721	6,947	7,285	6,837	6,999	6,997	6,974	6,741	6,667	7,490	6,740	6,740
195	8,005	8,966	9,219	9,223	9,838	8,853	9,292	8,717	8,922	8,921	8,887	8,589	8,495	9,551	8,599	8,599
200	5,320	5,958	6,125	6,128	6,533	5,880	6,176	5,791	5,927	5,928	5,901	5,703	5,642	6,347	5,717	5,717
210	5,433	6,087	6,254	6,259	6,662	5,999	6,310	5,913	6,051	6,054	6,017	5,819	5,760	6,481	5,849	5,849
220	4,015	4,499	4,620	4,625	4,914	4,430	4,665	4,370	4,470	4,475	4,439	4,298	4,257	4,789	4,331	4,331
225	100	112	115	115	122	110	116	109	111	112	111	107	106	119	108	108
230	997	1,117	1,147	1,148	1,218	1,099	1,158	1,085	1,110	1,111	1,100	1,067	1,057	1,188	1,078	1,078
240	2,265	2,540	2,606	2,610	2,762	2,497	2,633	2,467	2,522	2,528	2,494	2,424	2,406	2,699	2,455	2,455
250	3,390	3,803	3,901	3,906	4,126	3,736	3,942	3,694	3,775	3,787	3,724	3,629	3,608	4,036	3,683	3,683
260	5,118	5,745	5,893	5,898	6,221	5,642	5,953	5,585	5,704	5,725	5,609	5,484	5,460	6,086	5,574	5,574
270	9,971	11,198	11,488	11,492	12,105	10,997	11,599	10,898	11,125	11,172	10,894	10,694	10,667	11,834	10,877	10,877
270	1,477	1,659	1,702	1,703	1,793	1,629	1,718	1,615	1,648	1,655	1,614	1,584	1,580	1,753	1,611	1,611
270	3,047	3,422	3,510	3,511	3,699	3,360	3,544	3,330	3,399	3,414	3,329	3,268	3,259	3,616	3,323	3,323
270	462	518	532	532	560	509	537	505	515	517	504	495	494	548	504	504
270	1,016	1,141	1,170	1,170	1,233	1,120	1,181	1,110	1,133	1,138	1,110	1,089	1,086	1,205	1,108	1,108
270	277	311	319	319	336	305	322	303	309	310	303	297	296	329	302	302
270	185	207	213	213	224	204	215	202	206	207	202	198	198	219	201	201
270	185	207	213	213	224	204	215	202	206	207	202	198	198	219	201	201
System Avg	**125,462**	**140,612**	**144,614**	**144,601**	**154,059**	**139,019**	**145,636**	**136,882**	**140,082**	**140,134**	**139,127**	**135,089**	**133,902**	**149,565**	**135,262**	**135,262**
% of Homes by CZ (2014)	***0.80%***	***2.48%***	***2.58%***	***5.67%***	***1.10%***	***2.51%***	***4.55%***	***4.15%***	***4.79%***	***18.67%***	***6.81%***	***20.63%***	***14.59%***	***3.46%***	***4.06%***	***3.16%***
State-Wide Wghtd Avg.	**138,592**															
Savings	**5,479**															
	4.1%															

Figure 171: PV system energy generation and savings (TDV/year) for a solar ready home, minimal orientation improvement

	Climate Zone															
Azimuth	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**
150	23	29	29	30	33	31	32	33	31	32	28	30	29	37	31	
150	34	44	44	45	50	47	47	50	47	47	42	45	44	55	46	
150	11	15	15	15	17	16	16	17	16	16	14	15	15	18	15	
150	23	29	29	30	33	31	32	33	31	32	28	30	29	37	31	
150	68	88	87	90	100	93	95	99	94	95	85	90	87	110	92	
150	68	88	87	90	100	93	95	99	94	95	85	90	87	110	92	
150	306	395	393	404	450	420	427	447	423	426	381	404	392	495	414	
150	850	1,096	1,091	1,122	1,250	1,166	1,185	1,241	1,176	1,183	1,060	1,121	1,090	1,374	1,149	
150	261	336	334	344	383	357	363	380	361	363	325	344	334	421	352	
150	668	863	858	883	984	917	932	976	925	930	834	882	857	1,081	904	
150	340	439	436	449	500	466	474	496	470	473	424	448	436	550	460	
150	351	453	451	464	517	482	490	513	486	489	438	463	451	568	475	
150	340	439	436	449	500	466	474	496	470	473	424	448	436	550	460	
150	147	190	189	195	217	202	205	215	204	205	184	194	189	238	199	
150	351	453	451	464	517	482	490	513	486	489	438	463	451	568	475	
160	555	713	710	729	815	759	771	807	764	769	689	727	706	894	746	
170	902	1,155	1,150	1,180	1,322	1,230	1,250	1,309	1,236	1,245	1,115	1,176	1,142	1,448	1,208	
180	2,944	3,765	3,750	3,841	4,316	4,012	4,075	4,273	4,025	4,060	3,631	3,828	3,715	4,723	3,932	
190	741	947	943	965	1,087	1,010	1,025	1,076	1,012	1,021	912	962	934	1,188	988	
195	937	1,199	1,194	1,221	1,376	1,278	1,297	1,363	1,280	1,293	1,153	1,217	1,182	1,504	1,250	
200	617	790	787	805	907	843	856	900	844	853	759	802	779	992	824	
210	619	794	791	808	912	848	860	906	848	857	761	806	784	997	827	
220	447	577	574	586	662	616	624	659	616	623	551	586	570	724	600	
225	11	14	14	14	16	15	15	16	15	15	14	14	14	18	15	
230	108	141	140	143	161	150	152	161	150	152	134	143	139	176	146	
240	240	313	311	318	359	334	338	360	334	339	297	319	311	393	325	
250	348	459	455	466	525	490	495	529	490	497	433	468	458	575	476	
260	508	678	670	687	774	724	731	783	725	735	636	693	680	849	701	
270	955	1,289	1,272	1,307	1,469	1,379	1,388	1,496	1,382	1,402	1,204	1,323	1,303	1,613	1,333	
270	142	191	188	194	218	204	206	222	205	208	178	196	193	239	197	
270	292	394	389	399	449	421	424	457	422	428	368	404	398	493	407	
270	44	60	59	61	68	64	64	69	64	65	56	61	60	75	62	
270	97	131	130	133	150	140	141	152	141	143	123	135	133	164	136	
270	27	36	35	36	41	38	39	42	38	39	33	37	36	45	37	
270	18	24	24	24	27	26	26	28	26	26	22	24	24	30	25	
270	18	24	24	24	27	26	26	28	26	26	22	24	24	30	25	
System Avg	**14,410**	**18,650**	**18,537**	**19,014**	**21,332**	**19,875**	**20,159**	**21,244**	**19,956**	**20,141**	**17,880**	**19,013**	**18,514**	**23,380**	**19,453**	**-**
% of Homes by CZ (2014)	**0.80%**	**2.48%**	**2.58%**	**5.67%**	**1.10%**	**2.51%**	**4.55%**	**4.15%**	**4.79%**	**18.67%**	**6.81%**	**20.63%**	**14.59%**	**3.46%**	**4.06%**	**3.16%**
State-Wide Wghtd Avg.	**18,820**															
Savings	**768**															
	4.3%															

Figure 172: SWH system energy generation and savings (TDV/year) for a solar ready home, minimal orientation improvement

Azimuth	Climate Zone															
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
210	201	225	232	232	247	222	234	219	224	224	223	216	213	240	217	217
210	302	338	347	348	370	333	351	329	336	336	334	323	320	360	325	325
210	101	113	116	116	123	111	117	110	112	112	111	108	107	120	108	108
210	201	225	232	232	247	222	234	219	224	224	223	216	213	240	217	217
210	604	676	695	695	740	667	701	657	672	673	669	647	640	720	650	650
210	604	676	695	695	740	667	701	657	672	673	669	647	640	720	650	650
210	2,717	3,043	3,127	3,129	3,331	3,000	3,155	2,957	3,025	3,027	3,009	2,910	2,880	3,241	2,924	2,924
210	7,546	8,454	8,686	8,693	9,252	8,332	8,764	8,213	8,404	8,409	8,357	8,082	8,000	9,002	8,123	8,123
210	2,314	2,592	2,664	2,666	2,837	2,555	2,688	2,519	2,577	2,579	2,563	2,479	2,453	2,761	2,491	2,491
210	5,937	6,650	6,833	6,838	7,278	6,555	6,894	6,461	6,611	6,615	6,574	6,358	6,293	7,082	6,390	6,390
210	3,019	3,381	3,474	3,477	3,701	3,333	3,506	3,285	3,362	3,363	3,343	3,233	3,200	3,601	3,249	3,249
210	3,119	3,494	3,590	3,593	3,824	3,444	3,622	3,395	3,474	3,476	3,454	3,341	3,307	3,721	3,358	3,358
210	3,019	3,381	3,474	3,477	3,701	3,333	3,506	3,285	3,362	3,363	3,343	3,233	3,200	3,601	3,249	3,249
210	1,308	1,465	1,505	1,507	1,604	1,444	1,519	1,424	1,457	1,457	1,449	1,401	1,387	1,560	1,408	1,408
150	2,863	3,208	3,305	3,301	3,535	3,190	3,319	3,130	3,206	3,203	3,196	3,106	3,077	3,416	3,081	3,081
160	4,549	5,096	5,249	5,245	5,613	5,059	5,275	4,967	5,088	5,083	5,074	4,920	4,870	5,429	4,888	4,888
170	7,455	8,350	8,597	8,593	9,191	8,276	8,647	8,132	8,328	8,321	8,305	8,040	7,954	8,897	8,003	8,003
180	24,612	27,566	28,367	28,365	30,311	27,278	28,556	26,825	27,467	27,448	27,383	26,480	26,191	29,371	26,415	26,415
190	6,277	7,031	7,231	7,233	7,721	6,947	7,285	6,837	6,999	6,997	6,974	6,741	6,667	7,490	6,740	6,740
195	8,005	8,966	9,219	9,223	9,838	8,853	9,292	8,717	8,922	8,921	8,887	8,589	8,495	9,551	8,599	8,599
200	5,320	5,958	6,125	6,128	6,533	5,880	6,176	5,791	5,927	5,928	5,901	5,703	5,642	6,347	5,717	5,717
210	5,433	6,087	6,254	6,259	6,662	5,999	6,310	5,913	6,051	6,054	6,017	5,819	5,760	6,481	5,849	5,849
220	4,015	4,499	4,620	4,625	4,914	4,430	4,665	4,370	4,470	4,475	4,439	4,298	4,257	4,789	4,331	4,331
225	100	112	115	115	122	110	116	109	111	112	111	107	106	119	108	108
230	997	1,117	1,147	1,148	1,218	1,099	1,158	1,085	1,110	1,111	1,100	1,067	1,057	1,188	1,078	1,078
240	2,265	2,540	2,606	2,610	2,762	2,497	2,633	2,467	2,522	2,528	2,494	2,424	2,406	2,699	2,455	2,455
250	3,390	3,803	3,901	3,906	4,126	3,736	3,942	3,694	3,775	3,787	3,724	3,629	3,608	4,036	3,683	3,683
260	5,118	5,745	5,893	5,898	6,221	5,642	5,953	5,585	5,704	5,725	5,609	5,484	5,460	6,086	5,574	5,574
270	9,971	11,198	11,488	11,492	12,105	10,997	11,599	10,898	11,125	11,172	10,894	10,694	10,667	11,834	10,877	10,877
210	1,610	1,803	1,853	1,854	1,974	1,778	1,870	1,752	1,793	1,794	1,783	1,724	1,707	1,920	1,733	1,733
210	3,320	3,720	3,822	3,825	4,071	3,666	3,856	3,614	3,698	3,700	3,677	3,556	3,520	3,961	3,574	3,574
210	503	564	579	580	617	555	584	548	560	561	557	539	533	600	542	542
210	1,107	1,240	1,274	1,275	1,357	1,222	1,285	1,205	1,233	1,233	1,226	1,185	1,173	1,320	1,191	1,191
210	302	338	347	348	370	333	351	329	336	336	334	323	320	360	325	325
210	201	225	232	232	247	222	234	219	224	224	223	216	213	240	217	217
210	201	225	232	232	247	222	234	219	224	224	223	216	213	240	217	217
System Avg	**128,606**	**144,110**	**148,123**	**148,185**	**157,749**	**142,210**	**149,333**	**140,133**	**143,388**	**143,467**	**142,451**	**138,051**	**136,749**	**153,344**	**138,556**	**138,556**
% of Homes by CZ (2014)	***0.80%***	***2.48%***	***2.58%***	***5.67%***	***1.10%***	***2.51%***	***4.55%***	***4.15%***	***4.79%***	***18.67%***	***6.81%***	***20.63%***	***14.59%***	***3.46%***	***4.06%***	***3.16%***
State-Wide Wghtd Avg.	**141,823**															
Savings	**8,711**															
	6.5%															

Figure 173: PV system energy generation and savings (TDV/year) for a solar ready home, optimal orientation improvement

	Climate Zone															
Azimuth	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
180	24	30	30	31	35	32	33	34	32	32	29	31	30	38	31	
180	35	45	45	46	52	48	49	51	48	49	44	46	45	57	47	
180	12	15	15	15	17	16	16	17	16	16	15	15	15	19	16	
180	24	30	30	31	35	32	33	34	32	32	29	31	30	38	31	
180	71	90	90	92	104	96	98	103	97	97	87	92	89	113	94	
180	71	90	90	92	104	96	98	103	97	97	87	92	89	113	94	
180	318	407	405	415	466	433	440	461	435	438	392	413	401	510	425	
180	883	1,130	1,125	1,152	1,295	1,203	1,222	1,282	1,208	1,218	1,089	1,148	1,115	1,417	1,180	
180	271	346	345	353	397	369	375	393	370	373	334	352	342	434	362	
180	695	889	885	906	1,019	947	962	1,008	950	958	857	903	877	1,115	928	
180	353	452	450	461	518	481	489	513	483	487	436	459	446	567	472	
180	365	467	465	476	535	497	505	530	499	503	450	475	461	586	488	
180	353	452	450	461	518	481	489	513	483	487	436	459	446	567	472	
180	153	196	195	200	224	209	212	222	209	211	189	199	193	246	204	
150	351	453	451	464	517	482	490	513	486	489	438	463	451	568	475	
160	555	713	710	729	815	759	771	807	764	769	689	727	706	894	746	
170	902	1,155	1,150	1,180	1,322	1,230	1,250	1,309	1,236	1,245	1,115	1,176	1,142	1,448	1,208	
180	2,944	3,765	3,750	3,841	4,316	4,012	4,075	4,273	4,025	4,060	3,631	3,828	3,715	4,723	3,932	
190	741	947	943	965	1,087	1,010	1,025	1,076	1,012	1,021	912	962	934	1,188	988	
195	937	1,199	1,194	1,221	1,376	1,278	1,297	1,363	1,280	1,293	1,153	1,217	1,182	1,504	1,250	
200	617	790	787	805	907	843	856	900	844	853	759	802	779	992	824	
210	619	794	791	808	912	848	860	906	848	857	761	806	784	997	827	
220	447	577	574	586	662	616	624	659	616	623	551	586	570	724	600	
225	11	14	14	14	16	15	15	16	15	15	14	14	14	18	15	
230	108	141	140	143	161	150	152	161	150	152	134	143	139	176	146	
240	240	313	311	318	359	334	338	360	334	339	297	319	311	393	325	
250	348	459	455	466	525	490	495	529	490	497	433	468	458	575	476	
260	508	678	670	687	774	724	731	783	725	735	636	693	680	849	701	
270	955	1,289	1,272	1,307	1,469	1,379	1,388	1,496	1,382	1,402	1,204	1,323	1,303	1,613	1,333	
180	188	241	240	246	276	257	261	273	258	260	232	245	238	302	252	
180	389	497	495	507	570	530	538	564	531	536	479	505	490	623	519	
180	59	75	75	77	86	80	81	85	81	81	73	77	74	94	79	
180	130	166	165	169	190	177	179	188	177	179	160	168	163	208	173	
180	35	45	45	46	52	48	49	51	48	49	44	46	45	57	47	
180	24	30	30	31	35	32	33	34	32	32	29	31	30	38	31	
180	24	30	30	31	35	32	33	34	32	32	29	31	30	38	31	
System Avg	**14,759**	**19,011**	**18,910**	**19,372**	**21,778**	**20,266**	**20,560**	**21,647**	**20,325**	**20,521**	**18,245**	**19,345**	**18,816**	**23,839**	**19,823**	**-**
% of Homes by CZ (2014)	**0.80%**	**2.48%**	**2.58%**	**5.67%**	**1.10%**	**2.51%**	**4.55%**	**4.15%**	**4.79%**	**18.67%**	**6.81%**	**20.63%**	**14.59%**	**3.46%**	**4.06%**	**3.16%**
State-Wide Wghtd Avg.	**19,168**															
Savings	**1,116**															
	6.2%															

Figure 174: SWH system energy generation and savings (TDV/year) for a solar ready home, optimal orientation improvement

15.2 Life Cycle Cost Supporting Data

			Solar Ready Costs for All Homes			Retrofit Costs for Homes Installing PV					PV Energy Savings				Retrofit Costs for Homes Installing SWH					SWH Energy Savings			
Year	New Homes Built	New Construction PV Penetration	New Homes Incurring "PV Ready" Costs	Solar-Ready Unit Cost	Total Solar-Ready Costs	PV Penetration	Number of Homes Installing PV	Retrofit Unit Cost Adder without Solar Ready	Statewide Retrofit Costs (not discounted)	Retrofit Costs Present Value	PV Energy Savings (kBTU/ PV system)	Statewide PV energy savings (kBTU)	PV Energy Savings Value (non-discounted)	Present value of PV Energy Savings	SHW Penetration	Number of Homes Installing SHW	Retrofit Unit Cost Adder without Solar Ready	Statewide Retrofit Costs (not discounted)	Retrofit Costs Present Value	SWH Energy Savings (kBTU/ PV system)	Statewide SWH energy savings (kBTU)	SHW Energy Savings Value (non-discounted)	Present value of SHW Energy Savings
2011						0.58%	Current 2011 penetration								0.01%	Current 2011 penetration							
2012						0.66%									0.12%								
2013						0.74%									0.22%								
2014	103,438	0.82%	102,592	$ 182	$ 18,671,687	0.82%	846	new homes with PV							0.33%	339	new homes with SWH						
2015						0.90%	82	$ 2,687	$ 220,625	$ 214,199	8,711	715,364	$ 6,321	$ 6,137	0.43%	109	$ 1,132	$ 123,847	$ 120,240	1,116	122,044	$ 1,078	$ 1,047
2016						0.98%	82	$ 2,687	$ 220,625	$ 207,960	8,711	1,430,727	$ 12,642	$ 11,916	0.54%	109	$ 1,132	$ 123,806	$ 116,699	1,116	244,088	$ 2,157	$ 2,033
2017						1.06%	82	$ 2,687	$ 220,625	$ 201,903	8,711	2,146,091	$ 18,963	$ 17,354	0.64%	109	$ 1,132	$ 123,806	$ 113,300	1115.642	366,132	$ 3,235	$ 2,961
2018						1.14%	82	$ 2,687	$ 220,625	$ 196,022	8,711	2,861,454	$ 25,284	$ 22,464	0.75%	109	$ 1,132	$ 123,806	$ 110,000	1115.642	488,176	$ 4,313	$ 3,832
2019						1.22%	82	$ 2,687	$ 220,625	$ 190,313	8,711	3,576,818	$ 31,605	$ 27,262	0.86%	109	$ 1,132	$ 123,806	$ 106,796	1115.642	610,220	$ 5,392	$ 4,651
2020						1.29%	82	$ 2,687	$ 220,625	$ 184,770	8,711	4,292,182	$ 37,925	$ 31,762	0.96%	109	$ 1,132	$ 123,806	$ 103,686	1115.642	732,264	$ 6,470	$ 5,419
2021						1.37%	82	$ 2,687	$ 220,625	$ 179,388	8,711	5,007,545	$ 44,246	$ 35,976	1.07%	109	$ 1,132	$ 123,806	$ 100,666	1115.642	854,308	$ 7,549	$ 6,138
2022						1.45%	82	$ 2,687	$ 220,625	$ 174,163	8,711	5,722,909	$ 50,567	$ 39,918	1.17%	109	$ 1,132	$ 123,806	$ 97,734	1115.642	976,352	$ 8,627	$ 6,810
2023						1.53%	82	$ 2,687	$ 220,625	$ 169,091	8,711	6,438,273	$ 56,888	$ 43,600	1.28%	109	$ 1,132	$ 123,806	$ 94,887	1115.642	1,098,396	$ 9,705	$ 7,438
2024						1.61%	82	$ 2,687	$ 220,625	$ 164,166	8,711	7,153,636	$ 63,209	$ 47,033	1.38%	109	$ 1,132	$ 123,806	$ 92,123	1115.642	1,220,440	$ 10,784	$ 8,024
2025						1.69%	82	$ 2,687	$ 220,625	$ 159,384	8,711	7,869,000	$ 69,530	$ 50,230	1.49%	109	$ 1,132	$ 123,806	$ 89,440	1115.642	1,342,485	$ 11,862	$ 8,569
2026						1.77%	82	$ 2,687	$ 220,625	$ 154,742	8,711	8,584,363	$ 75,851	$ 53,200	1.60%	109	$ 1,132	$ 123,806	$ 86,835	1115.642	1,464,529	$ 12,940	$ 9,076
2027						1.85%	82	$ 2,687	$ 220,625	$ 150,235	8,711	9,299,727	$ 82,172	$ 55,955	1.70%	109	$ 1,132	$ 123,806	$ 84,306	1115.642	1,586,573	$ 14,019	$ 9,546
2028						1.93%	82	$ 2,687	$ 220,625	$ 145,859	8,711	10,015,091	$ 88,493	$ 58,504	1.81%	109	$ 1,132	$ 123,806	$ 81,850	1115.642	1,708,617	$ 15,097	$ 9,981
2029						2.01%	82	$ 2,687	$ 220,625	$ 141,611	8,711	10,730,454	$ 94,814	$ 60,857	1.91%	109	$ 1,132	$ 123,806	$ 79,466	1115.642	1,830,661	$ 16,176	$ 10,382
2030						2.09%	82	$ 2,687	$ 220,625	$ 137,486	8,711	11,445,818	$ 101,134	$ 63,024	2.02%	109	$ 1,132	$ 123,806	$ 77,152	1115.642	1,952,705	$ 17,254	$ 10,752
2031						2.17%	82	$ 2,687	$ 220,625	$ 133,482	8,711	12,161,182	$ 107,455	$ 65,012	2.13%	109	$ 1,132	$ 123,806	$ 74,905	1115.642	2,074,749	$ 18,332	$ 11,091
2032						2.25%	82	$ 2,687	$ 220,625	$ 129,594	8,711	12,876,545	$ 113,776	$ 66,832	2.23%	109	$ 1,132	$ 123,806	$ 72,723	1115.642	2,196,793	$ 19,411	$ 11,402
2033						2.33%	82	$ 2,687	$ 220,625	$ 125,819	8,711	13,591,909	$ 120,097	$ 68,490	2.34%	109	$ 1,132	$ 123,806	$ 70,605	1115.642	2,318,837	$ 20,489	$ 11,685
2034						2.41%	82	$ 2,687	$ 220,625	$ 122,155	8,711	14,307,272	$ 126,418	$ 69,995	2.44%	109	$ 1,132	$ 123,806	$ 68,548	1115.642	2,440,881	$ 21,567	$ 11,941
2035						2.49%	82	$ 2,687	$ 220,625	$ 118,597	8,711	15,022,636	$ 132,739	$ 71,354	2.55%	109	$ 1,132	$ 123,806	$ 66,552	1115.642	2,562,925	$ 22,646	$ 12,173
2036						2.56%	82	$ 2,687	$ 220,625	$ 115,142	8,711	15,738,000	$ 139,060	$ 72,574	2.65%	109	$ 1,132	$ 123,806	$ 64,613	1115.642	2,684,969	$ 23,724	$ 12,381
2037						2.64%	82	$ 2,687	$ 220,625	$ 111,789	8,711	16,453,363	$ 145,381	$ 73,663	2.76%	109	$ 1,132	$ 123,806	$ 62,732	1115.642	2,807,013	$ 24,803	$ 12,567
2038						2.72%	82	$ 2,687	$ 220,625	$ 108,533	8,711	17,168,727	$ 151,702	$ 74,627	2.87%	109	$ 1,132	$ 123,806	$ 60,904	1115.642	2,929,057	$ 25,881	$ 12,732
2039						2.80%	82	$ 2,687	$ 220,625	$ 105,372	8,711	17,884,090	$ 158,023	$ 75,472	2.97%	109	$ 1,132	$ 123,806	$ 59,130	1115.642	3,051,101	$ 26,959	$ 12,876
2040						2.88%	82	$ 2,687	$ 220,625	$ 102,303	8,711	18,599,454	$ 164,343	$ 76,205	3.08%	109	$ 1,132	$ 123,806	$ 57,408	1115.642	3,173,145	$ 28,038	$ 13,001
2041						2.96%	82	$ 2,687	$ 220,625	$ 99,323	8,711	19,314,818	$ 170,664	$ 76,831	3.18%	109	$ 1,132	$ 123,806	$ 55,736	1115.642	3,295,189	$ 29,116	$ 13,108
2042						3.04%	82	$ 2,687	$ 220,625	$ 96,430	8,711	20,030,181	$ 176,985	$ 77,356	3.29%	109	$ 1,132	$ 123,806	$ 54,113	1115.642	3,417,233	$ 30,194	$ 13,197
2043						3.12%	82	$ 2,687	$ 220,625	$ 93,621	8,711	20,745,545	$ 183,306	$ 77,785	3.39%	109	$ 1,132	$ 123,806	$ 52,537	1115.642	3,539,277	$ 31,273	$ 13,271
2044						3.20%	82	$ 2,687	$ 220,625	$ 90,894	8,711	21,460,909	$ 189,627	$ 78,124	3.50%	109	$ 1,132	$ 123,806	$ 51,006	1115.642	3,661,321	$ 32,351	$ 13,328
Totals					**$ 18,671,687**		**3,310**			**$ 4,324,343**				**$ 1,649,514**		**3,620**			**$ 2,426,694**				**$ 281,414**

Figure 175: Life cycle cost analysis data for scenario 1

			Solar Ready Costs for All Homes			Retrofit Costs for Homes Installing PV					PV Energy Savings				Retrofit Costs for Homes Installing SWH					SWH Energy Savings			
Year	New Homes Built	New Construction PV Penetration	New Homes Incurring "PV Ready" Costs	Solar-Ready Unit Cost	Total Solar-Ready Costs	PV Penetration	Number of Homes Installing PV	Retrofit Unit Cost Adder without Solar Ready	Statewide Retrofit Costs (not discounted)	Retrofit Costs Present Value	PV Energy Savings (kBTU/ PV system)	Statewide PV energy savings (kBTU)	PV Energy Savings Value (non-discounted)	Present value of PV Energy Savings	SHW Penetration	Number of Homes Installing SHW	Retrofit Unit Cost Adder without Solar Ready	Statewide Retrofit Costs (not discounted)	Retrofit Costs Present Value	SWH Energy Savings (kBTU/ PV system)	Statewide SWH energy savings (kBTU)	SHW Energy Savings Value (non-discounted)	Present value of SHW Energy Savings
2011						0.58%	Current 2011 penetration								0.01%	Current 2011 penetration							
2012						0.76%									0.21%								
2013						0.94%									0.41%								
2014	103,438	1.12%	102,279	$ 182	$ 18,614,697	1.12%	1,159	new homes with PV							0.60%	623	new homes with SWH						
2015						1.30%	187	$ 2,687	$ 501,037	$ 486,444	8,711	1,624,585	$ 14,355	$ 13,937	0.80%	204	$ 1,132	$ 231,371	$ 224,632	1,116	228,002	$ 2,015	$ 1,956
2016						1.48%	187	$ 2,687	$ 501,037	$ 472,276	8,711	3,249,171	$ 28,709	$ 27,061	1.00%	204	$ 1,132	$ 231,294	$ 218,017	1,116	456,004	$ 4,029	$ 3,798
2017						1.66%	187	$ 2,687	$ 501,037	$ 458,520	8,711	4,873,756	$ 43,064	$ 39,410	1.20%	204	$ 1,132	$ 231,294	$ 211,667	1115.642	684,006	$ 6,044	$ 5,531
2018						1.84%	187	$ 2,687	$ 501,037	$ 445,165	8,711	6,498,341	$ 57,419	$ 51,016	1.39%	204	$ 1,132	$ 231,294	$ 205,502	1115.642	912,008	$ 8,058	$ 7,160
2019						2.02%	187	$ 2,687	$ 501,037	$ 432,199	8,711	8,122,927	$ 71,774	$ 61,913	1.59%	204	$ 1,132	$ 231,294	$ 199,516	1115.642	1,140,010	$ 10,073	$ 8,689
2020						2.20%	187	$ 2,687	$ 501,037	$ 419,611	8,711	9,747,512	$ 86,128	$ 72,131	1.79%	204	$ 1,132	$ 231,294	$ 193,705	1115.642	1,368,012	$ 12,088	$ 10,123
2021						2.38%	187	$ 2,687	$ 501,037	$ 407,389	8,711	11,372,097	$ 100,483	$ 81,702	1.99%	204	$ 1,132	$ 231,294	$ 188,063	1115.642	1,596,014	$ 14,102	$ 11,466
2022						2.56%	187	$ 2,687	$ 501,037	$ 395,523	8,711	12,996,683	$ 114,838	$ 90,654	2.18%	204	$ 1,132	$ 231,294	$ 182,586	1115.642	1,824,017	$ 16,117	$ 12,723
2023						2.74%	187	$ 2,687	$ 501,037	$ 384,003	8,711	14,621,268	$ 129,192	$ 99,015	2.38%	204	$ 1,132	$ 231,294	$ 177,268	1115.642	2,052,019	$ 18,131	$ 13,896
2024						2.92%	187	$ 2,687	$ 501,037	$ 372,819	8,711	16,245,853	$ 143,547	$ 106,813	2.58%	204	$ 1,132	$ 231,294	$ 172,104	1115.642	2,280,021	$ 20,146	$ 14,991
2025						3.10%	187	$ 2,687	$ 501,037	$ 361,960	8,711	17,870,438	$ 157,902	$ 114,072	2.78%	204	$ 1,132	$ 231,294	$ 167,092	1115.642	2,508,023	$ 22,161	$ 16,009
2026						3.28%	187	$ 2,687	$ 501,037	$ 351,417	8,711	19,495,024	$ 172,257	$ 120,817	2.97%	204	$ 1,132	$ 231,294	$ 162,225	1115.642	2,736,025	$ 24,175	$ 16,956
2027						3.46%	187	$ 2,687	$ 501,037	$ 341,182	8,711	21,119,609	$ 186,611	$ 127,073	3.17%	204	$ 1,132	$ 231,294	$ 157,500	1115.642	2,964,027	$ 26,190	$ 17,834
2028						3.65%	187	$ 2,687	$ 501,037	$ 331,245	8,711	22,744,194	$ 200,966	$ 132,862	3.37%	204	$ 1,132	$ 231,294	$ 152,913	1115.642	3,192,029	$ 28,205	$ 18,647
2029						3.83%	187	$ 2,687	$ 501,037	$ 321,597	8,711	24,368,780	$ 215,321	$ 138,206	3.57%	204	$ 1,132	$ 231,294	$ 148,459	1115.642	3,420,031	$ 30,219	$ 19,397
2030						4.01%	187	$ 2,687	$ 501,037	$ 312,230	8,711	25,993,365	$ 229,676	$ 143,126	3.76%	204	$ 1,132	$ 231,294	$ 144,135	1115.642	3,648,033	$ 32,234	$ 20,087
2031						4.19%	187	$ 2,687	$ 501,037	$ 303,136	8,711	27,617,950	$ 244,030	$ 147,642	3.96%	204	$ 1,132	$ 231,294	$ 139,937	1115.642	3,876,035	$ 34,248	$ 20,721
2032						4.37%	187	$ 2,687	$ 501,037	$ 294,307	8,711	29,242,536	$ 258,385	$ 151,774	4.16%	204	$ 1,132	$ 231,294	$ 135,861	1115.642	4,104,037	$ 36,263	$ 21,301
2033						4.55%	187	$ 2,687	$ 501,037	$ 285,735	8,711	30,867,121	$ 272,740	$ 155,540	4.36%	204	$ 1,132	$ 231,294	$ 131,904	1115.642	4,332,039	$ 38,278	$ 21,829
2034						4.73%	187	$ 2,687	$ 501,037	$ 277,412	8,711	32,491,706	$ 287,094	$ 158,957	4.55%	204	$ 1,132	$ 231,294	$ 128,062	1115.642	4,560,041	$ 40,292	$ 22,309
2035						4.91%	187	$ 2,687	$ 501,037	$ 269,332	8,711	34,116,292	$ 301,449	$ 162,044	4.75%	204	$ 1,132	$ 231,294	$ 124,332	1115.642	4,788,043	$ 42,307	$ 22,742
2036						5.09%	187	$ 2,687	$ 501,037	$ 261,488	8,711	35,740,877	$ 315,804	$ 164,816	4.95%	204	$ 1,132	$ 231,294	$ 120,711	1115.642	5,016,045	$ 44,321	$ 23,131
2037						5.27%	187	$ 2,687	$ 501,037	$ 253,871	8,711	37,365,462	$ 330,159	$ 167,289	5.15%	204	$ 1,132	$ 231,294	$ 117,195	1115.642	5,244,047	$ 46,336	$ 23,478
2038						5.45%	187	$ 2,687	$ 501,037	$ 246,477	8,711	38,990,048	$ 344,513	$ 169,478	5.34%	204	$ 1,132	$ 231,294	$ 113,781	1115.642	5,472,050	$ 48,351	$ 23,785
2039						5.63%	187	$ 2,687	$ 501,037	$ 239,298	8,711	40,614,633	$ 358,868	$ 171,397	5.54%	204	$ 1,132	$ 231,294	$ 110,467	1115.642	5,700,052	$ 50,365	$ 24,055
2040						5.81%	187	$ 2,687	$ 501,037	$ 232,328	8,711	42,239,218	$ 373,223	$ 173,061	5.74%	204	$ 1,132	$ 231,294	$ 107,250	1115.642	5,928,054	$ 52,380	$ 24,288
2041						5.99%	187	$ 2,687	$ 501,037	$ 225,561	8,711	43,863,804	$ 387,577	$ 174,483	5.94%	204	$ 1,132	$ 231,294	$ 104,126	1115.642	6,156,056	$ 54,394	$ 24,488
2042						6.17%	187	$ 2,687	$ 501,037	$ 218,992	8,711	45,488,389	$ 401,932	$ 175,675	6.13%	204	$ 1,132	$ 231,294	$ 101,093	1115.642	6,384,058	$ 56,409	$ 24,655
2043						6.35%	187	$ 2,687	$ 501,037	$ 212,613	8,711	47,112,974	$ 416,287	$ 176,650	6.33%	204	$ 1,132	$ 231,294	$ 98,149	1115.642	6,612,060	$ 58,424	$ 24,792
2044						6.53%	187	$ 2,687	$ 501,037	$ 206,421	8,711	48,737,560	$ 430,642	$ 177,419	6.53%	204	$ 1,132	$ 231,294	$ 95,290	1115.642	6,840,062	$ 60,438	$ 24,900
Totals					**$ 18,614,697**		**6,755**			**$ 9,820,551**				**$ 3,746,033**		**6,755**			**$ 4,533,538**				**$ 525,736**

Figure 176: Life cycle cost analysis data for scenario 2

			Solar Ready Costs for All Homes			Retrofit Costs for Homes Installing PV					PV Energy Savings				Retrofit Costs for Homes Installing SWH					SWH Energy Savings			
Year	New Homes Built	New Construction PV Penetration	New Homes Incurring "PV Ready" Costs	Solar-Ready Unit Cost	Total Solar-Ready Costs	PV Penetration	Number of Homes Installing PV	Retrofit Unit Cost Adder without Solar Ready	Statewide Retrofit Costs (not discounted)	Retrofit Costs Present Value	PV Energy Savings (kBTU/ PV system)	Statewide PV energy savings (kBTU)	PV Energy Savings Value (non-discounted)	Present value of PV Energy Savings	SHW Penetration	Number of Homes Installing SHW	Retrofit Unit Cost Adder without Solar Ready	Statewide Retrofit Costs (not discounted)	Retrofit Costs Present Value	SWH Energy Savings (kBTU/ PV system)	Statewide SWH energy savings (kBTU)	SHW Energy Savings Value (non-discounted)	Present value of SHW Energy Savings
2011						**0.58%**	**Current 2011 penetration**								**0.01%**	**Current 2011 penetration**							
2012						0.80%									0.37%								
2013						1.02%									0.74%								
2014	103,438	**1.24%**	102,159	$ 182	$ 18,592,962	1.24%	1,279	new homes with PV							1.10%	*1,138*	new homes with SWH						
2015						1.46%	226	$ 2,687	$ 607,981	$ 590,273	8,711	1,971,346	$ 17,419	$ 16,911	1.46%	376	$ 1,132	$ 425,481	$ 413,088	1,116	419,286	$ 3,705	$ 3,597
2016						1.67%	226	$ 2,687	$ 607,981	$ 573,081	8,711	3,942,691	$ 34,837	$ 32,838	1.83%	376	$ 1,132	$ 425,340	$ 400,923	1,116	838,572	$ 7,410	$ 6,984
2017						1.89%	226	$ 2,687	$ 607,981	$ 556,389	8,711	5,914,037	$ 52,256	$ 47,822	2.19%	376	$ 1,132	$ 425,340	$ 389,246	1115.642	1,257,858	$ 11,114	$ 10,171
2018						2.11%	226	$ 2,687	$ 607,981	$ 540,184	8,711	7,885,382	$ 69,675	$ 61,905	2.55%	376	$ 1,132	$ 425,340	$ 377,909	1115.642	1,677,144	$ 14,819	$ 13,167
2019						2.33%	226	$ 2,687	$ 607,981	$ 524,450	8,711	9,856,728	$ 87,093	$ 75,127	2.92%	376	$ 1,132	$ 425,340	$ 366,902	1115.642	2,096,430	$ 18,524	$ 15,979
2020						2.55%	226	$ 2,687	$ 607,981	$ 509,175	8,711	11,828,073	$ 104,512	$ 87,527	3.28%	376	$ 1,132	$ 425,340	$ 356,215	1115.642	2,515,716	$ 22,229	$ 18,616
2021						2.77%	226	$ 2,687	$ 607,981	$ 494,344	8,711	13,799,419	$ 121,931	$ 99,141	3.64%	376	$ 1,132	$ 425,340	$ 345,840	1115.642	2,935,002	$ 25,933	$ 21,086
2022						2.99%	226	$ 2,687	$ 607,981	$ 479,946	8,711	15,770,764	$ 139,349	$ 110,004	4.01%	376	$ 1,132	$ 425,340	$ 335,767	1115.642	3,354,288	$ 29,638	$ 23,397
2023						3.21%	226	$ 2,687	$ 607,981	$ 465,967	8,711	17,742,110	$ 156,768	$ 120,150	4.37%	376	$ 1,132	$ 425,340	$ 325,987	1115.642	3,773,574	$ 33,343	$ 25,555
2024						3.42%	226	$ 2,687	$ 607,981	$ 452,395	8,711	19,713,455	$ 174,187	$ 129,611	4.73%	376	$ 1,132	$ 425,340	$ 316,493	1115.642	4,192,860	$ 37,048	$ 27,567
2025						3.64%	226	$ 2,687	$ 607,981	$ 439,219	8,711	21,684,801	$ 191,605	$ 138,420	5.10%	376	$ 1,132	$ 425,340	$ 307,274	1115.642	4,612,146	$ 40,753	$ 29,441
2026						3.86%	226	$ 2,687	$ 607,981	$ 426,426	8,711	23,656,147	$ 209,024	$ 146,605	5.46%	376	$ 1,132	$ 425,340	$ 298,325	1115.642	5,031,432	$ 44,457	$ 31,182
2027						4.08%	226	$ 2,687	$ 607,981	$ 414,006	8,711	25,627,492	$ 226,443	$ 154,196	5.82%	376	$ 1,132	$ 425,340	$ 289,636	1115.642	5,450,718	$ 48,162	$ 32,796
2028						4.30%	226	$ 2,687	$ 607,981	$ 401,947	8,711	27,598,838	$ 243,861	$ 161,221	6.19%	376	$ 1,132	$ 425,340	$ 281,200	1115.642	5,870,004	$ 51,867	$ 34,290
2029						4.52%	226	$ 2,687	$ 607,981	$ 390,240	8,711	29,570,183	$ 261,280	$ 167,706	6.55%	376	$ 1,132	$ 425,340	$ 273,009	1115.642	6,289,290	$ 55,572	$ 35,669
2030						4.74%	226	$ 2,687	$ 607,981	$ 378,874	8,711	31,541,529	$ 278,699	$ 173,676	6.91%	376	$ 1,132	$ 425,340	$ 265,058	1115.642	6,708,576	$ 59,277	$ 36,939
2031						4.96%	226	$ 2,687	$ 607,981	$ 367,839	8,711	33,512,874	$ 296,117	$ 179,156	7.28%	376	$ 1,132	$ 425,340	$ 257,337	1115.642	7,127,862	$ 62,981	$ 38,105
2032						5.17%	226	$ 2,687	$ 607,981	$ 357,125	8,711	35,484,220	$ 313,536	$ 184,169	7.64%	376	$ 1,132	$ 425,340	$ 249,842	1115.642	7,547,148	$ 66,686	$ 39,171
2033						5.39%	226	$ 2,687	$ 607,981	$ 346,723	8,711	37,455,565	$ 330,955	$ 188,739	8.00%	376	$ 1,132	$ 425,340	$ 242,565	1115.642	7,966,434	$ 70,391	$ 40,143
2034						5.61%	226	$ 2,687	$ 607,981	$ 336,625	8,711	39,426,911	$ 348,373	$ 192,886	8.37%	376	$ 1,132	$ 425,340	$ 235,500	1115.642	8,385,720	$ 74,096	$ 41,025
2035						5.83%	226	$ 2,687	$ 607,981	$ 326,820	8,711	41,398,256	$ 365,792	$ 196,631	8.73%	376	$ 1,132	$ 425,340	$ 228,641	1115.642	8,805,006	$ 77,800	$ 41,822
2036						6.05%	226	$ 2,687	$ 607,981	$ 317,301	8,711	43,369,602	$ 383,211	$ 199,995	9.09%	376	$ 1,132	$ 425,340	$ 221,982	1115.642	9,224,292	$ 81,505	$ 42,537
2037						6.27%	226	$ 2,687	$ 607,981	$ 308,059	8,711	45,340,948	$ 400,629	$ 202,996	9.46%	376	$ 1,132	$ 425,340	$ 215,516	1115.642	9,643,578	$ 85,210	$ 43,175
2038						6.49%	226	$ 2,687	$ 607,981	$ 299,087	8,711	47,312,293	$ 418,048	$ 205,652	9.82%	376	$ 1,132	$ 425,340	$ 209,239	1115.642	10,062,864	$ 88,915	$ 43,740
2039						6.71%	226	$ 2,687	$ 607,981	$ 290,375	8,711	49,283,639	$ 435,467	$ 207,981	10.18%	376	$ 1,132	$ 425,340	$ 203,145	1115.642	10,482,150	$ 92,620	$ 44,236
2040						6.92%	226	$ 2,687	$ 607,981	$ 281,918	8,711	51,254,984	$ 452,885	$ 210,001	10.55%	376	$ 1,132	$ 425,340	$ 197,228	1115.642	10,901,436	$ 96,324	$ 44,665
2041						7.14%	226	$ 2,687	$ 607,981	$ 273,707	8,711	53,226,330	$ 470,304	$ 211,726	10.91%	376	$ 1,132	$ 425,340	$ 191,483	1115.642	11,320,722	$ 100,029	$ 45,032
2042						7.36%	226	$ 2,687	$ 607,981	$ 265,734	8,711	55,197,675	$ 487,723	$ 213,172	11.27%	376	$ 1,132	$ 425,340	$ 185,906	1115.642	11,740,008	$ 103,734	$ 45,340
2043						7.58%	226	$ 2,687	$ 607,981	$ 257,995	8,711	57,169,021	$ 505,141	$ 214,355	11.64%	376	$ 1,132	$ 425,340	$ 180,491	1115.642	12,159,294	$ 107,439	$ 45,591
2044						**7.80%**	226	$ 2,687	$ 607,981	$ 250,480	8,711	59,140,366	$ 522,560	$ 215,288	**12.00%**	376	$ 1,132	$ 425,340	$ 175,234	1115.642	12,578,580	$ 111,143	$ 45,790
Totals					**$ 18,592,962**		**8,068**			**$ 11,916,702**				**$ 4,545,606**		**12,413**			**$ 8,336,982**				**$ 966,806**

Figure 177: Life cycle cost analysis data for scenario 3

			Solar Ready Costs for All Homes			Retrofit Costs for Homes Installing PV					PV Energy Savings				Retrofit Costs for Homes Installing SWH					SWH Energy Savings			
Year	New Homes Built	New Construction PV Penetration	New Homes Incurring "PV Ready" Costs	Solar-Ready Unit Cost	Total Solar-Ready Costs	PV Penetration	Number of Homes Installing PV	Retrofit Unit Cost Adder without Solar Ready	Statewide Retrofit Costs (not discounted)	Retrofit Costs Present Value	PV Energy Savings (kBTU/ PV system)	Statewide PV energy savings (kBTU)	PV Energy Savings Value (non-discounted)	Present value of PV Energy Savings	SHW Penetration	Number of Homes Installing SHW	Retrofit Unit Cost Adder without Solar Ready	Statewide Retrofit Costs (not discounted)	Retrofit Costs Present Value	SWH Energy Savings (kBTU/ PV system)	Statewide SWH energy savings (kBTU)	SHW Energy Savings Value (non-discounted)	Present value of SHW Energy Savings
2011						**0.58%**	**Current 2011 penetration**								**0.01%**	**Current 2011 penetration**							
2012						3.29%									2.79%								
2013						6.01%									5.56%								
2014	######	**8.72%**	94,418	$ 182	$ 17,184,114	8.72%	9,020	new homes with PV							8.34%	*8,627*	new homes with SWH						
2015						11.43%	2,807	$ 2,687	$ 7,539,979	$ 7,320,368	8,711	24,447,961	$ 216,020	$ 209,729	11.12%	2,872	$ 1,132	$ 3,251,608	$ 3,156,901	1,116	3,204,268	$ 28,313	$ 27,488
2016						14.15%	2,807	$ 2,687	$ 7,539,979	$ 7,107,153	8,711	48,895,922	$ 432,041	$ 407,240	13.89%	2,872	$ 1,132	$ 3,250,531	$ 3,063,938	1,116	6,408,537	$ 56,625	$ 53,375
2017						16.86%	2,807	$ 2,687	$ 7,539,979	$ 6,900,148	8,711	73,343,884	$ 648,061	$ 593,068	16.67%	2,872	$ 1,132	$ 3,250,531	$ 2,974,697	1115.642	9,612,805	$ 84,938	$ 77,730
2018						19.57%	2,807	$ 2,687	$ 7,539,979	$ 6,699,173	8,711	97,791,845	$ 864,082	$ 767,726	19.45%	2,872	$ 1,132	$ 3,250,531	$ 2,888,055	1115.642	12,817,073	$113,251	$ 100,622
2019						22.29%	2,807	$ 2,687	$ 7,539,979	$ 6,504,052	8,711	122,239,806	$ 1,080,102	$ 931,706	22.22%	2,872	$ 1,132	$ 3,250,531	$ 2,803,937	1115.642	16,021,341	$141,563	$ 122,114
2020						25.00%	2,807	$ 2,687	$ 7,539,979	$ 6,314,613	8,711	146,687,767	$ 1,296,123	$ 1,085,482	25.00%	2,872	$ 1,132	$ 3,250,531	$ 2,722,269	1115.642	19,225,610	$169,876	$ 142,269
2021						25.00%	-	$ 2,687	$ -	$ -	8,711	146,687,767	$ 1,296,123	$ 1,053,866	25.00%	-	$ 1,132	$ -	$ -	1115.642	19,225,610	$169,876	$ 138,125
2022						25.00%	-	$ 2,687	$ -	$ -	8,711	146,687,767	$ 1,296,123	$ 1,023,171	25.00%	-	$ 1,132	$ -	$ -	1115.642	19,225,610	$169,876	$ 134,102
2023						25.00%	-	$ 2,687	$ -	$ -	8,711	146,687,767	$ 1,296,123	$ 993,370	25.00%	-	$ 1,132	$ -	$ -	1115.642	19,225,610	$169,876	$ 130,196
2024						25.00%	-	$ 2,687	$ -	$ -	8,711	146,687,767	$ 1,296,123	$ 964,437	25.00%	-	$ 1,132	$ -	$ -	1115.642	19,225,610	$169,876	$ 126,404
2025						25.00%	-	$ 2,687	$ -	$ -	8,711	146,687,767	$ 1,296,123	$ 936,347	25.00%	-	$ 1,132	$ -	$ -	1115.642	19,225,610	$169,876	$ 122,722
2026						25.00%	-	$ 2,687	$ -	$ -	8,711	146,687,767	$ 1,296,123	$ 909,074	25.00%	-	$ 1,132	$ -	$ -	1115.642	19,225,610	$169,876	$ 119,148
2027						25.00%	-	$ 2,687	$ -	$ -	8,711	146,687,767	$ 1,296,123	$ 882,597	25.00%	-	$ 1,132	$ -	$ -	1115.642	19,225,610	$169,876	$ 115,677
2028						25.00%	-	$ 2,687	$ -	$ -	8,711	146,687,767	$ 1,296,123	$ 856,890	25.00%	-	$ 1,132	$ -	$ -	1115.642	19,225,610	$169,876	$ 112,308
2029						25.00%	-	$ 2,687	$ -	$ -	8,711	146,687,767	$ 1,296,123	$ 831,932	25.00%	-	$ 1,132	$ -	$ -	1115.642	19,225,610	$169,876	$ 109,037
2030						25.00%	-	$ 2,687	$ -	$ -	8,711	146,687,767	$ 1,296,123	$ 807,701	25.00%	-	$ 1,132	$ -	$ -	1115.642	19,225,610	$169,876	$ 105,861
2031						25.00%	-	$ 2,687	$ -	$ -	8,711	146,687,767	$ 1,296,123	$ 784,176	25.00%	-	$ 1,132	$ -	$ -	1115.642	19,225,610	$169,876	$ 102,778
2032						25.00%	-	$ 2,687	$ -	$ -	8,711	146,687,767	$ 1,296,123	$ 761,336	25.00%	-	$ 1,132	$ -	$ -	1115.642	19,225,610	$169,876	$ 99,784
2033						25.00%	-	$ 2,687	$ -	$ -	8,711	146,687,767	$ 1,296,123	$ 739,161	25.00%	-	$ 1,132	$ -	$ -	1115.642	19,225,610	$169,876	$ 96,878
2034						25.00%	-	$ 2,687	$ -	$ -	8,711	146,687,767	$ 1,296,123	$ 717,632	25.00%	-	$ 1,132	$ -	$ -	1115.642	19,225,610	$169,876	$ 94,056
2035						25.00%	-	$ 2,687	$ -	$ -	8,711	146,687,767	$ 1,296,123	$ 696,730	25.00%	-	$ 1,132	$ -	$ -	1115.642	19,225,610	$169,876	$ 91,317
2036						25.00%	-	$ 2,687	$ -	$ -	8,711	146,687,767	$ 1,296,123	$ 676,437	25.00%	-	$ 1,132	$ -	$ -	1115.642	19,225,610	$169,876	$ 88,657
2037						25.00%	-	$ 2,687	$ -	$ -	8,711	146,687,767	$ 1,296,123	$ 656,735	25.00%	-	$ 1,132	$ -	$ -	1115.642	19,225,610	$169,876	$ 86,075
2038						25.00%	-	$ 2,687	$ -	$ -	8,711	146,687,767	$ 1,296,123	$ 637,606	25.00%	-	$ 1,132	$ -	$ -	1115.642	19,225,610	$169,876	$ 83,568
2039						25.00%	-	$ 2,687	$ -	$ -	8,711	146,687,767	$ 1,296,123	$ 619,035	25.00%	-	$ 1,132	$ -	$ -	1115.642	19,225,610	$169,876	$ 81,134
2040						25.00%	-	$ 2,687	$ -	$ -	8,711	146,687,767	$ 1,296,123	$ 601,005	25.00%	-	$ 1,132	$ -	$ -	1115.642	19,225,610	$169,876	$ 78,771
2041						25.00%	-	$ 2,687	$ -	$ -	8,711	146,687,767	$ 1,296,123	$ 583,500	25.00%	-	$ 1,132	$ -	$ -	1115.642	19,225,610	$169,876	$ 76,476
2042						25.00%	-	$ 2,687	$ -	$ -	8,711	146,687,767	$ 1,296,123	$ 566,505	25.00%	-	$ 1,132	$ -	$ -	1115.642	19,225,610	$169,876	$ 74,249
2043						25.00%	-	$ 2,687	$ -	$ -	8,711	146,687,767	$ 1,296,123	$ 550,005	25.00%	-	$ 1,132	$ -	$ -	1115.642	19,225,610	$169,876	$ 72,086
2044						25.00%	-	$ 2,687	$ -	$ -	8,711	146,687,767	$ 1,296,123	$ 533,985	25.00%	-	$ 1,132	$ -	$ -	1115.642	19,225,610	$169,876	$ 69,987
Totals					**$ 17,184,114**		**25,860**			**$ 40,845,507**				**$ 22,378,183**		**25,860**			**$ 17,609,797**				**$ 2,932,993**

Figure 178: Life cycle cost analysis data for scenario 4

			Solar Ready Costs for All Homes			Retrofit Costs for Homes Installing PV					PV Energy Savings				Retrofit Costs for Homes Installing SWH					SWH Energy Savings			
Year	New Homes Built	New Construction PV Penetration	New Homes Incurring "PV Ready" Costs	Solar-Ready Unit Cost	Total Solar-Ready Costs	PV Penetration	Number of Homes Installing PV	Retrofit Unit Cost Adder without Solar Ready	Statewide Retrofit Costs (not discounted)	Retrofit Costs Present Value	PV Energy Savings (kBTU/ PV system)	Statewide PV energy savings (kBTU)	PV Energy Savings Value (non-discounted)	Present value of PV Energy Savings	SHW Penetration	Number of Homes Installing SHW	Retrofit Unit Cost Adder without Solar Ready	Statewide Retrofit Costs (not discounted)	Retrofit Costs Present Value	SWH Energy Savings (kBTU/ PV system)	Statewide SWH energy savings (kBTU)	SHW Energy Savings Value (non-discounted)	Present value of SHW Energy Savings
2011						0.58%	Current 2011 penetration								0.01%	Current 2011 penetration							
2012						3.32%									2.80%								
2013						6.06%									5.59%								
2014	######	8.80%	94,335	$ 182	$ 17,169,053	8.80%	9,103	new homes with PV							8.37%	8,661	new homes with SWH						
2015						11.54%	2,834	$ 2,687	$ 7,614,082	$ 7,392,312	8,711	24,688,236	$ 218,144	$ 211,790	11.16%	2,883	$ 1,132	$ 3,264,384	$ 3,169,304	1,116	3,216,857	$ 28,424	$ 27,596
2016						14.28%	2,834	$ 2,687	$ 7,614,082	$ 7,177,002	8,711	49,376,472	$ 436,287	$ 411,242	13.95%	2,883	$ 1,132	$ 3,263,302	$ 3,075,975	1,116	6,433,715	$ 56,848	$ 53,585
2017						17.02%	2,834	$ 2,687	$ 7,614,082	$ 6,967,963	8,711	74,064,708	$ 654,431	$ 598,897	16.74%	2,883	$ 1,132	$ 3,263,302	$ 2,986,384	1115.642	9,650,572	$ 85,272	$ 78,036
2018						19.76%	2,834	$ 2,687	$ 7,614,082	$ 6,765,013	8,711	98,752,944	$ 872,574	$ 775,271	19.52%	2,883	$ 1,132	$ 3,263,302	$ 2,899,402	1115.642	12,867,429	$ 113,696	$ 101,017
2019						22.50%	2,834	$ 2,687	$ 7,614,082	$ 6,567,974	8,711	123,441,180	$ 1,090,718	$ 940,863	22.31%	2,883	$ 1,132	$ 3,263,302	$ 2,814,953	1115.642	16,084,287	$ 142,120	$ 122,594
2020						25.24%	2,834	$ 2,687	$ 7,614,082	$ 6,376,673	8,711	148,129,416	$ 1,308,861	$ 1,096,151	25.10%	2,883	$ 1,132	$ 3,263,302	$ 2,732,964	1115.642	19,301,144	$ 170,544	$ 142,828
2021						27.98%	2,834	$ 2,687	$ 7,614,082	$ 6,190,945	8,711	172,817,652	$ 1,527,005	$ 1,241,594	27.89%	2,883	$ 1,132	$ 3,263,302	$ 2,653,363	1115.642	22,518,001	$ 198,967	$ 161,779
2022						30.72%	2,834	$ 2,687	$ 7,614,082	$ 6,010,626	8,711	197,505,888	$ 1,745,148	$ 1,377,636	30.67%	2,883	$ 1,132	$ 3,263,302	$ 2,576,081	1115.642	25,734,859	$ 227,391	$ 179,505
2023						33.46%	2,834	$ 2,687	$ 7,614,082	$ 5,835,559	8,711	222,194,124	$ 1,963,292	$ 1,504,700	33.46%	2,883	$ 1,132	$ 3,263,302	$ 2,501,049	1115.642	28,951,716	$ 255,815	$ 196,061
2024						36.20%	2,834	$ 2,687	$ 7,614,082	$ 5,665,592	8,711	246,882,360	$ 2,181,435	$ 1,623,193	36.25%	2,883	$ 1,132	$ 3,263,302	$ 2,428,203	1115.642	32,168,574	$ 284,239	$ 211,501
2025						38.94%	2,834	$ 2,687	$ 7,614,082	$ 5,500,574	8,711	271,570,596	$ 2,399,579	$ 1,733,507	39.04%	2,883	$ 1,132	$ 3,263,302	$ 2,357,479	1115.642	35,385,431	$ 312,663	$ 225,875
2026						41.68%	2,834	$ 2,687	$ 7,614,082	$ 5,340,364	8,711	296,258,832	$ 2,617,722	$ 1,836,018	41.82%	2,883	$ 1,132	$ 3,263,302	$ 2,288,815	1115.642	38,602,288	$ 341,087	$ 239,232
2027						44.42%	2,834	$ 2,687	$ 7,614,082	$ 5,184,819	8,711	320,947,068	$ 2,835,866	$ 1,931,086	44.61%	2,883	$ 1,132	$ 3,263,302	$ 2,222,150	1115.642	41,819,146	$ 369,511	$ 251,619
2028						47.16%	2,834	$ 2,687	$ 7,614,082	$ 5,033,805	8,711	345,635,304	$ 3,054,009	$ 2,019,060	47.40%	2,883	$ 1,132	$ 3,263,302	$ 2,157,427	1115.642	45,036,003	$ 397,935	$ 263,082
2029						49.90%	2,834	$ 2,687	$ 7,614,082	$ 4,887,189	8,711	370,323,540	$ 3,272,153	$ 2,100,270	50.19%	2,883	$ 1,132	$ 3,263,302	$ 2,094,590	1115.642	48,252,860	$ 426,359	$ 273,664
2030						52.64%	2,834	$ 2,687	$ 7,614,082	$ 4,744,844	8,711	395,011,777	$ 3,490,296	$ 2,175,037	52.97%	2,883	$ 1,132	$ 3,263,302	$ 2,033,582	1115.642	51,469,718	$ 454,783	$ 283,406
2031						55.38%	2,834	$ 2,687	$ 7,614,082	$ 4,606,645	8,711	419,700,013	$ 3,708,440	$ 2,243,667	55.76%	2,883	$ 1,132		$ -	1115.642	54,686,575	$ 483,207	$ 292,348
2032						58.12%	2,834	$ 2,687	$ 7,614,082	$ 4,472,470	8,711	444,388,249	$ 3,926,583	$ 2,306,454	58.55%	2,883	$ 1,132		$ -	1115.642	57,903,432	$ 511,631	$ 300,529
2033						60.86%	2,834	$ 2,687	$ 7,614,082	$ 4,342,204	8,711	469,076,485	$ 4,144,727	$ 2,363,680	61.34%	2,883	$ 1,132		$ -	1115.642	61,120,290	$ 540,055	$ 307,986
2034						63.60%	2,834	$ 2,687	$ 7,614,082	$ 4,215,732	8,711	493,764,721	$ 4,362,870	$ 2,415,615	64.12%	2,883	$ 1,132		$ -	1115.642	64,337,147	$ 568,478	$ 314,753
2035						66.34%	2,834	$ 2,687	$ 7,614,082	$ 4,092,944	8,711	518,452,957	$ 4,581,014	$ 2,462,521	66.91%	2,883	$ 1,132		$ -	1115.642	67,554,004	$ 596,902	$ 320,864
2036						69.08%	2,834	$ 2,687	$ 7,614,082	$ 3,973,732	8,711	543,141,193	$ 4,799,157	$ 2,504,644	69.70%	2,883	$ 1,132		$ -	1115.642	70,770,862	$ 625,326	$ 326,353
2037						71.82%	2,834	$ 2,687	$ 7,614,082	$ 3,857,992	8,711	567,829,429	$ 5,017,301	$ 2,542,225	72.49%	2,883	$ 1,132		$ -	1115.642	73,987,719	$ 653,750	$ 331,250
2038						74.56%	2,834	$ 2,687	$ 7,614,082	$ 3,745,624	8,711	592,517,665	$ 5,235,444	$ 2,575,492	75.27%	2,883	$ 1,132		$ -	1115.642	77,204,576	$ 682,174	$ 335,584
2039						77.30%	2,834	$ 2,687	$ 7,614,082	$ 3,636,528	8,711	617,205,901	$ 5,453,588	$ 2,604,664	78.06%	2,883	$ 1,132		$ -	1115.642	80,421,434	$ 710,598	$ 339,386
2040						80.04%	2,834	$ 2,687	$ 7,614,082	$ 3,530,609	8,711	641,894,137	$ 5,671,731	$ 2,629,952	80.85%	2,883	$ 1,132		$ -	1115.642	83,638,291	$ 739,022	$ 342,681
2041						82.78%	2,834	$ 2,687	$ 7,614,082	$ 3,427,776	8,711	666,582,373	$ 5,889,875	$ 2,651,557	83.64%	2,883	$ 1,132		$ -	1115.642	86,855,148	$ 767,446	$ 345,496
2042						85.52%	2,834	$ 2,687	$ 7,614,082	$ 3,327,938	8,711	691,270,609	$ 6,108,018	$ 2,669,673	86.42%	2,883	$ 1,132		$ -	1115.642	90,072,006	$ 795,870	$ 347,856
2043						88.26%	2,834	$ 2,687	$ 7,614,082	$ 3,231,008	8,711	715,958,845	$ 6,326,162	$ 2,684,484	89.21%	2,883	$ 1,132		$ -	1115.642	93,288,863	$ 824,294	$ 349,786
2044						91.00%	2,834	$ 2,687	$ 7,614,082	$ 3,136,901	8,711	740,647,081	$ 6,544,305	$ 2,696,167	92.00%	2,883	$ 1,132		$ -	1115.642	96,505,721	$ 852,718	$ 351,308
Totals					$ 17,169,053		94,129			$ 149,239,358				$ 56,927,106		95,163			$ 40,991,722				$ 7,417,556

Figure 179: Life cycle cost analysis data for scenario 5