Measuring California ENERGY STAR® Homes: Inside and Out

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ABSTRACT

The California ENERGY STAR® New Homes Program provides millions of dollars in rebates to production builders to construct more energy efficient housing. Program implementers use performance-based Title 24 software applications as a tool for estimating program-driven energy savings. A recent California new construction potential study (Itron 2006) used a similar performance-based approach to project energy savings potential. However, Title 24 performance-based programs were designed to demonstrate code compliance, not for estimating energy savings.

Title 24 (for low-rise residential buildings) only considers the energy use of end-uses that builders can affect during construction: hot water heating, space cooling and space heating.[1] To meet the CA ENERGY STAR® New Homes Program guidelines, these combined end-uses must perform at least 15% better than a minimally compliant home (2001 Title 24 Package D). California Home Energy Rating System (C-HERS) protocols are followed to ensure that the construction characteristics match the design intent of the participating builders.

This paper focuses on a number of issues that are at the heart of the evaluation. The paper will discuss how independent inspections of building characteristics at 110 ENERGY STAR® New Homes were used to verify how well C-HERS protocols perform as a checks and balances system for the Program. The paper discusses differences found between the proposed and as-built projects and how the inspection results are used to re-simulate building performance for calculating energy savings. The paper also provides some comparisons between participant construction practice and standard practice.

The paper also explores challenges related to the impact evaluation and why different measurement approaches were used to understand the energy effects of the Program, including the installation of metering equipment, which continuously recorded hourly hot water, heating and cooling energy use for one year in 100 ENERGY STAR® Homes.

Background on the California ENERGY STAR® New Homes Program

Title 24 for low-rise residential buildings only considers the energy use of end-uses that builders can affect during construction: hot water heating, space cooling and space heating. To meet California's ENERGY STAR® New Homes Program guidelines, these end-uses must combine to perform at least 15% better than a minimally compliant home. Like many other ENERGY STAR® new homes programs, the California Program provides rebates, marketing assistance and training to builders.

California Home Energy Rating System (C-HERS) protocols are followed to ensure that the construction characteristics match the design intent of the participating builders. Inspection protocols require C-HERS testing for one in seven production homes, while all construction

[1] Not including hardwired lighting and some appliances.

plans are required to pass a plan check verification step. The results of the C-HERS inspections are input and stored within a data registry designed specifically for tracking data related to the location and design of the home.

Although more than one entity has been certified by the California Energy Commission to provide C-HERS services,[2] our evaluation only included data provided by the California Home Energy Efficiency Rating System organization (CHEERS) and their network of trained C-HERS providers since all of the HERS inspections for the 2002-03 Program were performed using CHEERS. Although CHEERS does not have a direct participatory role in program implementation, they are certainly a key player in the program logic and theory. In short, they are responsible for training and certifying C-HERS inspectors, tracking C-HERS measure data and performing quality assurance throughout these processes.

Background on the California ENERGY STAR® New Homes Program Evaluation

RLW Analytics was selected to evaluate the 2002, 2003 and 2004-05 California ENERGY STAR® New Homes Program. Although the work is being performed under two contracts, the evaluations will be completed in three unique phases:

- Phase I: Preliminary ex post impact evaluation of the 2002 Program. This phase included a preliminary gross savings evaluation and a truncated process evaluation. This phase was completed in June 2004.
- Phase II: Final ex post impact evaluation of the 2002 and 2003 Programs. This phase produced the final savings estimates for the two program years. This phase was completed in May 2006.
- Phase III: Final ex post impact and process evaluation of the 2004-05 Program. This phase is currently in process and is expected to be completed in November 2006.

RLW presented the results from Phase I at the 2004 ACEEE Summer Study. While the 2004 paper focused on results from the Phase I study, this paper summarizes some of the results and conclusions from the Phase II research. Therefore, a more expanded explanation of the research components comprising the Phase II study follows.

- 110 single family and 25 multifamily post-occupancy inspections of ENERGY STAR® homes: a comparison of the as-planned to the as-built features,
- Installation of end-use metering equipment in 100 single family homes and 24 multifamily complexes,
- Re-simulation of inspected homes using the as-built inspection data to inform the as-planned Title 24 models,
- Expansion of re-simulated results to program population,
- Difference of Differences analysis for estimation of program impacts,
- Building characteristics analysis comparing ENERGY STAR® homes to non-participant group,

[2] CalCERTS, CBPCA, Home Enalasys' and CHEERS (http://www.energy.ca.gov/HERS/notices/2006-04-28_provider_approval.html)

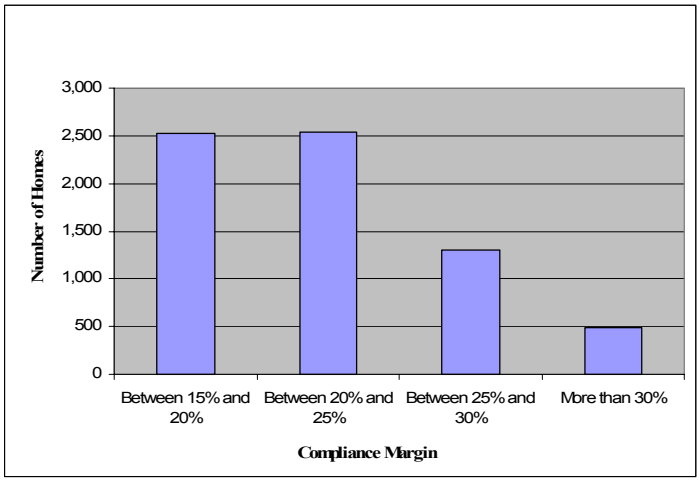
- Limited single family billing analysis, and
- Surveys with multifamily builders.

Measuring Program Compliance

To become ENERGY STAR® accredited in California, homes must exceed California's Title 24 energy code by at least 15%. Otherwise stated, these homes must have an energy budget that is 15% less than the energy budget of a home built minimally compliant with 2001 Title 24's prescriptive Package D. However, builders rarely practice prescriptive based compliance methods, as they prefer performance based compliance which allows for optimization of energy performance through careful consideration of construction and material costs affecting energy efficiency. Using performance-based methods, program participants can achieve savings by trading-off between heating, cooling and water heating budgets. As a result, the energy efficiency improvement may be all gas, all electric, or most commonly some combination of both.

Program participants are finding it relatively easy to comply with the Program's 15% efficiency threshold, evidenced by the compliance rates seen amongst program participants. While the statewide average compliance margin is 22.6% (RLW 2006), Figure 1 shows the distribution of homes within compliance margin percentage bins. Given these results, one might conclude that the Program is producing more energy savings than planned since many participants have exceeded the Program baseline of 15%.

Figure 1. ENERGY STAR® Compliance Margins for Single Family Homes



Source: CHEERS Registry Data

Even though C-HERS inspections were a required part of the Program process (even if the project did not include any C-HERS measures), RLW completed 110 inspections to verify the accuracy of the data contained in the CHEERS Registry. This was a necessary step in the Program evaluation design, constituting the Verification in EM&V. One-hundred and ten single family and 25 multifamily sites were sampled from the population of completed projects for inspection.

The goal of the inspections was to physically verify as many Title 24 modeled building characteristics affecting energy consumption as possible. For some measures, RLW was unable

to perform complete inspections. These measures that RLW was unable to inspect (or test) included performance testing (blower door and duct leakage testing), wall insulation levels and window properties (SHGC and U-value). In these cases, the evaluation assumed that the measure complied with Program documentation. RLW inspectors were able to physically verify all other building characteristics.

The inspections revealed rather significant differences between the builder as-planned and as-built characteristics. Ninety percent of the inspected single family homes were found to have one or more characteristics different from their Title 24 plans, which RLW would later re-model using Title 24 compliance software. On average, the as-built characteristics led to *more* energy efficient single family homes than planned.

The main characteristics that affected the modeled energy consumption were: total window area, equipment efficiencies, radiant barrier, TXV valves, overhangs, and hot water re-circulating timers.

The following graphs and tables show the results for some key characteristics. Results are shown by home, although individual home identifiers have been suppressed. Figure 2, Figure 3, and Figure 4 are typical of the results found through the on-site inspections for hot water heater efficiency, cooling SEER and window area, respectively. Each shows that the majority of planned vs. as-built (or inspected) results are the same. While a handful of homes have higher efficiency, and a few have lower efficiency, the net result is a slightly higher average efficiency.

Figure 2. Planned vs. Inspected Hot Water Heater Energy Factor

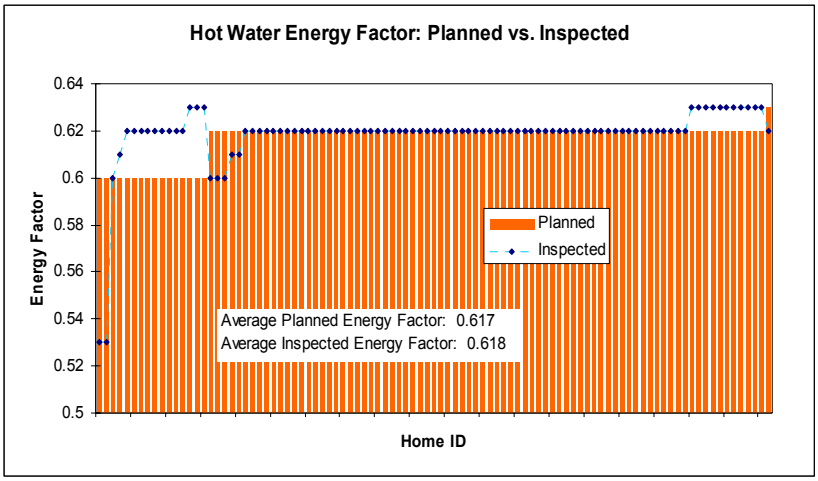


Figure 3. Planned vs. Inspected SEER

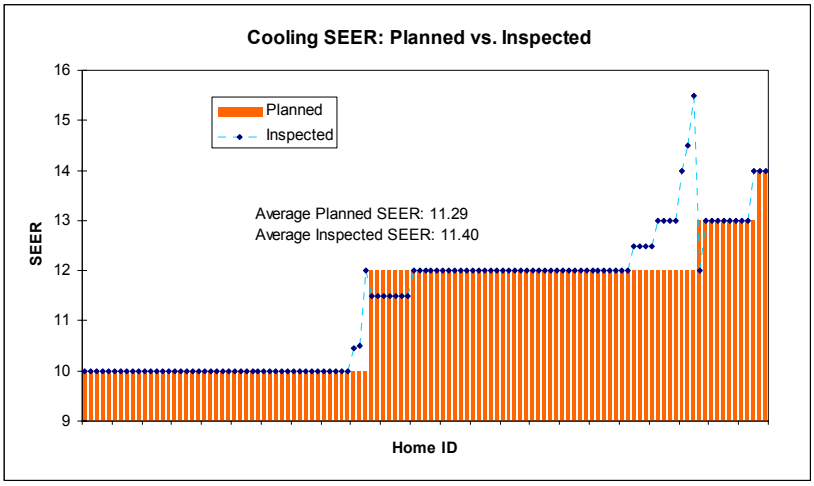


Figure 4. Planned vs. Inspected Total Window Area

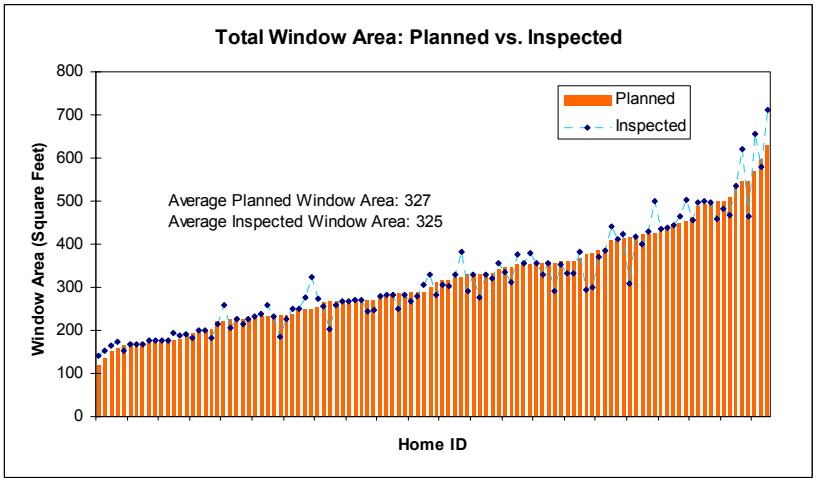


Table 1 shows the inspection data in a slightly different format. The table shows some of the differences between the as-planned and as-built characteristics discovered during the on-site inspections. For example, there were 221 instances where a window overhang was found to be present, but was not in the as-planned model. Conversely, there were 139 cases where there was no overhang, yet an overhang was in the as-planned model. In all cases the inspection showed that the net effect was more efficient.

Table 1. Planned vs. Inspected Measures

Measure	Planned	Inspected	Frequency	Net Energy Effect
Window Overhang	No	Yes	221	More Efficient
	Yes	No	139	
TXV Valve	No	Yes	25	More Efficient
	Yes	No	6	
Radiant Barrier	No	Yes	13	More Efficient
	Yes	No	0	
HW Recirc. Timer	No	Yes	7	More Efficient
	Yes	No	0	

When differences between the as-planned and the as-built characteristics were found, the next step was to analyze how they might affect the energy savings of the Program. This was accomplished with ratio estimation techniques, to produce what are known as b-ratio estimators. Additional goals of the on-site inspections were to see if the Program's process was functioning as intended, and as an opportunity to install metering equipment for the 2004/05 metering study.

Our first step approach to estimating the energy impacts resulting from the RLW inspections was to remodel the home using Title 24 files. RLW obtained the original Title 24 compliance model submitted by the builder for this purpose. As a result of our on-site field observations, it was decided to not make any re-modeling adjustments if the on-site physical characteristics were found to be within +/- 10% of the original plan. This was to permit a reasonable margin for measurement error of characteristics that often could not be measured precisely within the project budget (for example, roof area). For equipment efficiencies, re-modeling was conducted if *any* differences were found, since the data were assumed to be 100% accurate, and equipment efficiencies can have a big impact on energy consumption.

Why Did 90% of Inspected Single Family Homes Require Remodeling?

The answer to this is not entirely clear, but possible reasons include:

- Variation (or errors) in Title 24 modeling of plans
- Official plan changes not entered into CHEERS
- Un-official plan changes
- Multiple plan options not accurately captured
- Changes in equipment specifications and/or suppliers

Expanding the On-Site Inspection Results to the Population of ENERGY STAR® Homes

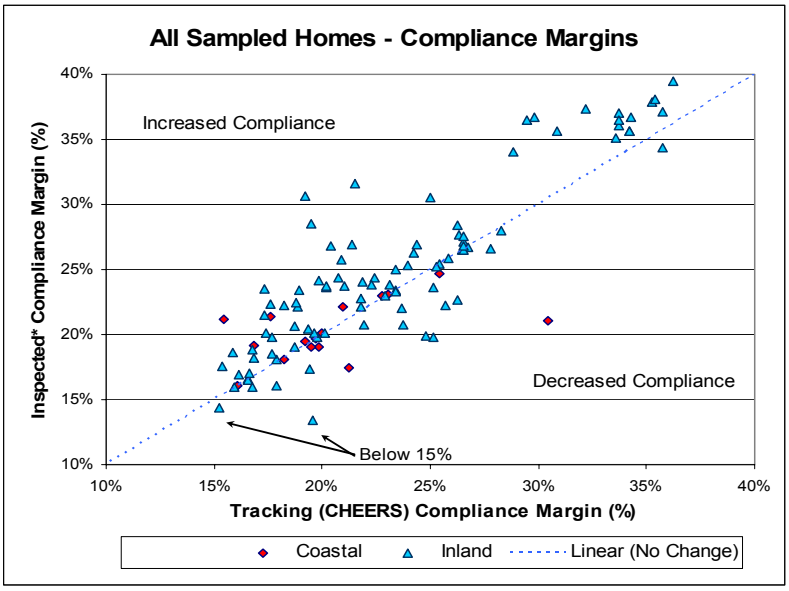
The single family on-site inspections revealed that the average energy Compliance Margins were at least as good as the plans.[3] Figure 5 shows the compliance margin results for all 110 homes inspected by RLW. Most compliance margins increased, some decreased, and two homes fell below the minimum Program requirements (below 15%). The margins for both

[3] Both planned (CHEERS tracking) and inspected energy savings are themselves modeled estimates of energy savings based on building characteristics. "Inspected energy savings" does not represent a measurement of actual energy savings, but rather an inspection of the building characteristics that are the input values to Title 24 energy modeling software, such as EnergyPro or Micropas. Potential bias in the modeling software would impact both planned and "inspected" energy savings.

inland and coastal homes show similar variation, even though there are far fewer coastal sites than there are inland sits.

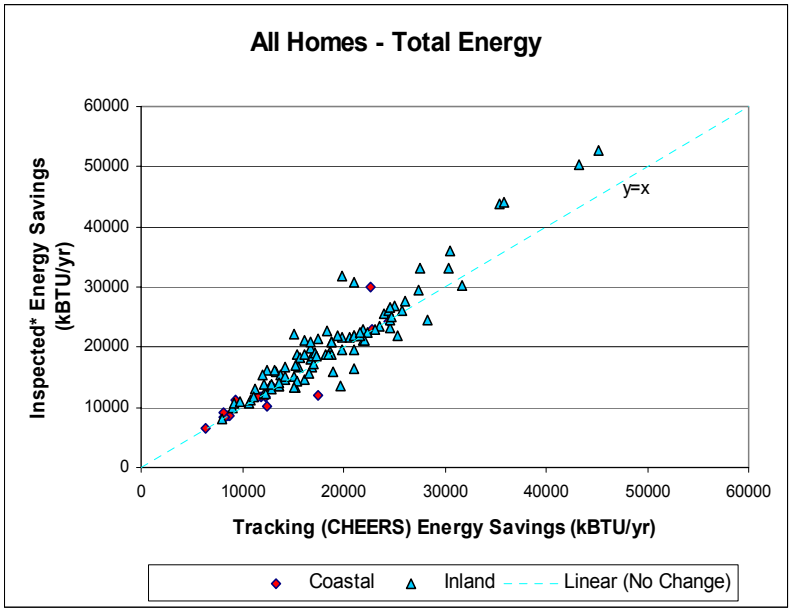
As can be seen from these figures, compliance margins range from 15% to 40%, suggesting that there are is significant room for efficiency improvements beyond the current energy code. Furthermore, the results also imply that it is not overly difficult to comply with the program's 15% threshold. The results also showed that total energy savings depends greatly on the total energy budget, which is highly dependent upon the climate zone in which the home is located. For example, a coastal home with a 40% compliance margin may save less energy than an inland home with a 15% compliance margin, simply because Title 24 modeled energy use is so much greater for inland homes than it is for coastal homes.

Figure 5. Title 24 Energy Compliance Margins (110 Inspected ENERGY STAR® Homes)



In contrast to Figure 5, Figure 6 shows that the modeled energy savings remains closely tied to the planned estimates. This is not surprising however, since the two measurements are based on the same method of measurement, Title 24 compliance software.

Figure 6. All Inspected Homes – Tracking vs. Inspected Total Energy



How ENERGY STAR® Homes Compare to Non Participant Homes

In 2004 Itron completed the California Statewide Residential New Construction Baseline study (Itron 2004). A total of 575 non-participant homes were surveyed for detailed housing characteristics and Title 24 models were built. Using the building characteristics data provided by Itron, RLW compared many of the key energy characteristics in order to better understand how differently these non-participant homes are constructed relative to the participant homes, and how these differences might support future conclusions regarding program-induced energy savings. In the report, Itron found that non-participant homes built to the 2001 Title 24 standards were 3.9% compliant on average (Itron 2004). (Recall ENERGY STAR® participants were found to be 22.6% compliant on average, page 3).

Using the CHEERS Registry and the data from the inspections, it was pretty simple to determine what participant builders were doing to comply with the Program. Still, all of our energy savings methods were calculated based on the output from Title 24 code compliance software, which was not designed for the purpose of estimating energy savings. In order to provide some perspective on home features that were being used to exceed Title 24 we compared the ENERGY STAR® home characteristics to non-participant home characteristics.

Surprisingly, the building characteristics comparison demonstrated only *minor* differences between participants and non-participants. The average size of homes was found to be very close: ENERGY STAR® Homes were found to be 2,427 square feet and non-participants were found to be 2,558 square feet on average. Table 2 shows many more comparison results. The most profound differences are found in two categories: presence of thermal expansion valves (TXV) and fenestration efficiency. Interestingly, even though a larger number of participant homes have TXVs, the *average* efficiency (SEER) is the same between the two groups. Window efficiency, a measure that usually improves both heating and cooling efficiency, and thus gas and electric energy usage, seems to be the primary difference when considering these data. It is important to note that the list omits “tight ducts”. This is an

important point, because while many participant builders took advantage of this measure, non-participants did not.

Table 2. Building Characteristics Comparison of ENERGY STAR® Participants to Non Participants

	ENERGY STAR (n=6850)	Non-participant (n=575)
Square Footage	2,427	2,579
DHW Energy Factor (40/50 Gal Tanks)	0.61	0.59
Heating AFUE	0.82	0.81
Cooling system with TXV	47%	18%
Cooling SEER	11	11
% of area with Radiant Barrier	5%	5%
Window to floor area	17%	16%
Window U-value	0.39	0.42
Window SHGC	0.35	0.45
Wall R-value	13	14
Attic R-value	31	31

Source: RLW 2006 and Itron 2004

Measuring Energy Savings

The results of the inspection and comparison analyses raised some questions about the most appropriate method to use to measure energy savings. As we saw, improved compliance rates are not necessarily equal to increases in energy savings. When comparing participants to non-participants, average compliance rates vary significantly, yet when we compare average building characteristics there are only minimal differences. To understand why, RLW conducted some added analysis, and is in the process of improving previous methods for measuring Program energy savings.

For the single family Program, RLW performed two different analyses for determining the Program's energy saving impacts. Although this paper does not delve into these approaches, some of the high level results are worthy of discussing for the context of this paper.

The approach used to present the study impact results (RLW 2006) is the Difference of Differences (D of D) method. In this method participant efficiency is compared to non-participant efficiency. By doing so, naturally occurring savings (i.e., free ridership) are accounted for as part of the baseline because standard practice replaces the Title 24 baseline. The baseline study (Itron 04) found that homes built in the inland regions of CA were on average non-compliant, while CA coastal homes were on average more than compliant. The Difference of Differences energy savings analysis method, which is based on the output of Title 24 compliance software, produces large energy savings values for inland homes and little savings for coastal homes due to the net differences between the participant and non-participant compliance margins. Since the majority of ENERGY STAR® Homes were located in the inland regions of the state where energy budgets tend to be greater, and coupled with the fact that Itron reported a non-compliant inland baseline, we found significant program induced energy savings using the D of D method.

Contrast these findings with a simple billing analysis RLW completed using data from the baseline homes and thousands of participant homes. The primary objective of this part of the study was to supplement the D of D calculation of Program savings with a case study of the realized savings in climate zones where there was enough available data to conduct a billing

analysis. Without demographic information such as occupancy and income, billing analysis is limited as a tool for computing Program savings. However, even without this information, it can be a useful indicator of whether those demographic variables are impacting Program savings.

We found energy savings in a handful of analyzed climate zones, but predominantly found inconclusive or negative savings. We performed a second billing analysis that controlled for the number of stories and found that the amount of energy savings varied greatly between single-story and multi-story structures. Ultimately, however, the data available for the billing analysis of the 2002-03 CA ENERGY STAR® New Homes was insufficient to allow accurate estimation of energy savings across all climate zones. However, the analysis as conducted did bring to light a number of issues that will be investigated more fully in future evaluations.

Conclusions and Next Steps

There are many levels of measurement going into the ENERGY STAR® New Homes Program EM&V, all with the common goal of measuring the success of the Program to produce lasting energy savings. The challenge has been the inconsistency between the results, thereby creating uncertainty with regard to impact results. As evaluators, part of the difficulty is defining what the evaluation is measuring. The obvious response is energy savings; however it is more complex than that.

Take for example the compliance analysis; sure ENERGY STAR® homes are far more compliant, or efficient, than non-participants. Yet when we compare actual utility billing data, why don't we see more significant energy savings? Does it mean the demographic makeup of ENERGY STAR® buyers is dramatically different from non-participants? Or perhaps ENERGY STAR® buyers operate their home differently, simply because they own ENERGY STAR®. If not, perhaps the savings is merely noise, swamped by all the other energy consuming loads found in the home – resulting in further evidence that the association between improvements in Title 24 compliance and energy savings is weak.

Which raises the question, what does a 15% compliance margin equal in terms of energy savings, 5%, 15%, or 30%, we just don't know; however the question is an important one. If the Program's goal is simply to produce more efficient housing than standard practice, then by many accounts the Program has met the goal. However, if energy savings is also the goal, which it seems to be, then measurement becomes much more subjective and convoluted.

To help improve the D of D methodology and test the accuracy of Title 24 compliance software, RLW is currently metering 100 ENERGY STAR® homes. Meters have been installed to record 8,760 hours of data for hot water heating, cooling and heating. These results will be used to evaluate the relative accuracy of the Title 24 compliance software as an energy savings estimation tool and its ability to simulate energy consumption reasonably well. Using the metered data RLW will improve the existing D of D methodology for determining energy impacts, and will also carry over to other studies and programs that have relied on Title 24 compliance software to project energy savings (Itron 2006).

RLW will also further explore and mine the billing data in climate zones where enough data were available for analysis. Specifically, more analysis will be done so that demographic differences are captured in the analysis. The results will not only improve the findings associated with the billing analysis, they should also help explain demographic differences, if any, between participant and non-participant home buyers and home locations.

References

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