Moving beyond 'Better than Code': New Market Transforming Zero Net Energy Aligned Residential New Construction Programs

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ABSTRACT

Zero Net Energy (ZNE) goals necessitate a new paradigm for residential new construction efficiency programs. The traditional program framework provides incentives for the difference in energy use between a designed building and a minimally code compliant building. In most cases the assessment only includes certain portions of a building's total energy use – those regulated by building and appliance standards. Programs aligned with ZNE goals must evolve their core metrics and methods such that all building end uses are addressed and energy efficiency is no longer measured by how far energy use is below the ceiling (code), but instead how close it is to the floor (zero net energy use). Additional care must be taken to maintain equity between climate zones with significantly varied heating and cooling demands. Finally, for a program to have a powerful impact on the market it must be simple to implement and simple in which to participate.

Residential new construction programs administered by the four investor-owned utilities in California have recently made this pivot with a groundbreaking program redesign effort for 2014. The new program uses an adapted version of the CA HERS Index as the basis of its eligibility criteria and incentive scale, supplemented by incentive bonuses based on low total energy use.

This paper will discuss the analysis performed to determine this structure as well as other bells and whistles included in the new program design.

Introduction

The California Advanced Homes Program (CAHP) is the most recent of a long history of utility run residential new construction energy efficiency programs in California. In operation since January, 2010 it has performed admirably to transform the market, to push builders to deeper energy savings, and to support the state's Codes and Standards effort. CAHP is operated by each of the four California investor owned utilities; Pacific Gas and Electric (PG&E), San Diego Gas and Electric (SDG&E), Southern California Edison (SCE), and the Southern California Gas Company (SoCalGas).

The residential new construction market is integral to California's energy reduction strategies. Homes built today will have an impact on energy use for 50 to 100 years. Furthermore it is significantly more cost effective to design and build energy efficient homes from the start, than to retrofit improvements down the road. The California Public Utility Commission (CPUC) recognizes this by designating residential new construction programs as part of the utilities' core portfolio. The primary means of improving residential new construction efficiency in the state is

through an aggressive Codes and Standards (C&S) effort. California's Title 24, Part 6 is the states building energy code. Energy efficiency incentive programs complement C&S by advancing the market ahead of the code. The programs shepherd efficiency measures and design practices to market, bringing down the cost of advanced buildings. This helps Codes & Standards meet the rigorous cost effectiveness criteria required of code mandates.

Program History

Residential new construction programs in California have been available since the late 90's. Early program designs awarded prescriptive incentives for whole house performance and/or specific energy efficiency measures. "Percent better than code" was established as the primary metric for program participation. Homes with modeled energy use 15% less than a minimally code compliant building were awarded a base incentive. This percentage energy reduction is also referred to as the compliance percent. Eventually, a second tier of incentives was offered to drive builders to produce deeper savings. In 2010, the CAHP program was launched with continuously escalating incentives based on the energy savings and percent better than code, as shown in Figure 1 from the program's handbook. The program entry was still tied to 15% better than code. Homes that met this minimal criterion received $75 per kW saved, $0.43 per kWh saved and $1.72 per therm saved. Homes that demonstrated code compliance better than 15% received higher incentives per energy commodity. These commodity rates scaled up to their maximum rates at 45% better than code. A home with a compliance percent of 45% or more would receive $225 per kW saved $1.29 per kWh saved and $5.14 per therm saved. In addition, the program paid bonus incentives for meeting other criteria such as enrolling in the New Solar Homes Partnership Tier II program.

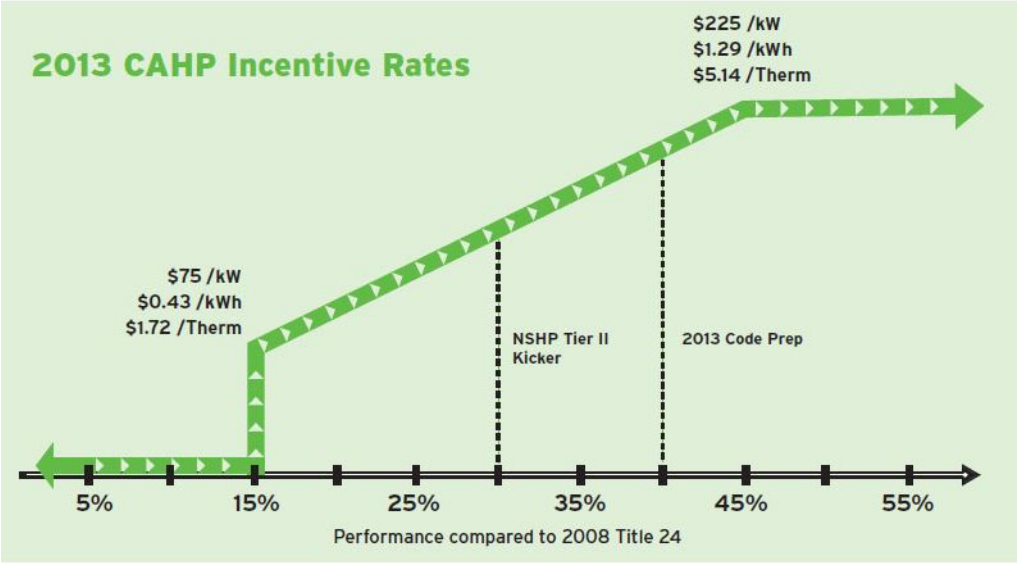

Figure 1. CAHP incentive rates for the 2008 Energy code based program.

The purpose of the escalating incentives was to incent builders for small incremental improvements over time, and therefore raise the overall compliance percent above the entry threshold of 15%. By this metric, the program has been successful. In PG&E territory, average program compliance is 25% above code. The escalating incentives have been shown to drive

deeper savings from participating builders. Incremental measures costs in many cases have reduced dramatically, partly as a result of this program. For instance, in some markets the cost for quality insulation installation has been reduced from a price premium of $600 per home to a standard insulation practice that demands no additional costs to the builder.

The program has also seen success by leveraging existing energy code compliance infrastructure. Energy models and HERS registrations which are required by the state to show code compliance are also used by the program to verify incentives and energy savings. This has made participation relatively easy for builders.

However, despite these successes the program has some elements that need to improve or change for it to continue to serve its function. The custom incentive calculation for this program is complex and difficult for a builder to quickly gauge what their incentives will be. Two homes that perform to the same compliance percent can have significantly different incentive levels, even within the same development and climate zone. This is due to the fact that homes of different size and design will demonstrate different total energy savings, even if they have the same compliance percent. Additionally, since the program savings and incentives are based entirely on Title 24, Part 6 performance energy modeling (California's energy code), the program is slow to respond to new energy measures or technology. Until new modeling methodologies can be studied, tested and approved by the California Energy Commission (CEC) for code compliance, a builder is given no credit for those new measures by the program. In this way, CAHP cannot truly drive advanced homes, despite its namesake. Instead it is limited to incenting only marginally improved homes under the Title 24 performance modeling rules. Additionally, as a code based program, only the code regulated energy loads of heating, cooling, ventilation and domestic hot water are addressed.

Program Redesign

The four utilities that operate CAHP recognized a clear need to redesign the program to coincide with the launch of a new, more rigorous energy code. The 2013 Title 24, Part 6 energy code is scheduled for implementation starting July 1st, 2014. At the same time, California's 2020 ZNE residential goals[1] are approaching swiftly with only two code cycles remaining before the goal needs to be met. For CAHP to continue to serve its role in the advancement of code, it needed to be redesigned. The goals of the redesigned program were to:

- Create a program that explicitly drives towards ZNE
- Include all energy end-uses within the building's envelope
- Equitably drive advanced buildings in all climate zones
- Create a program that can adapt to new technologies and energy measures
- Create a program that is simple for builders to participate, and simple for utilities to implement
- Continue to support and use California's energy efficiency regulatory infrastructure

The research and redesign initiative described in this paper only addresses single-family construction. Research for the multi-family program was also conducted with similar methods and conclusions. However, that effort is not addressed directly in this paper.

[1] California's state goal is that all residential new construction be zero net energy (ZNE) by 2020

Program Metrics

The first task was to determine a new energy efficiency metric that could be used by the CAHP program as a long-standing basis to define energy efficiency. The existing metric, percent above code, is fundamentally flawed to serve this long-term purpose. First, it's not truly whole - building (at least in California). The Title 24, Part 6 energy code baseline only includes the regulated loads of heating, cooling, ventilation and domestic hot water. Lighting, appliance, behavior, and plug loads are omitted. This means that percent above code cannot be used in context with ZNE. In some mild climate zones such as those on the coast, as little as 25% of a typical home's energy use would be included. For ZNE to be achieved, a truly whole-building metric is necessary.

Second, the metric is upside down in relation to ZNE. The program metric should be able to simply and directly communicate the intent of promoting home energy use closer to zero, with a metric that runs in that same direction. Percent above code references the improvement a home has made relative to the code baseline (the ceiling; a maximum amount of energy the home can be shown to use to meet code). A ZNE-based metric necessarily references how close a home is to zero energy use (the floor; zero net energy use). What's more, in this analogy, the ceiling height changes from home to home based on climate zone, building size, surface area, and the HVAC and water heating technologies selected. Percent above code can't be used to accurately compare the efficiency of two different buildings.

Finally, as the code baseline shrinks after each code update, the denominator of the percent above code equation shrinks as well. This leads to perverse results. In some climate zones minor efficiency improvements that yield small energy savings can result in spectacularly high percentages above code. Preliminary analysis of buildings using the 2013 energy code showed that simply taking credit for quality insulation installation (QII) can yield upwards of 15% above code in some climate zones. With rigorous efficiency standards, percent above code can no longer be used as a central and fair descriptor of energy efficiency. An example is illustrated below in figure 2.

Table 1. Energy efficiency comparison of two buildings

Building Location	**San Diego (CZ 7)**	**Fresno (CZ 13)**
Building Type	2,100 default	2,100 default
Energy Efficiency Measures	2013 Prescriptive Plus:	2013 Prescriptive Plus:
Envelope	Quality Insulation Installation (QII)	QII U30/S22 windows R-21 wall cavity
HVAC	-	SEER 15, EER 13 92% AFUE
DHW	0.82 EF tankless heater	0.82 EF tankless heater all pipes insulated
Other	-	R-8 ducts
Annual Code Savings (kWh)	13 kWh	607 kWh
Annual Code Savings (therms)	98 therms	149 therms
Annual kTDV use	123,000	218,000
2013 T24 Compliance %	**45%**	**32%**

The Fresno building employs a long list of efficiency measures, and saves considerably more kWh and therms than its San Diego counterpart. However, looking at percent above code only, the Fresno home is significantly worse.

New CAHP Energy Efficiency Metric Research

The research investigated a number of options to replace percent above code as the core CAHP program metric (listed below). The selections were constrained to energy use intensity (EUI) metrics that drove towards zero as the building's efficiency improved.

- Time Dependant Valuation (TDV) Energy (kTDV/sf/yr)
- Site Energy (kBtu/sf/yr)
- RESNET HERS Index Score
- California HERS whole-house design rating

The concept of Time Dependent Valuation (TDV) was incorporated into California's Title 24, Part 6, Building Efficiency Standards in 2005 as means to appropriately assign value to energy savings based on the time of day and year it is saved, as well as its source (electricity or natural gas). As a metric TDV addresses the important issue of peak demand in California and serves to encourage and reward measures that save energy when it is most valuable on a statewide basis.

TDV is a purely analytical and economic tool, and is not reflected in nor directly relevant to the energy use and corresponding utility bills of a building. TDV Energy is not representative of expected consumer energy use or costs, but rather represents the value of its energy use (and

savings) to the state. TDV is a well-established and accepted means of assigning value to time of energy use in California. The energy industry, though not consumers, are highly familiar with it. TDV energy is central to the CEC's definition of code ZNE and therefore its use would support statewide regulatory goals. However this metric was not selected by CAHP due to its confusing complexity to consumers and builders amongst other reasons.

Site energy does not value or account for the time value of California energy use (and savings). It is attractive as a more 'pure' energy number; however, as it is likely less opaque and more readily understandable by builders and homeowners who do not regularly encounter TDV. In a march toward zero, a CAHP site energy metric would help indicate to these market players how a particular home contributes towards California's ZNE goal. However this metric was not selected as it does not directly support California's energy efficiency regulatory structure.

The RESNET HERS index score is a nationally recognized and well established energy use index administered by the non-profit Residential Energy Services Network. The score can be calculated by approved software, most commonly REM/Rate. It includes all energy end uses of the house normalized to a score from 150 to 0. The score does not incorporate TDV values so does not align with California's specific regulatory goals, and therefore was not selected.

The CA HERS whole-house design rating is similar to the RESNET HERS index. It's a 'Miles-per-gallon' rating that runs from 250 to 0, representing its TDV energy use, normalized relative to a reference home built to meet the Title 24 2008 prescriptive (Package D) requirements. The reference home has a score of exactly 100, while ZNE is 0. The score is based on TDV Energy use including all energy end uses from both regulated and non-regulated loads and therefore directly supports California's regulatory goals. Additionally, the simulation protocols are nearly identical to those for Title 24 compliance; therefore, the use of the metric would not require extra modeling. Additionally, since the reference building is static, the score framework could be maintained from now until 2020 ZNE goals and beyond.

Therefore the CA HERS whole-house design rating was selected as the best option for CAHP. However, there are a few deficiencies that have added challenge to designing and launching an efficiency program based on this metric. First, it is not yet well established in the market. While the score has been calculable under the 2008 Title 24 energy code, very few market participants were doing so. Most participants were calculating the whole-house HERS Index for existing homes rather than a design rating developed for new construction. Some nuances of the metric have therefore not been tested or vetted for widespread use in the new construction industry. This includes a large-home scale back equation that increases a home's rating for homes over 2,500 square feet as well as severely limited options to show improvements to lighting, appliances and plug loads. Additionally, while the metric is defined and documented relative to the 2008 code, final rule-set definitions have not yet been established for the 2013 code. Therefore CA HERS design rating calculations haven't yet been embedded into compliance software.

The CAHP Score

In light of these limitations (and other factors), the redesigned program instead is using what is being called a CAHP Score. The CAHP Score is closely derived from the CA HERS design rating in intention and in mathematical construct. The CAHP Score will determine a home's incentive amount. A lower CAHP Score will yield a higher incentive.

To facilitate calculation in approved compliance software, the TDV energy use of the CAHP score's baseline reference building is side-calculated from the 2013 Energy code Standard

design results in an effort to approximate the appropriate 2008 Package D reference building. Furthermore, the large-home scale back equation has been eliminated so that the efficiency program is more able to serve the entirety of the new construction market. Additionally, as an efficiency program, the program eliminated design rating credit for installing solar PV energy. It is the intention to continue to coordinate with the Energy Commission as the CA HERS design rating's rule set and technical standards are finalized.

Of note: though the selection of the CAHP Score metric was made with the statewide zero net energy goals explicitly in mind, and in coordination with the state's ZNE action plan, CAHP does not intend on using the ZNE term in its marketing materials or program collateral. ZNE as a term garners remarkable enthusiasm and passion amongst builders and the public. However, it is vital to recognize that the lay-understanding of ZNE to homeowners that drives this passion will be zero net energy bills or zero net energy metering. A CAHP ZNE or ZNE-ready building will be neither. It will be based on TDV energy, a metric entirely different and complicated to understand. In order to reduce confusion, and so as not to taint the ZNE term in the public mind, CAHP's ZNE based program will refrain from branding itself as such. In this way, the program will be better able to meet its long term goal of promoting advanced energy efficient residential homes.

CAHP Points

In order to meet the goal of having a metric responsive to new technologies and program goals the program has introduced CAHP Points. CAHP Points reduce the CAHP Score and increase the building's incentive. They were developed and will be awarded for energy efficiency measures and concepts not included in current modeling software. Four initial CAHP point opportunities will be available when the program launches, with more under development.

Two of the initial four CAHP Point offerings are designed to combat one of the key deficiencies of the CAHP Score as a ZNE Metric. The CAHP score is by definition, a *relative* energy use metric. The score is derived relative to a reference building of the same size and in the same climate zone. However, ZNE is by definition an *absolute* energy use metric. A ZNE home uses a specified absolute quantity of energy annually, which is then offset by onsite renewables. A specific and program-consistent CAHP Score cannot be used to define ZNE or ZNE-ready due to high variability between climate zone, house sizes, and design choices. Figure 3 illustrates this point:

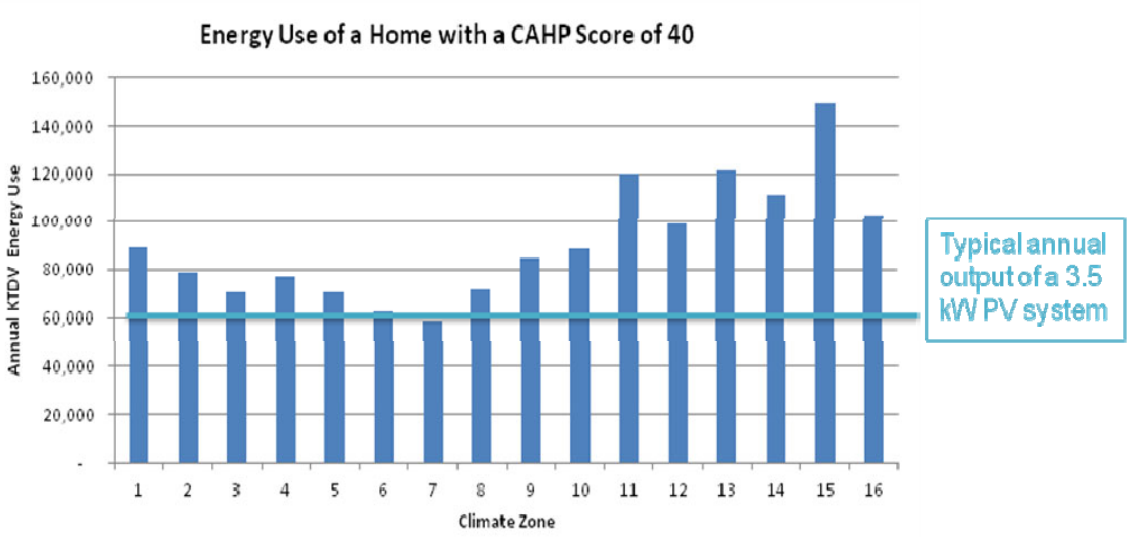

Figure 2. Energy use of a home with a CAHP Score of 40 across all 16 CA climate zones.

To reach ZNE goals, the program needs to promote reduction of energy use in both absolute, and relative terms. As shown in the Figure 3, the annual energy use of homes with the same CAHP score varies from under 60,000 annual kTDV to over 150,000 kTDV. On an absolute basis, this representative highly efficient home design could only be considered ZNE-ready in a handful of locations. However, on a relative energy basis, all 16 can safely be referenced as being efficient. In practice, having a relative metric is necessary for the program to be equitable across the wildly diverse climate zones. For instance, the energy use required to keep a home comfortable in the central valley of California is significantly higher than what is required on the coasts. Therefore, builders in the central valley need to be rewarded along the long spectrum of incremental improvements from the baseline building to an efficient building. The CAHP score does this admirably. However, in coastal regions, a builder will reach an absolute energy use that has achieved the target of ZNE-ready at a much higher CAHP Score than an inland counterpart. Therefore, to give credit to advanced buildings that reach, or get close to reaching the program's goal, CAHP points will be awarded to homes that are shown to meet low absolute annual energy use targets. Homes that use less than 100,000 kTDV/year will be awarded 5 CAHP Points (subtracted from the homes initial CAHP Score). Homes that use less than 60,000 kTDV/year will be awarded an additional 5 CAHP Points.

The first level has been determined to be attainable by small production homes that are considerably energy efficient. The deeper level is calibrated to coincide with the energy use of a typical 3.5 kW residential solar panel, and will not be easily met, but is a target point for a truly ZNE-Ready home.

Other CAHP Points will be designed and awarded to fulfill certain goals that the CAHP Score itself cannot incent. Such as:

- Support of the efficiency measures targeted by the utilities Codes and Standards and Emerging Technologies departments
- Improved energy efficiency design principles that will be necessary to reach ZNE goals
- Energy efficiency technologies that cannot currently be modeled in code software

- Energy efficiency technologies that impact the non-regulated loads of lighting, appliances and plug loads

One initial CAHP point offering is specific to support Codes & Standards. 5 CAHP Points will be awarded to homes that meet the 2016 Title 24 Energy code (or a proxy of that code) early.

Other CAHP point options may be introduced to push the market towards better design strategies. The first such offering is 3 CAHP Points for homes that take part in DOE's Zero Energy Ready Home program. Builders that take part in this program will learn the value of an integrated energy efficiency design strategy, as well as to learn the value of intensive installation verifications as required by the Challenge Home Program.

Additional CAHP Points will be awarded for energy technologies that either cannot be modeled in code, or impact non-regulated loads. Due to research scope limitations, the initial program launching in July, 2014 will not include any such offerings. However some preliminary concepts that are being explored for future use are:

- Home energy management systems
- 100% high efficacy lighting
- ENERGY STAR® appliances standard
- Solar thermal space heating
- Groundwater radiant cooling systems
- Domestic hot water heat recovery systems

In addition, the program will build a customized CAHP Point option for new technologies that show promise from preliminary engineering calculations. In order to be eligible, the home(s) using the technology must agree to energy use monitoring. The monitoring results will assist the energy efficiency industry in determining what technologies to continue to improve and install. Technologies that are confirmed to save energy can then be woven into eventual code updates. Measures that don't meet their expectations can be weeded out based on actual use data. This 'Pay first, ask questions later' mentality will spur innovation that will be necessary to bring the market to its technical ZNE potential.

Program Specifics: Entry Threshold & Incentives

Considerable research was conducted to turn the program concept, as outlined above, into a functional program offering. First, it was necessary to determine a CAHP Score that could serve as a program entry threshold. Next, incentive levels that were enticing to builders relative to incremental building costs, and also cost effective for program operations, needed to be set.

Program Entry Threshold

The program has traditionally used 15% above code as the entry threshold to differentiate efficient buildings deserving of incentives. An appropriate CAHP Score that could be used for the same purpose was determined by running over 600 energy models in the 2013 Energy code's beta software. Two different prototype buildings were run in all 16 climate zones using 14

different design packages. To keep the program relatively consistent to prior program offerings, it was desired to use a CAHP score that correlated roughly with 15% above code. Figure 4 below shows a sample of the data.

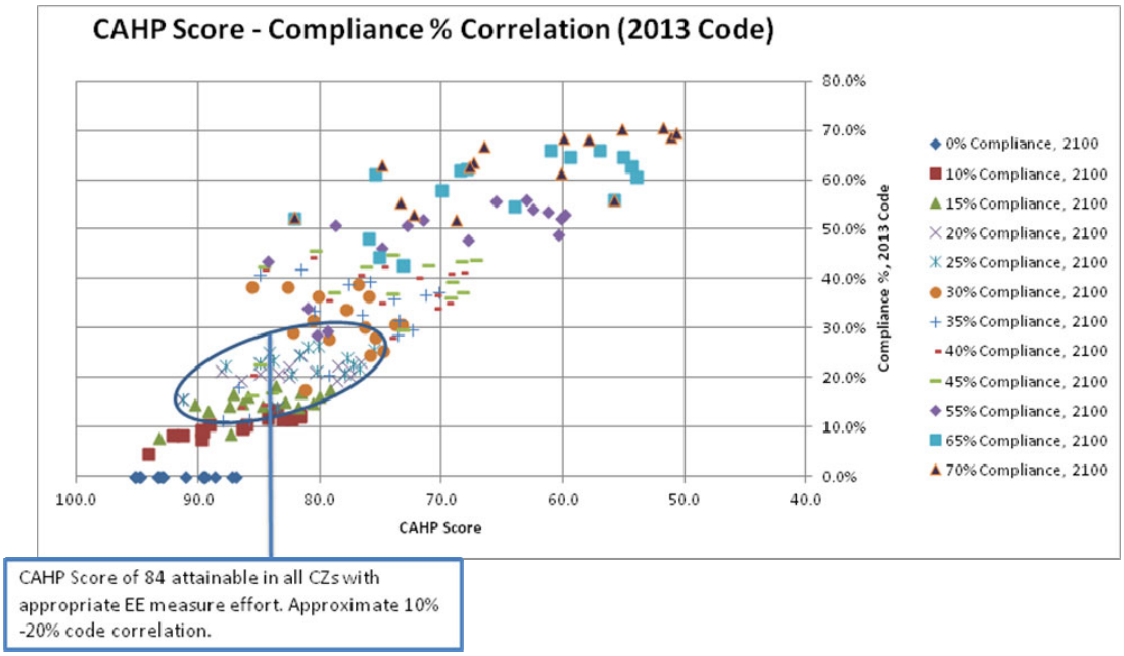

Figure 3. CAHP Score to compliance percent correlation scatter chart.

Each scatter point represents the CAHP Score and percent above code results of a building simulation. Each distinct point style represents a particular design strategy. The data shows considerable variation between climate zones. In particular, climate zones with low heating and cooling loads yielded low CAHP Score reductions from the design improvements relative to high use climates. This is explained by the high fraction of non-regulated load-use compared to the total whole-building energy budget of those buildings. The research explored the option of splitting the program into two or three sub programs, designed to serve groups of climate zones based on their energy use. It was determined that such a design may be more equitable across the state. However, it would also add considerable complexity and confusion to the program design, and therefore the idea was dismissed.

A CAHP Score of 84 was determined as a fair entry point, accessible in all climate zones, and aggressive enough to require efficiency design strategies from builders in all climate zones. A CAHP Score of 84 correlates roughly to 10%-20% code compliance. Due to the nature of the new metric, there may be specific designs, particularly in hot climates that reach a CAHP Score of 84 with minimal improvement over code. The benefit of having a single entry point statewide was sufficient to dismiss this program design concern.

CAHP Incentives

The program's incentive amounts were set to fulfill a set of goals that in some cases conflict with each other:

- Target approximately 50% of incremental builder cost program wide

- Be high enough to entice builders to participate
- Be cost effective to implement for the utility
- Be simple to communicate and understand
- Be predictable to builders

Incremental builder costs are a central component to the incentive determination. However, accurate and applicable builder cost data was not readily available. The most comprehensive data available was compiled in 2008 and was based on improvements to the 2008 energy code. Much of the data was obsolete due to reductions in cost since the data were compiled, or due to changes in the cost baseline with the energy code upgrade. To improve on the available data, six program participants were interviewed including three builders, two Title 24 consultants and one HVAC specialist. They were asked for high and low estimates of each measure used to create the design packages, relative to a prescriptive code baseline. For some interview subjects, the measures selected were not familiar, or the baseline reference didn't match the subject's knowledge base. Therefore the ranges of answers for some measures were significant, lowering confidence in the final results considerably. The responses were evaluated, taking into account the confidence and knowledge base of each respondent and assigned incremental cost values to each measure. These were applied to the measure packages used in the CAHP Score correlation modeling. This yielded an approximate cost-to-CAHP score relationship. This cost curve varied by climate type as expected.

Additionally, two competing factors reduced confidence in the final estimates. First, the measure packages selected for research were not intentionally chosen with cost effectiveness in mind. A savvy builder would be able to find lower cost methods to reach a certain CAHP score. From this assessment, estimates were likely elevated. Second, the real baseline for a builder is almost certainly not the prescriptive code baseline. Each builder will have a unique baseline that likely uses most of the low cost, highly effective energy efficiency measures and does not use higher cost prescriptive measures. Therefore, to reach above code program thresholds, the builder will be left with higher cost measures than this assessment assumed. By this logic, cost estimates were likely low. However, the cost estimates from this research were the best available data source to set incentive levels against.

An incentive curve was developed to comprise 50% of the incremental builder cost on average across all climate zones based on an anticipated range of CAHP Scores. Since the cost curve increases exponentially relative to CAHP score, the incentive curve also has a built in escalation to match. The final incentives reward $300 to a home with a CAHP Score of 84. Each reduction in CAHP score achieved from 84 to 75 yields the builder an additional $100 while reductions below 75 yield $200 per point. The incentive curve is shown in figure 5.

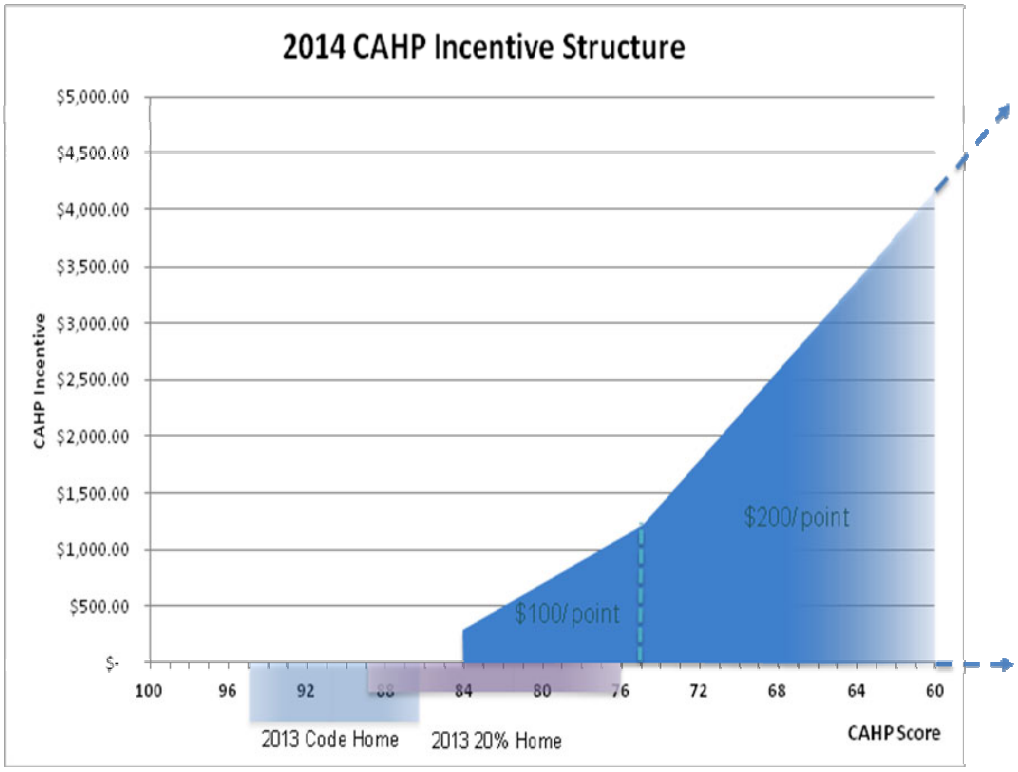

Figure 4. 2014 CAHP Incentive structure.

Conclusions

The redesigned program will launch on July 1st, 2014 at the same time the new energy code goes into effect. The design successfully met the primary program goals. The core efficiency metric drives conceptually to ZNE and includes all energy end-uses within the home's envelope. The program will continue to rely on the state's existing energy efficiency infrastructure such as TDV energy values, HERS verifications and Title 14 energy modeling. The program is equitable to all climate zones with base incentives derived from the relative CAHP Score metric, but with bonuses awarded for meeting aggressive absolute low energy use targets. The built in CAHP points give the program a nimble mechanism to increase incentives for particular program goals such as pushing innovation and integrated design strategies. Finally, the program is relatively simple to understand, participate in and implement.

This program will run as designed for at least six months, at which time incentive levels may be reconsidered due to the uncertainty in the cost curve and therefore the incentive values. Additional program design edits may also be considered based on participant feedback over the initial six months.