Residential New Construction Energy Efficiency: Getting the Biggest Bang for the Buck

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ABSTRACT

How much more does it cost to build a new single family energy efficient home than a "standard practice" home? What are the least-cost combinations of measures that provide the greatest energy savings? What are the implications for Zero Net Energy homes with readily available energy efficiency measures (EEM), and at what cost?

These questions were addressed by recent research using modeling software and systematic simulation methods to simultaneously consider energy savings with incremental costs. Results from the research included in this paper show:

- It is possible to reduce energy consumption up to 39%-62% compared to code with commonly available EEMs for single family residential new construction in California.
- There are many low-cost and no-cost measure combinations that allow California builders to significantly exceed Title 24 building code. The same may be possible outside California.
- Randomly selecting EEMs will likely yield increased costs without increased efficiency. The best measure combinations vary significantly by climate and must be selected thoughtfully.
- Incremental efficiency increases come at increasing costs. Exceeding code by 20% may cost $500, while reaching 40% may cost $5,000 or more.
- The majority of a California new home's energy consumption can be outside the scope of Title 24, which does not address appliances, plug loads, and most lighting. Those pursuing zero net energy new homes must look beyond Title 24 code requirements.

The results are being used to inform new construction program design and incentive levels, and may be used for builder design assistance.

Introduction

While there are many tools available that examine the energy efficiency of new single family homes, almost none simultaneously consider energy efficiency *and* incremental cost. The main goal of our research was to answer three key questions:

- How much more does it cost to build a new single family energy efficient home than a "standard practice" home?
- What are the least-cost combinations of energy efficiency measures (EEM) that provide the greatest energy savings?
- How far along the path toward Zero Net Energy is currently achievable with readily available EEMs, and at what cost?

The EEMs considered in this research only included measures that are commercially available and were considered to have a reasonable chance of inclusion by California production home builders.

Background

Study Scope

The goal of this study was to create an updateable Excel-based tool that simultaneously considers single family new home energy efficiency and incremental cost. By basing the tool in Excel, it can be easily updated with revised measure costs and revised standard practices as market conditions change. The research described in this paper was completed in 2008, and is currently planned for update in 2011, to support California's energy efficiency programs.

California's building code, Title 24 (CEC 2008), was last updated in January 2010 for single family residential new construction and uses sixteen distinct climate zones, as shown in **Figure 1**.

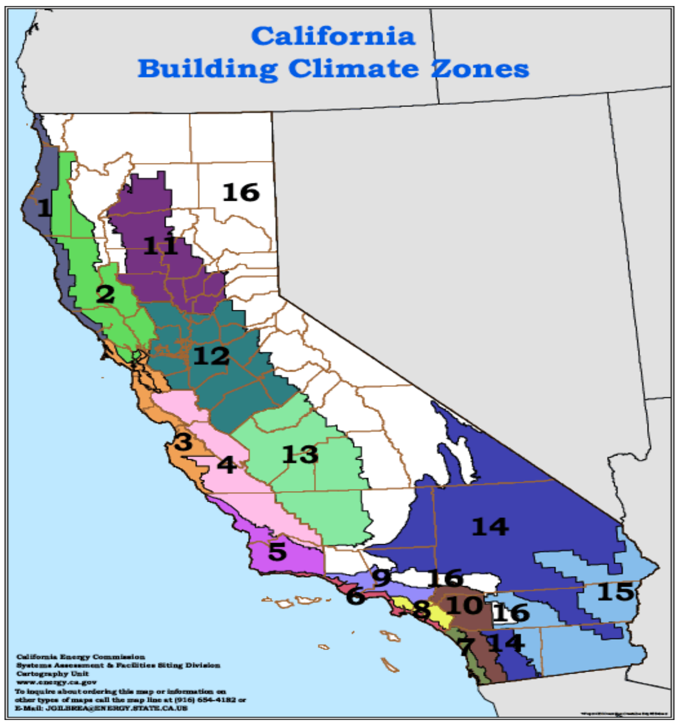

Figure 1. California's Sixteen Building Climate Zones (CEC 2008)

Title 24 addresses only three energy end-uses in new single family homes: space heating, space cooling, and water heating. All other energy consumption such as lighting,[1] appliances and plug loads[2] are outside the scope of Title 24. For those interested in building zero net energy homes, this is critical to consider as these additional loads can be a significant portion of a home's total energy consumption, especially in California's relatively mild climate.

Methodology

California regulators, utilities, builders and energy consultants have been using building energy simulation tools for both building energy efficiency standards development and compliance since the

[1] Title 24 does include some mandatory hard-wired lighting requirements, but there is no lighting energy budget.
[2] Appliances and plug loads include all plug-in electric devices, such as televisions, and gas appliances, such as clothes dryers and cooking stoves.

1980's. As a result, California has well-developed calculations and assumptions that form the basis of Title 24 building energy efficiency standards.

Package D (prescriptive) and Standard Practice (performance)

Title 24 offers a prescriptive method of compliance for each climate zone, called Package D (CEC 2009, 1-17 – 1-18, 1.6.2 Prescriptive Packages), which requires the inclusion of a fixed set of EEMs and design requirements. Title 24 also offers a performance method of compliance, in which any combination of EEMs can be used as long as the modeled energy consumption is equal to or lower than the Package D modeled home's energy consumption (CEC 2009, 1-18, 1.6.3 Performance Approach). In practice, production builders always use the performance method of compliance as it is less expensive and offers greater flexibility. The EEM combination most commonly used within each climate zone to comply with Title 24 is defined by this study as standard practice. This study uses standard practice as the baseline for estimating incremental costs.

Compliance Margin

Title 24 provides a convenient energy efficiency baseline for this study, the Package D (prescriptive) home's modeled energy consumption. Compliance margin is the difference between the simulated energy use of the Package D home minus the simulated energy use of the proposed home. A positive compliance margin means that the home complies with code. When expressed as a percentage, the compliance margin is divided by the energy use of the Package D home, which is a good proxy for efficiency. Results throughout this paper are presented as compliance margin percent, but these results are climate zone specific *since California building code (Title 24) varies by climate zone*. As a result, two identically constructed homes in different climate zones can have different compliance margins and different incremental costs.

Incremental Cost

Incremental cost in this study is an estimate of a production builder's additional cost to build a new home including materials, labor, and inspection costs when applicable, relative to standard practice, not Package D. Package D was considered a poor baseline for incremental cost since no production builders actually construct Package D homes to comply with code.

Incremental costs for new homes in this model were built up from a sum of incremental measure costs relative to base-level measures defined to be the lowest efficiency measure with a default incremental cost of zero. For example, three levels of attic insulation were considered, R30, R38, and R49. Since R30 is the minimum code requirement in all climate zones, it is defined as the base level attic insulation with an incremental cost of zero. Then, the incremental cost to install R38 was estimated relative to installing R30. In this case the incremental cost estimate was based strictly on increased material cost, since no additional labor or HERS inspections costs were anticipated. A similar approach was used for R49, and other measures.

EEMs (Energy Efficiency Measures)

The initial focus of the study was to identify individual measures and incremental costs that production builders would likely use to achieve compliance with the building standards. This information is summarized in **Table 1** for building envelope (envelope) measures and in **Table 2** for non-envelope measures. Measures include an array of features recognized in California's new construction market. EEMs for envelope include windows, insulation (walls, roof, and slab edge), radiant barriers, cool roofs, infiltration, verified insulation installation quality, and thermal mass.

Table 1. EEMs and Costs for Envelope Measures

Measure Descrption			Average Size 2700ft2			
Measure	Description	Unit	Units	Builder Low Cost	Builder Ave Cost	Builder High Cost
Envelope						
Window	0.67 U/0.70 SHGC	GlassArea	468	$0	$0	$0
	0.57 U/0.70 SHGC	GlassArea	468	$0	$0	$0
	0.55 U/0.70 SHGC	GlassArea	468	$0	$0	$0
	0.67 U/0.40 SHGC	GlassArea	468	$176	$205	$234
	0.57 U/0.40 SHGC	GlassArea	468	$176	$205	$234
	0.40 U/0.65 SHGC	GlassArea	468	$351	$410	$468
	0.40 U/0.40 SHGC	GlassArea	468	$351	$410	$468
	0.40 U/0.35 SHGC	GlassArea	468	$351	$410	$468
	0.37 U/0.56 SHGC	GlassArea	468	$351	$410	$468
	0.34 U/0.30 SHGC	GlassArea	468	$351	$410	$468
	0.33 U/0.22 SHGC	GlassArea	468	$702	$819	$936
	0.49 U/0.65 SHGC	GlassArea	468	$176	$205	$234
Walls	R13	WallArea	2074	$0	$0	$0
	R13+R4 foam	WallArea	2074	$291	$339	$388
	R15	WallArea	2074	$249	$290	$332
	R15+R4 foam	WallArea	2074	$540	$630	$719
	R19	WallArea	2074	$249	$290	$332
	R19+R4 foam	WallArea	2074	$540	$630	$719
	R21	WallArea	2074	$358	$417	$477
	R21+R4 foam	WallArea	2074	$648	$757	$865
Roof	R30	CeilingArea	1450	$0	$0	$0
	R38	CeilingArea	1450	$109	$127	$145
	R49	CeilingArea	1450	$272	$317	$363
SlabEdge	R0	SlabLength	158	$0	$0	$0
	R7	SlabLength	158	$770	$899	$1,027
RadBarrier	No	RoofArea	1813	$0	$0	$0
	Yes	RoofArea	1813	$285	$333	$381
CoolRoof	No	RoofArea	1813	$0	$0	$0
	Yes	RoofArea	1813	$816	$952	$1,088
Infiltration	No	Units	1	$0	$0	$0
	Housewrap	WallArea	2074	$415	$467	$519
	Test 3.2 SLA	Units	1	$177	$207	$236
InsQuality	No	Units	1	$0	$0	$0
	Yes	Units	1	$216	$252	$288
Mass	Std	SlabArea	1250	$0	$0	$0
	40% Exposed	SlabArea	1250	$2,500	$2,813	$3,125

EEMs for non-envelope measures in **Table 2** include the following cooling system measures: available combinations of SEER[3] and EER[4], TXV[5], verified refrigerant charge[6] (or a charge indicator light),

[3] Seasonal Energy Efficiency Ratio (SEER) is the ratio of the total cooling capacity during normal periods of operation divided by the total electric energy input during the same time period. Higher is more efficient

[4] Energy Efficiency Ratio (EER) is the ratio of net cooling capacity (in Btu/hr.) to total rate of electrical energy input (in watts), of a cooling system under designated operating conditions. Higher is more efficient.

verified air flow[7], verified fan watts[8], and verified maximum cooling capacity[9]. The heating system EEM is furnace AFUE[10]. Duct system EEMs include the R-value of the system and verified duct leakage testing[11]. Finally, water heating EEMs include the type and EF[12].

Table 2. EEMs and Costs for Non-Envelope Measures

Measure Descrption			Average Size 2700ft2			
Measure	Description	Unit	Units	Builder Low Cost	Builder Ave Cost	Builder High Cost
Cooling System						
AirCond	13/10	Systems	1	$0	$0	$0
	13/11	Systems	1	$10	$11	$13
	13/12	Systems	1	$205	$239	$273
	15/12	Systems	1	$488	$569	$650
TXV	No	Systems	1	$0	$0	$0
	Yes	Systems	1	$50	$56	$63
ChargeLight	No	Systems	1	$0	$0	$0
	Yes	Systems	1	$181	$211	$241
AirFlowTest	No	Systems	1	$0	$0	$0
	Yes	Systems	1	$191	$223	$255
FanEnergyTest	No	Systems	1	$0	$0	$0
	Yes	Systems	1	$71	$83	$95
MaxCoolCap	No	Systems	1	$0	$0	$0
	Yes	Systems	1	$5	$6	$7
Heating System						
Furnace	78%	Units	1	$0	$0	$0
	80%	Units	1	$0	$0	$0
	92%	Units	1	$585	$683	$780
	96%	Units	1	$1,170	$1,365	$1,560
Duct System						
Duct	R4.2	DuctLength	318	$0	$0	$0
	R6.0	DuctLength	318	$310	$362	$414
	R8.0	DuctLength	318	$465	$543	$620
	Conditioned Space	DuctLength	318	$2,386	$2,784	$3,182
DuctTest	No	Systems	1	$0	$0	$0
	Yes	Systems	1	$203	$237	$271
	Lower Leakage	Systems	1	$0	$0	$0
Water Heating						
WaterHeat	57% EF	Units	1	$0	$0	$0
	62% EF	Units	1	$0	$0	$0
	84% EF Tankless	Units	1	$975	$1,138	$1,300
	60% EF with 50% solar	Units	1	$2,000	$4,000	$6,000

[5] Thermostatic Expansion Valve (TXV) is a refrigerant metering valve installed on an air conditioner either at the factory or at the building site that helps mitigate the impact of improper refrigerant charge.
[6] Verified refrigerant charge means that the amount of refrigerant in the air conditioner is tested by a HERS rater to verify that it is properly charged. A properly charged air conditioner is more efficient.
[7] Verified air flow means that the air flow in the duct system is tested by a HERS rater to insure that there is adequate air flow. Air conditioners with adequate air flow perform better.
[8] Verified fan watts means that the fan watts for the air handler are tested by a HERS rater to verify the power consumption. Lower fan watts, as long as adequate air flow is maintained, results in a more efficient air conditioning system.
[9] Verified maximum cooling capacity means that a properly sized air conditioner, based on ASHRAE load calculations, is installed and verified by a HERS rater. An appropriately sized air conditioner is likely more efficient and more comfortable.
[10] Annualized Fuel Utilization Efficiency (AFUE) is the ratio of annual output energy compared to annual input energy. Higher is more efficient
[11] Verified duct leakage testing means that the air leakage of the duct system is tested and verified by a HERS rater. Lower leakage ducts improve the energy efficiency of both the heating and cooling system.
[12] Energy Factor (EF) is the rating that estimates the overall annual efficiency of a water heater. Higher is more efficient.

Various measures were then grouped into logical combinations as it usually takes a number of measures to bring a home into compliance. The grouping process is complicated by the unusual number of climates found in California requiring different combinations of EEMs in each climate zone to achieve compliance. As previously discussed, another complicating factor when grouping EEMs is the fact that it is "standard practice" for builders to achieve compliance using a set of EEMs other than those required in Title 24, known as Package D. Often a given set of EEMs selected by a builder as an alternative to Package D are in fact less costly than Package D. A good example of the difference in cost is windows. Currently, the marketplace provides windows, such as a low conductance frame (vinyl, wood) with a low solar gain low emissivity glass coating, that outperform the window specifications referenced in Package D at no additional cost.

Next, the study turned to identifying two single family home prototypes. The first prototype is a 2100 ft^2 one story slab on grade and the second prototype, shown in **Figure 2**, is a 2700 ft^2 two-story slab on grade. Simulations were then run for various unique combinations of EEMs to create a database of heating, cooling and water heating energy use estimates. We completed 1571 simulations for each prototype in each of the 16 California climate zones resulting in a database of 50,272 runs. The California approved MICROPAS building energy analysis software was used to construct the simulations. MICROPAS is widely used for standards development and code compliance in California.

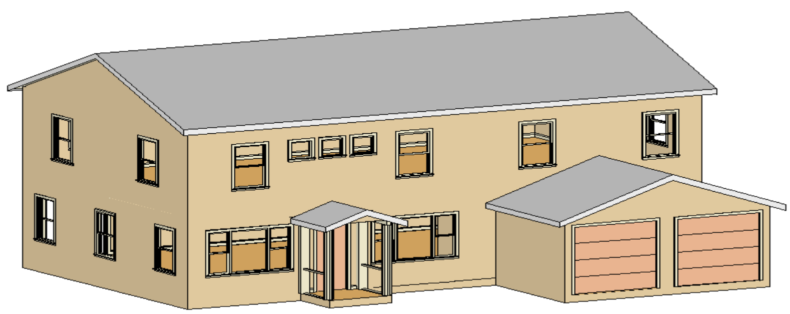

Figure 2. 2700 ft^2 Prototype Home

A number of different energy use metrics were estimated including the energy use metric used by the Title 24 standards called time dependent valuation[13] (TDV). TDV is similar to the concept of a source multiplier in that it enables electrical and gas energy use to be added together except that it is applied hourly and is usually expressed as TDV/ft2 of conditioned floor area. This is especially applicable to electrical energy, for which the value of a kWh on peak during a hot summer weekday afternoon when significant cooling is required is many times the value of a kWh off-peak. In addition, traditional metrics such as the therms, kWh and kW demand are included.

To manage this information, a robust spreadsheet was developed that enables the user to select, sort, and filter the results based on costs and targeted compliance margins. The user may also adjust the EEM costs and adjust the baseline features mentioned earlier to reflect updated standard practice for each California climate zone. The result is an updateable Excel-based tool with a useful life until the code is changed, typically about every four years in California.

A portion of the main spreadsheet results for climate zone 12 are shown in **Table 3**. At the top of the spreadsheet are rows for the standard and baseline reference homes. In this example note that the baseline home, which is the home with the set of features that builders are likely to use, is already 6%

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[13] Time Dependent Valuation is more fully described in the 2008 *Reference Appendices* at http://www.energy.ca.gov/title24/2008standards/

above the standard and actually costs $1,127 less than Package D. This is because the builder is likely to use features, such as better windows, which outperform the standard prescriptive features in Package D. The next few rows show statistics for the selected sorting and filtering followed by rows with results for the 1571 cases. In this example, which has been filtered to only show results that are 15% or more above code and then sorted by incremental builder cost, the least cost measure combination cost $686 more than standard practice. After a break in the table to skip the many middle range cases, we find a few cases with high incremental cases that builders would not usually favor.

Table 3. Sample Climate Zone 12 Results, Filtered > 15% above code, sorted by incremental cost

Climate Zone 12 Results			2700 ft2 home			2008 software			2008 standard design		Average cost level		
	TDV Energy					Percent Above			Builder Cost		Site Energy		
	kTDV/ft2					2008 Standard		Tier	Total	Incremental		Total	
	Heat	Cool	Fan	Dhw	Total	Cool	Total	Level	$	$	kW	kWh	Therms
Reference													
Standard	20.91	20.57	0.65	14.86	56.99	0%	0%		$3,004	$1,127	3.42	1907	592
Baseline	19.62	19.67	0.65	13.80	53.74	4%	6%		$1,878	$0	3.42	1925	545
Filtered													
Average	18.04	14.14	0.65	12.67	45.50	31%	20%	1	$4,073	$2,195	2.63	1475	500
Minimum	12.66	11.55	0.65	7.30	35.39	17%	15%	1	$2,564	$686	2.18	1337	319
Maximum	21.45	17.00	0.65	13.80	48.38	44%	38%	1	$10,032	$8,155	3.19	1669	573
Case													
776	17.13	16.64	0.65	13.80	48.22	19%	15%	1	$2,564	$686	2.88	1669	507
827	18.77	14.27	0.65	13.80	47.49	31%	17%	1	$2,565	$687	2.72	1482	532
495	21.02	12.36	0.65	13.80	47.83	40%	16%	1	$2,620	$743	2.33	1387	566
505	21.45	11.88	0.65	13.80	47.78	42%	16%	1	$2,667	$789	2.26	1377	573
666	19.78	14.15	0.65	13.80	48.38	31%	15%	1	$2,721	$844	2.57	1514	548
825	18.34	13.78	0.65	13.80	46.57	33%	18%	1	$2,746	$868	2.64	1440	525
835	18.77	13.36	0.65	13.80	46.58	35%	18%	1	$2,792	$915	2.49	1432	532
501	21.02	11.57	0.65	13.80	47.04	44%	17%	1	$2,848	$970	2.18	1345	566
796	17.13	16.09	0.65	13.80	47.67	22%	16%	1	$2,894	$1,016	2.88	1603	507
485	18.88	14.67	0.65	13.80	48.00	29%	16%	1	$2,900	$1,022	2.88	1540	530
291	17.42	15.88	0.65	13.80	47.75	23%	16%	1	$2,919	$1,041	2.72	1566	515
831	18.34	12.91	0.65	13.80	45.70	37%	20%	1	$2,973	$1,096	2.41	1392	525
523	21.45	11.55	0.65	13.80	47.45	44%	17%	1	$2,997	$1,119	2.26	1337	573
815	16.52	16.48	0.65	13.80	47.45	20%	17%	1	$3,025	$1,147	3.19	1616	495
686	19.78	13.73	0.65	13.80	47.96	33%	16%	1	$3,051	$1,173	2.57	1464	548
481	18.51	14.29	0.65	13.80	47.25	31%	17%	1	$3,081	$1,203	2.80	1506	525
289	17.05	15.41	0.65	13.80	46.91	25%	18%	1	$3,100	$1,222	2.64	1529	510
853	18.77	12.98	0.65	13.80	46.20	37%	19%	1	$3,122	$1,244	2.49	1387	532
621	16.51	15.51	0.65	13.80	46.47	25%	18%	1	$3,125	$1,247	2.64	1529	501
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1312	15.94	13.01	0.65	7.30	36.90	37%	35%	1	$9,350	$7,472	2.57	1361	370
1263	14.28	17.00	0.65	7.30	39.23	17%	31%	1	$9,623	$7,745	3.11	1643	344
1098	12.66	14.78	0.65	7.30	35.39	28%	38%	1	$9,962	$8,084	2.80	1442	319
1318	15.34	13.01	0.65	7.30	36.30	37%	36%	1	$10,032	$8,155	2.57	1361	360

Research Findings

Without regard to cost, **Figure 3** shows that new California homes can have compliance margins of 39% to 62%, depending on climate zone.

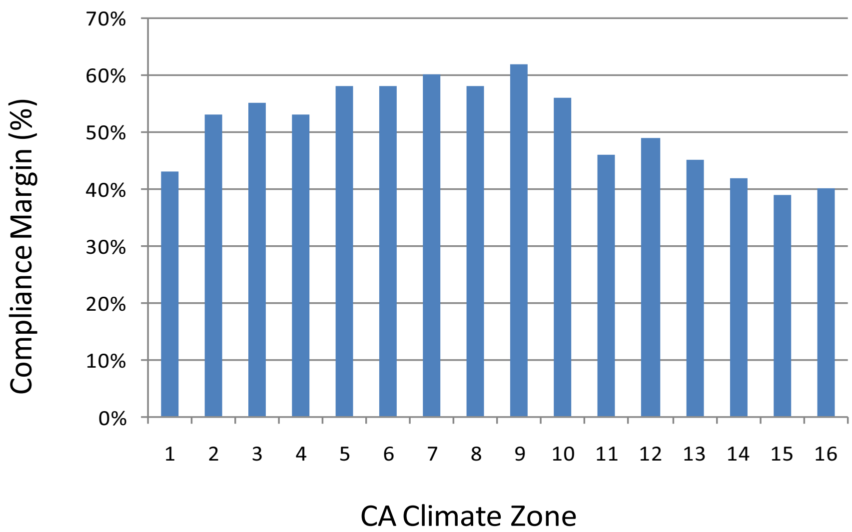

Figure 3. Maximum achievable[14] compliance margin in California is 39%-62%

This important finding informs policymakers, builders, and program designers of the potential to exceed Title 24 using measures currently available in the single family residential new construction market. Note that while a home with a 100% compliance margin uses zero energy for space heating, space cooling, and water heating, it is not a zero net energy home due to significant energy use for lighting, appliances, and plug loads.

Figure 4 shows the compliance margin and estimated incremental cost for home case #456 (randomly selected), and the Package D home which prescriptively complies with Title 24.

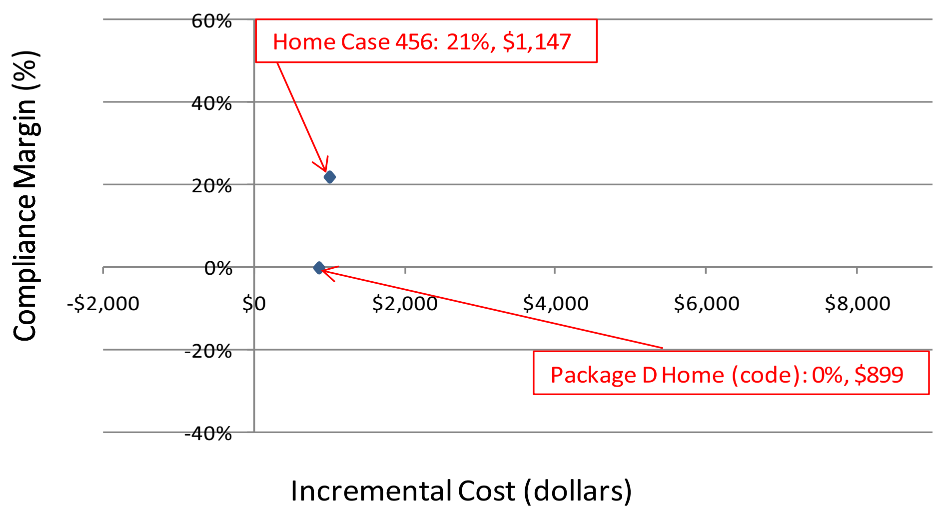

Figure 4. Compliance margin and incremental cost for two simulated homes in Climate Zone 13

By definition, the Package D home exactly meets code (0% compliance margin), but it does have an incremental cost as described in the methodology section, because it is being compared to the

[14] Maximum achievable efficiency is only within the bounds of this research which considered commonly available EEMs as described in the methodology section

standard practice home using the performance method of compliance. This demonstrates why builders tend to exclusively use the compliance method in California: they can build homes that meet code at lower cost with flexibility to choose the measures they can most easily incorporate into their buildings. The specific measures included in each of these homes are listed in **Table 4**.

Table 4. EEM combinations and estimated incremental costs for two homes in Climate Zone 13

	Measure	Package D Home	Home Case 456
Envelope	Walls	R19	R13+R4 foam
	Roof	R38	R38
	SlabEdge	R0	R0
	Infiltration	No	No
	RadBarrier	Yes	Yes
	CoolRoof	Yes	No
	InsQuality	No	No
Glass	Window	0.40 U/0.40 SHGC	0.34 U/0.30 SHGC
HVAC	AirCond	13/10	13/12
	ChargeLight	Yes	Yes
	AirFlowTest	No	Yes
	FanEnergyTest	Yes	Yes
	MaxCoolCap	No	Yes
	Furnace	0.78	0.92
Duct	Duct	R6.0	R6.0
	DuctTest	Yes	Yes
Mass	Mass	Std	Std
Dhw	Dhw	57% EF	62% EF
	Compliance Margin	0%	21.5%
	Incremental Cost	$899	$1,147

Table 4 shows that eight measures differ among the homes to achieve a 21.5% compliance margin demonstrating the EEMs used to generate the compliance margin and incremental cost results as described in the methodology section.

Figure 5 displays most[15] of the 1571 homes that were modeled with unique EEM combinations for climate zone 13.

[15] Homes with compliance margins less than -40% are omitted.

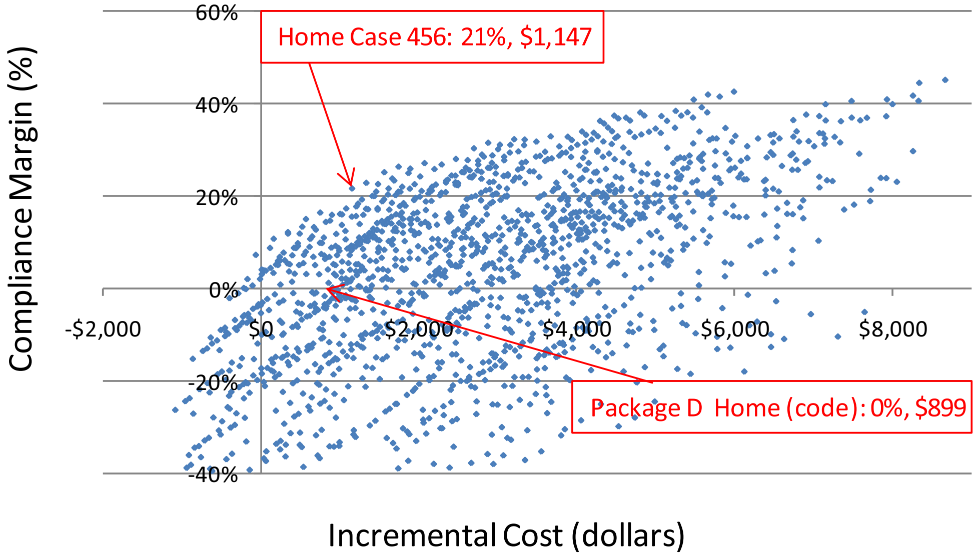

Figure 5. Simulated homes in Climate Zone 13

Figure 5 shows where case #456 and the Package D home fall in the spectrum of modeled homes. It is also evident that there are many homes with a wide range of compliance margins and incremental costs, each with its own unique combination of EEMs.

The results shown in **Figure 6** are the same as those presented in **Figure 5**, but have been grouped into four areas.

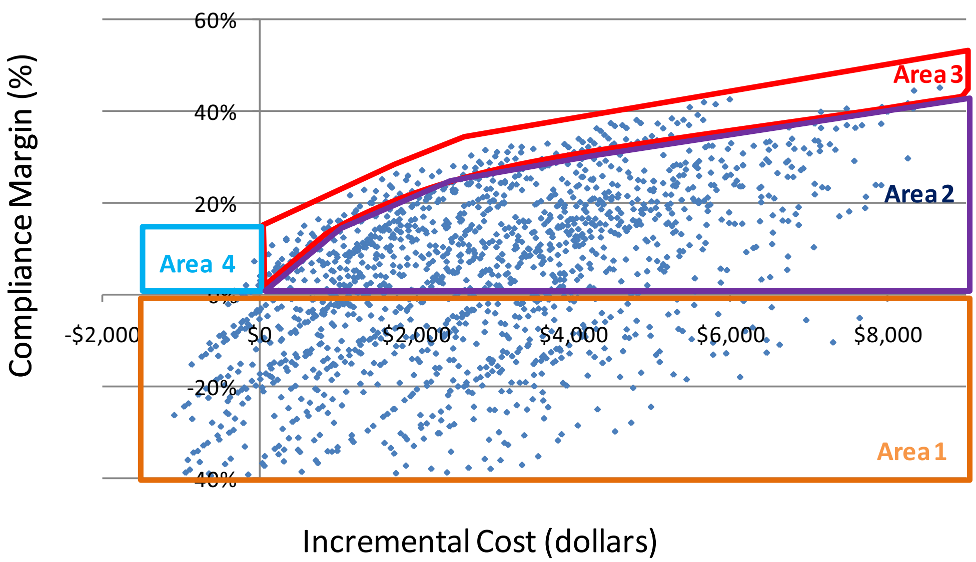

Figure 6. Climate Zone 13: Interpreting the Results

Area 1 homes provide zero "bang for the buck" because none meet code – indicated by their negative compliance margins – rendering them of little interest to builders. Still, many of these homes have significant incremental costs, some in excess of $6,000. This demonstrates that randomly selecting EEMs for new homes can result in significant expense with no efficiency gain.

Area 2 homes provide a low bang for the buck because their EEM combinations are not the least-cost option for a given compliance margin. All of these homes could be built because they meet code, however, there are homes with EEM combinations above Area 2 that achieve the same compliance margin for a lower cost, or a higher compliance margin for the same cost.

Area 3 homes provide the biggest bang for the buck because they include the least-cost options for each compliance margin, or the highest attainable compliance margin for a given cost. We included the least-cost option, and a few lesser cost options, for each compliance margin in Area 3 to demonstrate builders' need to tradeoff between EEMs to accomodate their respective building needs. A second characteristic of Area 3 is the flattening of the least-cost homes distribution indicated by the bend in the upper border of Area 3. This occurance indicates that each incremental percentage increase in compliance margin comes at an increased cost. For example, **Figure 6** shows that achieving compliance margins above approximately 42% yields almost zero efficiency gains, even for an extra $3,000. This flattening of the least-cost distribution is a critical finding observed througout all climate zones.

Area 4 homes provide some bang for *no* buck because these homes actually meet or exceed code with *zero or negative* incremental cost, but there are few homes in this area. Since our baseline for cost was standard practice, this indicates that builders are already close to the least-cost EEM combination to minimize costs while meeting code.

These results from Climate Zone 13 demonstrate that there are many EEM combinations that achieve high efficiency at varying costs levels. Our study found that this pattern is consistent across all California climate zones. Therefore, to exceed code, builders must carefully select measure combinations to achieve high efficiency at least cost. Nationally, these findings suggest that state and regional investigations of optimal measure combinations for various climates may yield efficiency improvements for little or no incremental cost.

Table 5 includes least-cost EEM combinations with a ~20% compliance margin in climate zones 2, 3, 13, and 15, representing homes in Napa, San Francisco, Fresno, and Palm Springs, respectively.

Table 5. Least-cost EEMs for Climate Zone 2, 3, 13, 15 homes with compliance margin ~20%

	Measure	CZ 2 - Case 607	CZ 3 - Case 583	CZ 13 - Case 456	CZ 15 - Case 454
Envelope	Walls	R13+R4 foam	R13+R4 foam	R13+R4 foam	R13+R4 foam
	Roof	R38	R38	R38	R38
	SlabEdge	R0	R0	R0	R0
	Infiltration	Test 3.2 SLA	Test 3.2 SLA	No	No
	RadBarrier	No	No	Yes	Yes
	CoolRoof	No	No	No	No
	InsQuality	No	No	No	No
Glass	Window	0.34 U/0.30 SHGC	0.37 U/0.56 SHGC	0.34 U/0.30 SHGC	0.34 U/0.30 SHGC
HVAC	AirCond	13/11	13/10	13/12	13/12
	ChargeLight	Yes	No	Yes	Yes
	AirFlowTest	No	No	Yes	Yes
	FanEnergyTest	No	No	Yes	Yes
	MaxCoolCap	No	No	Yes	Yes
	Furnace	0.8	0.8	0.92	0.92
Duct	Duct Insulation	R6.0	R8.0	R6.0	R8.0
	DuctTest	Yes	Yes	Yes	Yes
Mass	Mass	Std	Std	Std	Std
Dhw	Dhw	62% EF	62% EF	62% EF	62% EF
	Compliance Margin	20.2%	20.1%	21.5%	21.0%
	Incremental Cost	$666	$387	$1,147	$918
	Major City	Napa	San Francisco	Fresno	Palm Springs
	Climate Zone Type	Transitional	Coastal	Inland	Desert

The EEM list reveals several findings. First, the measures do vary by climate zone, confirming that optimal EEM selection is climate dependent. Second, homes from various climate zones with almost identical compliance margins can have different incremental costs. Third, some EEMs are found in all four homes such as R38 attic insulation and .62EF water heaters. The .62EF water heater measure is no surprise since the estimated incremental cost above .575EF water heater is $0. Finally, the homes in climate zones 13 and 15 have identical EEMs except for R6 vs. R8 ducts respectively. This result isn't too surprising since Fresno and Palm Springs have similar (extreme) climates.

Conclusions

This research was completed in 2008, and an update is underway for 2011. Although the update will reflect changes to California Title 24, update some incremental measure costs, and incorporate changes to standard (construction) practice, we do not expect the major findings of this research to be affected. In summary, the major findings include:

- It is possible to exceed Title 24 by 39%-62% with commonly available EEMs for single family residential new construction, depending on climate zone.
- Creating an updateable tool of research results prolongs the life of the research's usefulness.
- The majority of a California new home's energy consumption can be outside the scope of Title 24, which does not address appliances, plug loads, and most lighting. Those pursuing zero net energy new homes must look beyond Title 24.
- Randomly selecting EEMs will likely yield increased costs without increased efficiency. The best measure combinations vary significantly by climate and must be selected thoughtfully.
- There are many low-cost and no-cost measure combinations that allow builders to significantly exceed Title 24 building code. The same is likely possible outside California.
- Incremental compliance margin increases come at ever increasing costs. For example, exceeding Title 24 by 20% may cost $500, while reaching 40% may cost $5,000 or more.

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