EVALUATION, MEASUREMENT AND VERIFICATION OF THE 2002 & 2003 CALIFORNIA STATEWIDE ENERGY STAR® NEW HOMES PROGRAM

PHASE II REPORT

June 14, 2006

FINAL REPORT

Study ID: PGE0208

(Revised August 14, 2006)

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This study was conducted at the request of the California Public Utilities Commission. The study was managed by PG&E. It was funded through the public goods charge (PGC) for energy efficiency and is available for download at www.calmac.org.

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Acknowledgements

Authorship Acknowledgement

RLW would like to thank and give credit to Itron. Itron is wholly responsible for the Title 24 Consultant section of this report. Itron also completed a significant portion of the single family builder surveys. RLW appreciates the opportunity to have worked with Itron on this part of the study and we recognize the important contribution they have made to help make the report comprehensive and of great value to the various project stakeholders.

Acknowledgements

Several organizations and people deserve acknowledgement for their assistance and contributions to the Phase II ENERGY STAR® New Homes Evaluation, Measurement and Verification Report. First, we would like to thank Dionne Adams of Pacific Gas and Electric for her leadership and contributions that made the final phase of the project a success. We also recognize the Program Managers and Evaluators of each utility, including Cece Barros of PG&E, Lisa Brewer, and Shahana Samiullah of SCE, and David Blanke and Henry DeJesus of SoCalGas and SDG&E, for their ongoing assistance, communication, and cooperation with the evaluation staff. RLW also thanks Dawn Carton of CHEERS for her timely feedback and assistance with respect to the CHEERS data.

RLW would also like to acknowledge and thank the many builders, developers and homeowners that took the time to participate in telephone and on-site surveys. The information gleaned from these activities form the backbone of this report, which could not have been completed without their participation.

Skumatz Economic Research and Associates (SERA) deserves recognition for their hard work and contributions to the research efforts. SERA was responsible for the multifamily net to gross and non-energy benefits sections of this report.

Lastly, we would like to acknowledge and commend the utilities for being named ENERGY STAR® 'Partner of the Year' by the U.S. Environmental Protection Agency and Department of Energy. Sharing the award are Southern California Edison Company, Pacific Gas & Electric Company, San Diego Gas & Electric and Southern California Gas Company.

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1. Executive Summary

Introduction

This document is the Phase II evaluation, measurement and verification (EM&V) report for the 2002 and 2003 California ENERGY STAR® New Homes Programs (ESH program). The Phase I evaluation provided preliminary analysis and estimates of ex post energy savings, while this Phase II evaluation provides final estimates. California's Investor Owned Utilities (PG&E, SCE, SDG&E, and SCG) implemented the ESH program in each of their respective service territories. This evaluation of the 2002 and 2003 ESH program is a study mandated by the California Public Utility Commission (CPUC) and managed by Pacific Gas and Electric. It was funded through the public goods charge (PGC) for energy efficiency and is available for download at www.calmac.org. RLW Analytics (RLW) of Sonoma, California was the primary evaluation, measurement and verification contractor on this project. Skumatz Economic Research and Associates (SERA) was responsible for determination of the multifamily net-to-gross and non-energy benefits (NEBS) included in this report.

ENERGY STAR® New Homes Program Overview

The California ENERGY STAR® New Homes Program provides financial incentives, education, and marketing (the program elements) to California builders who construct new residences that exceed the state's mandatory minimum energy efficiency standards. The program primarily targets single family production builders and multifamily developers, although high rise buildings can also participate in the program. California's energy efficiency standards for residential and non-residential new buildings are set by the California Energy Commission (CEC) in the Title 24 energy code.[1] Since residential energy consumption is significantly affected by weather, Title 24 recognizes sixteen distinct climate zones within California as shown in Figure 1. For the purposes of this report, coastal climate zones are defined to be CEC climate zones 1-7, and inland climate zones are 8-16.

[1] http://www.energy.ca.gov/title24/

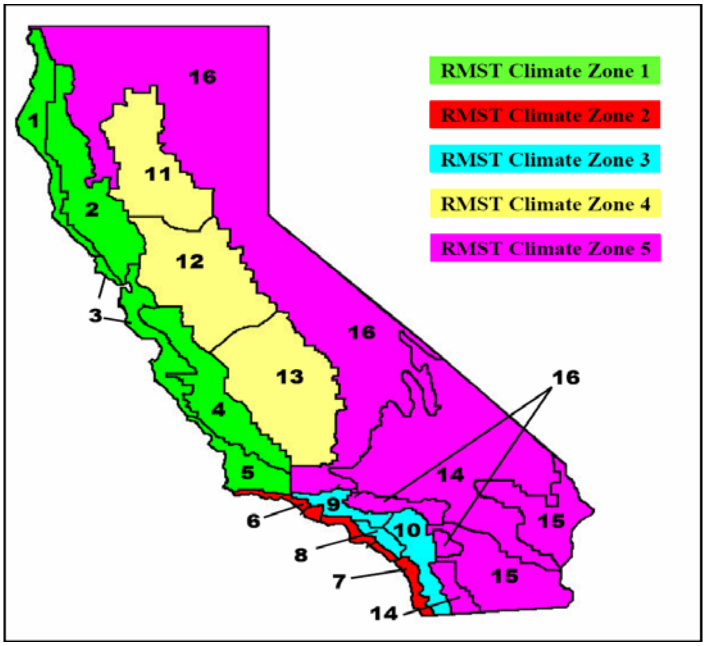

Figure 1: California Energy Commission 16 Climate Zones

Participating builders that exceed California's Title 24 residential standards by 15% or more receive cash incentives, in addition to training and marketing support. Table 1 summarizes the dollar amount a builder received for each unit that met ESH program standards.[2]

Type	15-19.99% Compliance	20% + Compliance
Single Family (CZ 1-7)	$ 400	$ 700
Single Family (CZ 8-16)	$ 500	$ 900
Multifamily	$ 150	$ 250

Table 1: 2002 Incentive Rates Per Unit

Like any new construction program, the ESH program has a long life cycle, owing to the long lead time associated with building large developments of new homes. Program participants have 24 months from the time they are accepted into the Program to complete construction. In some cases, program managers provide three month extensions to participants requesting additional construction time. For example, under the 2002 ESH program, builders were able to participate up until December 31, 2002, after which they had roughly 24 months to finish the projects. Thus, the final projects were allowed to be completed by December 31, 2004, or possibly later if time extensions were granted to any of the participant builders.

[2] For the 2003 Program, the incentive rates changed; single family units (CZ 8-16) with 20% or more compliance margin received $700 per unit (instead of $900/unit in 2002) and all other units that exceed 20% compliance receive no additional incentive than the amount from the 15% compliance rate.

The longevity of the Program is important for understanding what is included in the evaluation. As noted above, this evaluation only considers projects that were completed and approved[3] in 2002 and 2003. The 2004-05 EM&V study will evaluate homes completed in 2004 and 2005, which will be a hybrid of 2002, 2003, and 2004-05 program-year homes. Figure 2, taken from the CHEERS Registry, illustrates these points by showing the approval status of projects by Program year.

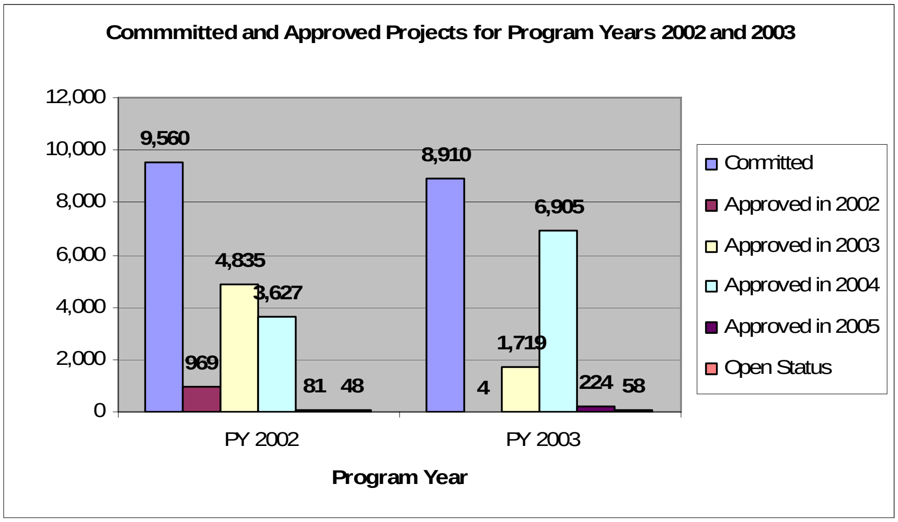

Figure 2: Number of Participant Projects (SF and MF) Approved and Committed by Program Year

Program Implementation Differences

Each utility had somewhat different implementation methods for the program which are described in this report. However, major program elements such as program qualification levels and incentive levels were uniform statewide.

Evaluation Background

This study is the first impact evaluation ever conducted for the Statewide ESH program. The goals of the Phase II report are to provide gross and net impact savings estimates for the single family and multifamily components of the 2002 and 2003 ESH programs. The study sought to measure Program impacts using various methods. Evaluation of energy "savings" is only meaningful in the context of comparison to a reference or baseline. For this Program, the ideal metric of energy savings would be obtained by comparing each Energy Star Home (participant) to its equivalent non-Energy Star home (non-participant). Since equivalent non-Energy Star homes were not constructed, other methods were needed to estimate energy savings.

[3] A structure becomes "approved" when its construction is complete and it has completed and passed all necessary C-Hers measure inspections.

Discussion of gross and net impacts is conducted in the context of estimated parameters, defined below.

Energy savings Annual energy savings due to exceeding Title 24 building code minimum requirements.

Simple Gross savings Participant energy savings from a summation of tracking database (CHEERS) savings.

Adjusted gross savings Also called **Gross ex post savings**. Simple gross savings adjusted by on-site inspection findings (takes into account differences between planned building characteristics and inspected characteristics).

Net Ex Post savings Participant energy savings due to the program (excludes free ridership).

Net savings Same as Net Ex Post savings in this report.

Free ridership Also called **Naturally Occurring savings.** Participant energy savings that would have occurred absent the program. In this study naturally occurring savings are equivalent to non-participant energy efficiency beyond Title 24 package D requirements.[4] Note that a single program participating home can have partial free ridership.

Net-to-Gross Ratio $NTG = \frac{NetExPost}{GrossExPost}$

Spillover Non-participant energy savings due to the program.

Ex Ante (Net) savings Energy savings estimates (calculated by RLW) based on each IOU's per-unit savings estimates. Ex ante savings = (number of actual units approved) x (IOU per-unit savings estimate filed in PIP) x (0.8 NTG factor).

Two distinct approaches were attempted to evaluate the gross and net impacts resulting from the single family Program: an engineering-based "difference-of-differences" approach and a billing data analysis. A less rigorous evaluation method, termed the "simple gross", was used for measuring gross savings resulting form the multifamily Program component. Survey data were collected from builders of multifamily projects for determining construction practices absent the Program and overall net Program effects. These methods are thoroughly described in this report.

There were several key data sources used by RLW to conduct this evaluation. The first data source is the California Home Energy Efficiency Rating System (CHEERS) Registry. RLW worked closely with CHEERS throughout the study to obtain extracts from the CHEERS Registry. Registry data includes detailed building characteristics information for participant structures. For a large number of the participant structures in the CHEERS Registry, RLW also obtained the original Micropas or EnergyPro Title 24 files. These files were provided by the implementers.

[4] http://www.energy.ca.gov/title24/

Another key data source used for this study is the 2004 Residential New Construction Baseline Study[5] (the baseline study). It is important to note that this study grouped CEC climate zones into five Regional Market Share Tracking (RMST) climate zones. The study's prime contractor provided RLW with raw data collected by building surveyors, as well as structure-specific Title 24 output generated in the process of conducting the baseline study.

For the billing analysis, billing usage data was acquired from each of the investor owned utilities (IOUs). Several thousand participant single family homes' billing data was collected covering an eighteen month period, when available. Billing usage data was also collected for the non-participant (baseline) homes.

Lastly, RLW obtained Program implementation planning (PIP) estimates of gas and electric savings from each investor owned utility, at the unit level. RLW required this information in order to determine the *ex* ante Program savings. Some background is provided as it is useful for understanding why RLW was required to calculate the ex ante savings.

For Program years 2002 and 2003 utilities filed their Annual Earning Assessment Proceeding (AEAP) report, which summarize Program accomplishments and energy savings. The values included in the AEAP report often become the *ex* ante value used for Program impact evaluation. However, RLW was not able to use the AEAP energy saving values because, for this particular Program, the AEAP energy savings values are only estimates and are inclusive of energy savings resulting from both completed structures and *committed structures* (project planned for completion at some future date). The evaluation, on the other hand, considers realization of energy savings only for structures considered complete.[6] Therefore it was necessary for RLW to calculate the *ex ante* energy savings using *only completed structures* and the per unit savings found in each utility's Program Implementation Plan.

Key Evaluation Findings

Program Participation: Single Family, Multifamily, and High Rise Units

Figure 3 shows the number of approved units by type and utility. The total number of dwelling units approved in 2002 and 2003 was 14,301. Of these, there were a total of 6,850 single family Energy Star Homes approved, representing roughly 2% to 3% of California new single family construction. Future program year participation rates may be higher once the build out delay is accounted for and program awareness is increased.

[5] 2004 California Residential New Construction Baseline Study (Itron, 2004).

[6] For the purpose of the evaluation, "completed" was defined by the final C-HERS inspection date, designated in CHEERS by a date and "approved".

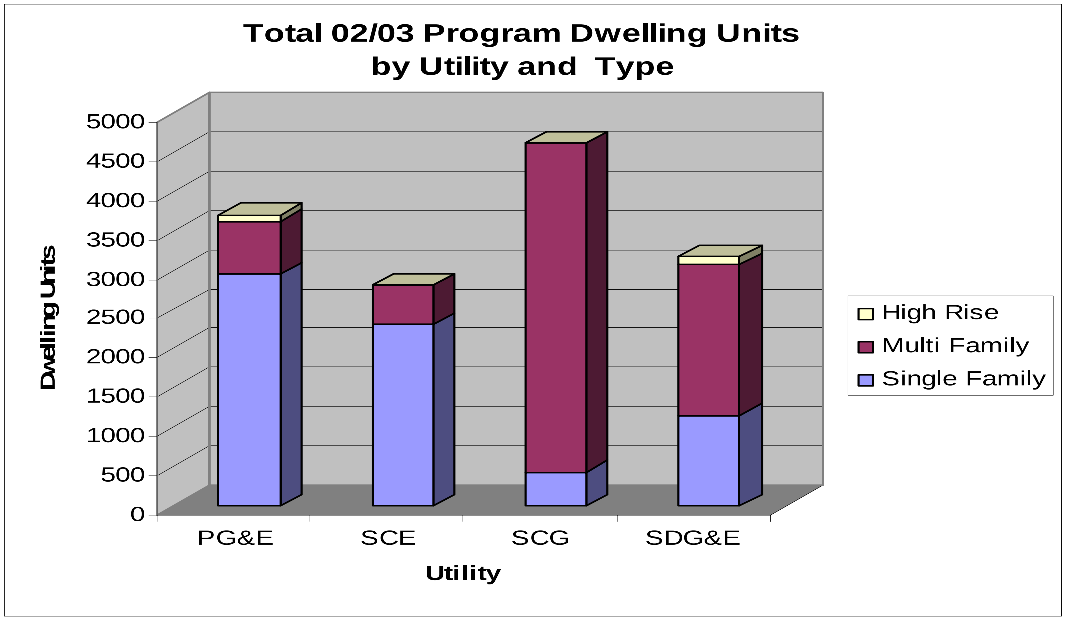

Figure 3: Number of Approved Units by Type and Utility

	2002 Dwelling Units			2003 Dwelling Units			
	Single Family	Multi-Family	High Rise	Single Family	Multi-Family	High Rise	Total
PG&E	675	16	70	2,280	659	0	3,700
SCE	91	0	0	2,220	501	0	2,812
SCG	27	376	0	405	3810	0	4,618
SDG&E	250	348	0	902	1571	100	3,171
Total	1,043	740	70	5,807	6,541	100	14,301

Table 2: Summary of Dwelling Units Completed[7]

[7] A single family home is one dwelling unit.

Ex ante and ex post energy savings were estimated based on *actual dwelling units completed* in calendar years 2002 and 2003, as shown in Table 2. Due to the time to build out projects, many more units were completed in 2003 than in 2002.

Net Ex Post Program Energy Savings

Total program net ex post electricity savings were 5,803,747kWh and gas savings were 665,375 therms. These savings include all program participants: single family, multifamily, and high-rise projects.

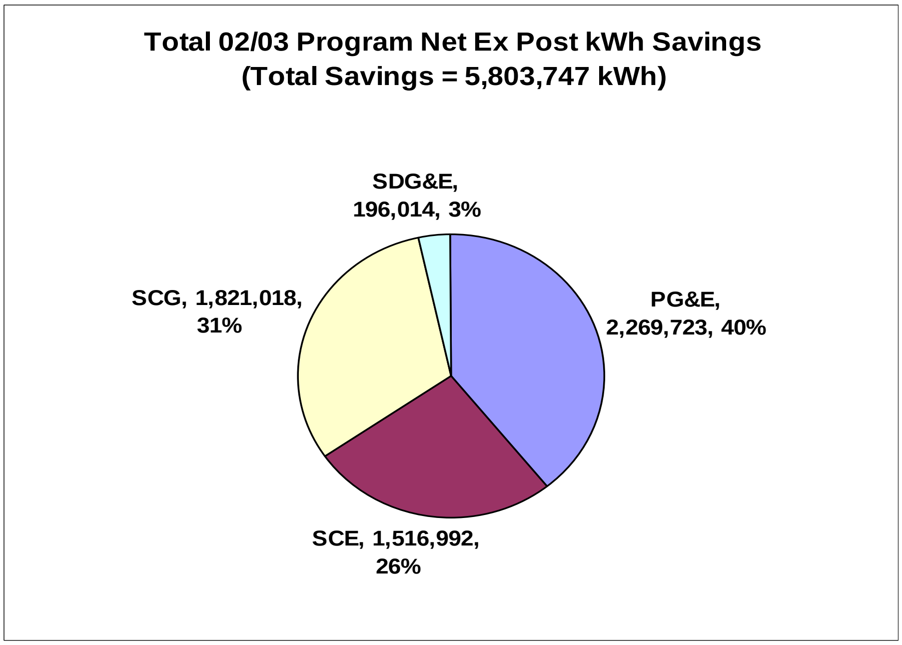

Figure 4: Electricity (kWh) Ex Post Savings by Utility

kWh	2002 Ex Post	2003 Ex Post	*2002 & 2003* Total
PG&E	376,629	1,893,094	2,269,723
SCE	78,456	1,438,536	1,516,992
SCG	188,389	1,632,629	1,821,018
SDG&E	20,683	175,331	196,014
Total	664,157	5,139,590	5,803,747

Table 3: Electricity (kWh) Ex Post Savings by year

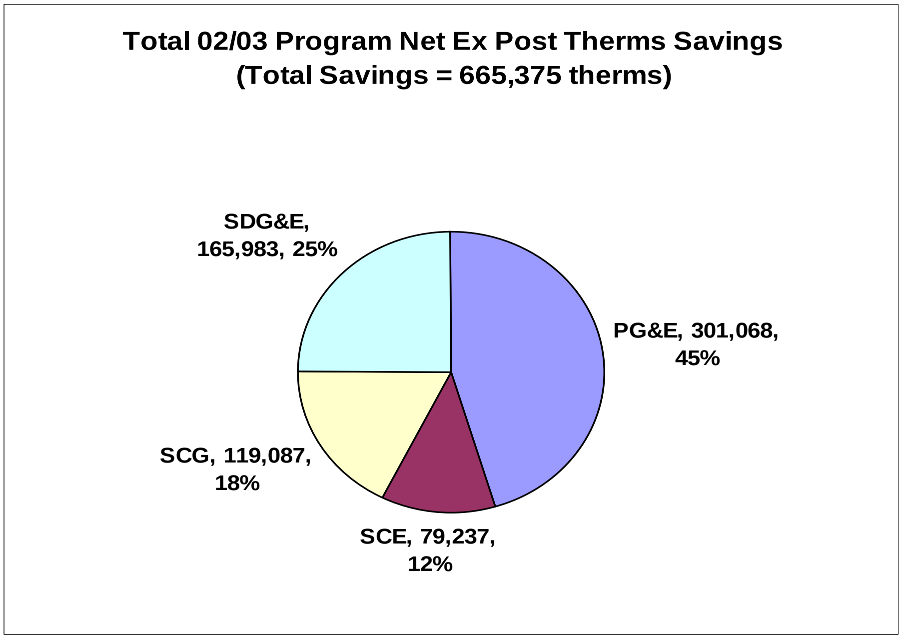

Figure 5: Gas (therms) Ex Post Savings by Utility

Therms	2002	2003	*2002 & 2003*
	Ex Post	*Ex Post*	*Total*
PG&E	51,868	249,200	301,068
SCE	6,728	72,510	79,237
SCG	8,455	110,633	119,087
SDG&E	68,190	97,792	165,983
Total	135,240	530,135	665,375

Table 4: Gas (therms) Ex Post Savings by Year

Net Realization Rates

Ex ante estimates were not available from all utilities for all housing types and fuel types, and therefore realization rates could only be calculated when ex ante estimates were available. Furthermore, as explained in the introduction, ex ante values were calculated due to an accounting change to "completed units"[8] based on each utility's original per-dwelling-unit savings estimates. Ex ante calculations are detailed in Chapters 7 and 14. Ex post savings (net Program savings) estimation methods are described in chapters throughout this report.

Utility electricity savings realization rates, including single family, multifamily, and high-rise[9] projects are:

[8] At the time utilities filed Program information with the CPUC, estimates were based on homes "signed up" within a Program year – not constructed (completed). Since that time, it was determined to conduct this evaluation based on homes actually constructed within a Program year. Due to this accounting change, it was necessary to calculate ex ante estimates based on that change.

[9] High Rise ex ante values were estimated by applying low-rise multifamily per unit savings estimates.

	2002 kWh			2003 kWh		
	Ex Ante	***Ex Post***	***Realization Rate***	***Ex Ante***	***Ex Post***	***Realization Rate***
PG&E	114,341	376,629	329%	547,064	1,893,094	346%
SCE	63,118	78,456	124%	2,474,784	1,438,536	58%
SCG	63,168	115,136	182%	1,067,424	1,632,629	153%
SDG&E	230,380	20,683	9%	895,207	175,331	20%
Total	471,006	590,905	125%	4,984,479	5,139,590	103%

Table 5: Combined (single family, multifamily, and high-rise) Electricity Savings Realization Rates

Utility gas savings realization rates are:

	2002 Therms			2003 Therms		
	Ex Ante	***Ex Post***	***Realization Rate***	***Ex Ante***	***Ex Post***	***Realization Rate***
PG&E	60,943	51,868	85%	319,187	249,200	78%
SCE	None	NA	NA	None	NA	NA
SCG	8,723	7,994	92%	118,776	110,633	93%
SDG&E	13,932	68,190	489%	50,682	97,792	193%
Total	83,598	128,052	153%	488,646	457,625	94%

Table 6: Combined Gas Savings Realization Rates

Note that total ex post savings in Table 3 and Table 4 do not always match totals in Table 5 and Table 6 since the latter do not include ex post savings when ex ante estimates were not available.

Single Family Net-to-Gross Ratios (NTG)

Single family NTG was determined by calculation,

$$NTG_{SF} = \frac{NetExPost}{GrossExPost}$$, where

GrossExPost = Inspection-adjusted gross tracking savings[10]

NetExPost = Net savings (difference-of-differences methodology)

The single family NTG results are shown in Table 7 and Table 8. Electricity NTG ratios vary widely across IOUs and Program years, from -0.20 to 2.25. The statewide electric NTG ratio is 1.51 for 2002, and 1.21 for 2003, implying negative free-ridership both years. This is consistent with the new construction baseline study used for the analysis, and is a direct result of negative naturally occurring cooling savings among non-participants.[11] That is, on average, non-participant homes do not meet Title 24 package D cooling energy

[10] As a result of single family on-site verification inspections, small adjustments were made to the gross tracking energy savings to reflect true as-built findings. Detailed results of these inspections are provided in this report.

[11] As determined by the 2004 California Residential New Construction Baseline Study (Itron, 2004). Non-participant homes exceeded cooling budgets primarily in inland climate zones. Some homes made up the deficit with energy savings in other areas (heating or hot water), but the study found that 27% of homes surveyed were not Title 24 compliant. The compliance of another 30% could not be determined within the error bounds of the data collected.

budgets. In fact, the non-participant baseline study found that 27% of homes surveyed did not meet Title 24 energy requirements period.

	Gross Ex Post 2002	Net Ex Post 2002	NTG RATIO 2002	Gross Ex Post 2003	Net Ex Post 2003	NTG RATIO 2003
PGE	168,922	380,763	2.25	1,031,724	1,818,960	1.76
SCE	92,391	78,456	0.85	1,669,846	1,431,206	0.86
SCG	55,687	73,252	1.32	858,507	1,181,588	1.38
SDGE	31,160	-6,114	-0.20	197,678	107,880	0.55
Total	**348,160**	**526,358**	**1.51**	**3,757,756**	**4,539,634**	**1.21**

Table 7: Electric (kWh) Net to Gross Ratios

Gas NTG ratios are more consistent across IOUs and Program years. The statewide gas NTG ratio is 0.63 for 2002 and 0.44 for 2003, implying high average free-ridership of 53%. This is a direct result of high naturally occurring "savings" in the two gas end-uses, heating and especially water heating.

	Gross Ex Post 2002	Net Ex Post 2002	NTG RATIO 2002	Gross Ex Post 2003	Net Ex Post 2003	NTG RATIO 2003
PGE	70,344	46,056	0.65	369,529	216,725	0.59
SCE	9,850	6,728	0.68	234,109	55,130	0.24
SCG	1,334	461	0.35	19,578	6,489	0.33
SDGE	18,913	9,755	0.52	81,022	34,184	0.42
Total	**100,441**	**63,000**	**0.63**	**704,239**	**312,528**	**0.44**

Table 8: Gas (Therms) Net to Gross Ratios

For a graphical representation of single family natural and net savings see **Figure 12: Single Family Net Energy Savings.**

Multifamily and High Rise Net-to-Gross (NTG)

The multifamily NTG ratio was determined through telephone surveys, conducted by SERA. A single NTG ratio was estimated statewide for all utilities, and both 2002 and 2003 program years.

Multifamily NTG_{MF} range: 0.56-0.69

Multifamily NTG_{MF} *average*: 0.625

Details of the estimation methodology can be found in this report.

General Conclusions & Recommendations

1. **Program participants account for roughly 10% of residential new construction**. This is an approximation based on total number of homes permitted, not constructed.

2. **Both the implementers and the evaluators based Program impacts on Title 24 modeling software.** If the software models are inaccurate or biased, then the results of the Program and this evaluation will be inaccurate or biased. This is a potential weakness of this evaluation. Although not rigorous, the 2004-05 evaluation is investigating the accuracy of Micropas and EnergyPro to determine how well they model energy use of newly built ENERGY STAR® homes by comparison to metered data.
3. **Builders are complying with the ENERGY STAR® Program requirements through end-use trade-offs.** Performance-based compliance is the widely preferred method for Title 24 compliance and the only method for Program compliance. Builders trade off between the three end-uses (water heating, heating and cooling) in order to reach the 15% compliance margin. The result of these tradeoffs often produces significant disparity between the end-use compliance margins, and can also produce negative end-use compliance margins – resulting in negative end-use savings.
4. **The ENERGY STAR® Program has influenced builders to start using HERS measures and HERS inspectors more.** In a comparison of non-participant homes to participant homes, participant builders are more likely to use HERS measures than are non-participants. Builders were required to have a HERS inspector verify the building characteristics, even when no HERS measures were implemented. This requirement has helped develop the HERS rating industry and helped to prepare builders for future code where HERS measures and inspections will be more prevalent.
5. **A more efficient home does not necessarily equate to less energy consumption.** Analysis of billing data, although limited to only a few climate zones, showed that some groups of ENERGY STAR® homes used more energy on average than similar non-participant homes. Although the homes were more efficient, they still used more energy. These results suggest that occupancy, behavior and demographics of buyers are key Program elements which are currently overlooked by the Program theory. Program managers should consider whether the goal of the Program is less energy use, or more efficient energy use.
6. **The tracking database used for the evaluation (CHEERS registry) does not always have accurate data which makes EM&V work less accurate.** Some of the inaccuracies may originate with CHEERS, but some certainly originate with the Title 24 modelers who upload the data to CHEERS. RLW recommends continued review and QC of the registry.
7. **There is no uniformity in Title 24 modeling by builders or plan check agencies.** HERS inspections, plan check and evaluation can be challenging when Title 24 documentation approaches vary so greatly. For example, a single multifamily Structure ID can represent a single dwelling unit, an entire building, or multiple buildings. Utility plan check agencies could consider written protocols for Title 24 documentation format. Going a step further, considering the complexity of Title 24 compliance, the CEC and the implementers may want to consider

mandatory certification for those engaged in providing Title 24 services to the ESH program. CABEC[12] currently offers a voluntary certification.

8. **Enhance the quality and type of data in CHEERS and other approved C-HERS registries.** We recommend that C-HERS inspectors be trained and required to input actual field values resulting from inspections into the registry. We would also recommend expanding the inspection requirements to include additional data collection and input, such as make and model number for furnaces, boilers, water heaters, air conditioner condensing units, evaporator coils and results from performance testing.
9. **Enforcement of codes and standards may not be as rigorous as is generally perceived.** Many structures are not built to code (Itron baseline study), not built to plan (RLW on-site inspections), and sometimes not even modeled in the correct CEC climate zone.
10. **The implementers need a statewide Program tracking system, other than the CHEERS registry.** The CHEERS databases is not an effective system for tracking Program information, especially as new C-HERS providers become active and begin working with participant builders. Each implementer not only has their own approach to tracking basic participation information, each tracks different data using different software (e.g. Excel, Access). A purpose of the statewide implementation of the ESH program was to increase uniformity in program delivery and program administration, including things such as tracking databases. A single statewide tracking system should be implemented.
11. **The utilities should work toward a common approach to estimating energy savings.** The four utilities used varying approaches to estimate AEAP filed savings. Utilizing a common approach would benefit Program administration as well as Program evaluation. Moreover, a common approach may actually be more cost effective and accurate.

[12] http://www.cabec.org/ The California Association of Building Energy Consultants (CABEC) is a non-profit organization providing up-to-date, reliable information about the California Title 24 Energy Standards and related building energy efficiency topics.

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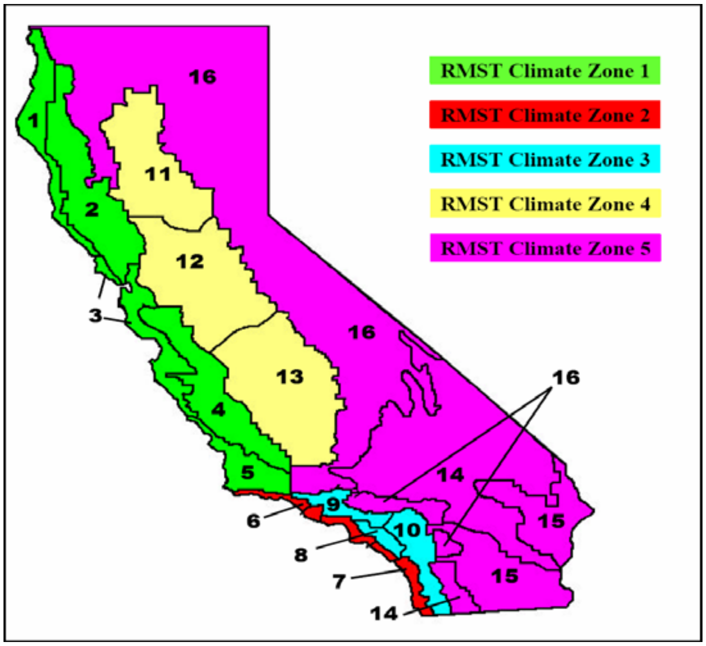

Figure 6: California Energy Commission 16 Climate Zones

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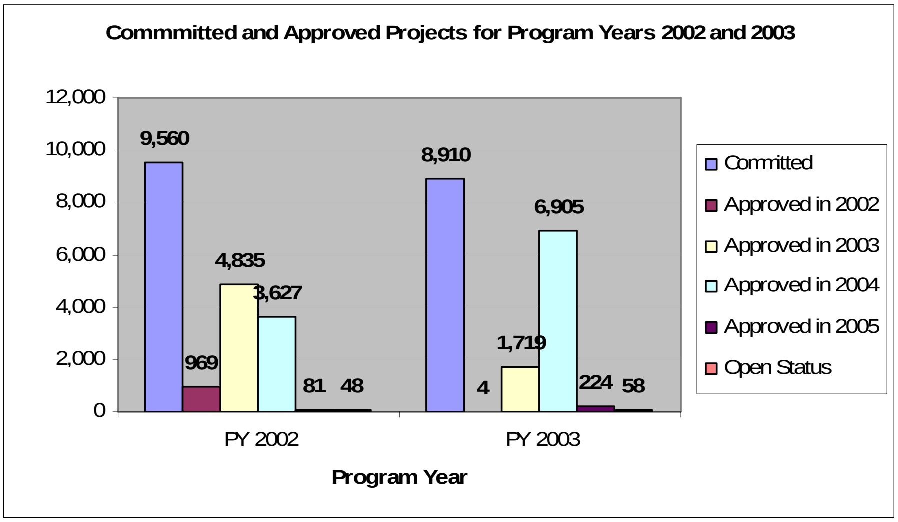

Figure 7: Number of Participant Projects (SF and MF) Approved and Committed by Program Year

[15] A structure becomes "approved" when its construction is complete and it has completed and passed all necessary C-Hers measure inspections.

Program Process Overview

Figure 8 gives a brief description of the process of program participation and the connection between the various parties involved with the California ENERGY STAR® Program.

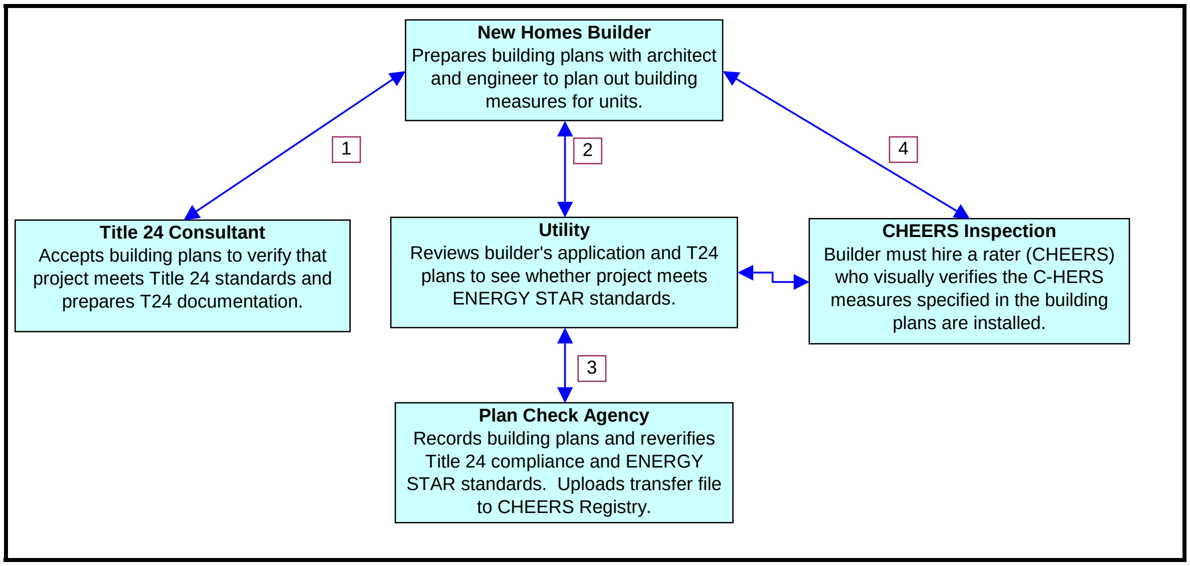

Figure 8: ENERGY STAR® Homes Program Compliance Process

Step 1: Once builders have the building designs prepared, all builders submit the plans to Title 24 consultants who then prepare the required compliance documentation. Title 24 requirements are California law, which include energy efficiency minimum requirements, and must be met by all builders, regardless of whether they intend to participate in the Energy Star Homes program or not.

Step 2: If builders want to participate in the ESH program, they must design beyond the minimum Title 24 requirements to meet ESH program requirements (at least 15% higher efficiency). Builders must submit their building plans, Title 24 documentation, and a short application to the appropriate utility. At this stage, construction is usually in the planning and design, or early construction stage. If the utility approves the application, the ESH program reserves incentive funds for the builder based on the projected number of units approved.

Step 3: After the utility reviews and approves the builder's project(s), it submits the building plans to a plan check agency that re-verifies Title 24 and ESH program compliance. Once approved, the plan check agency uploads the Title 24 output file (called the "transfer file") to the CHEERS registry.

Step 4: Once builders have actually constructed the homes, they must hire a HERS rater to verify HERS measures, if any, *and to verify all other design specifications specified in the Title 24 file including elements of the building envelope, fenestration and mechanical systems*. Verifications are completed via on-site inspection(s) and/or test(s) of the constructed unit. If a builder constructs multiple units of the same design, not every unit requires inspection, but a sample of units is inspected.

CHEERS is a non-profit organization that has been approved by the California Energy Commission (CEC) to provide testing, verification, and certification of the California Home Energy Rating System (C-HERS) measures. ENERGY STAR® Homes may include a number of C-HERS energy efficiency measures. All new or renovated homes that include C-HERS measures are contained in the CHEERS Registry. Therefore, the CHEERS registry is a database of building and energy characteristics for homes with one ore more C-HERS measures, and/or ENERGY STAR® homes. Again, the CHEERS Registry is populated by extracting data from the Title 24 building file,[16] which is then uploaded to the CHEERS registry via the Internet.

Builders receive incentives from the utility once their homes pass the CHEERS verification process.

The 2002 ESH program provided incentives to builders that applied and reserved program funds during calendar year 2002. Due to the nature of residential new construction, many of the participant homebuilders do not complete construction until 2003 or later.

Program Implementation Differences

Each utility had somewhat different implementation methods for the program which are summarized in Table 10. However, major program elements such as program qualification levels and incentive levels were uniform statewide.

Function	PG&E	SCE	SDG&E/SCG	Notes
Title 24 Consultant	Builder Selects	Builder Selects	Builder Selects	Not necessarily a program function. Consol provides this service for many SF builders.
Plan Check Agency	SolData	SF - Consol MF - Consol or HMG	In-house	Since, in many cases, Consol did the original Title 24 they hired CHEERS to randomly sample some of the Consol plan checks. Doug Beaman and Associates performed this function as a sub to CHEERS.
Design Assistance	SF - None MF- Builder Selects	None	In-house	No design assistance (DA) for SF. PG&E had a DA incentive for MF projects, though it is not clear if any incentives were ever paid. HMG provided DA to some of the MF projects. SEMPRA provided DA services to about half of participating projects.
C-HERS Inspections	Builder Selects	Builder Selects	In-house	Consol also performs C-HERS inspections. Since the builder selects the rater they perform the ratings for builders they work with. So, Consol does the title 24, plancheck, and C-HERS inspections. SCE hired CHEERS to do some independent Q/A of Consol sites.

Table 10: Implementation Differences Between Utilities

These implementation differences were not the focus of this evaluation. In the 2004-2005 program evaluation, there is a process evaluation component that looks more closely at how the program is functioning, the differences between utilities, identifying process weaknesses, and suggestions for improving program process.

[16] A Title 24 building file, also known as a C-2R file, is an inspection report that qualifies the newly constructed home to comply with California's Title 24 standards.

C-HERS Measures

California Home Energy Rating System measures are special energy efficiency measures that can be implemented by builders to achieve higher efficiency construction. To take credit for the measures, they must be inspected by a certified HERS rater. There were six C-HERS measures in effect during the 2002-2003 ESH program years (under the 2001 version of Title 24), shown in Table 11.

C-HERS Measure	Rater Verification
Improved duct location (ducts in conditioned spaces)	Visual inspection
ACCA Manual D duct design and installation	Inspect/measure dimensions for compliance
Tight ducts, < 6% leakage	Duct leakage testing with duct blaster
Reduced air infiltration	Requires blower door testing and mechanical ventilation visual inspection if SLA is 3.0-1.5
TXV or proper refrigerant charge and airflow	Visual inspection for TXV, test for charge
Reduced duct surface area	Measure dimensions; requires ACCA Manual D duct design

Table 11: C-HERS Measures and Verification Method

About HERS

The California Energy Commission is required by Public Resources Code Section 25942 to establish regulations for a Home Energy Rating System (HERS) Program to certify home energy rating services in California. The goal of the program is to provide reliable information to differentiate the energy efficiency levels among California homes and to guide investment in cost-effective home energy efficiency measures.

The California HERS Program includes field verification and diagnostic testing available through Commission-certified providers. The Energy Commission has a process for certifying Home Energy Rating System (HERS) raters who perform third-party inspections when verification of duct sealing, thermostatic expansion valves (TXVs), refrigerant charge, airflow measurement, and building envelope sealing measures are used when complying with the 2005 Standards (effective October 1, 2005). Testing and verification protocols are summarized and located in both the Residential and Nonresidential Field Verification and Diagnostic Testing Regulations Manuals.

Phase I regulations establishing field verifications and diagnostic testing services administered by HERS providers became effective on June 17, 1999. The California Certified Energy Rating & Testing Services (CalCERTS) and the California Home Energy Efficiency Rating System (CHEERS) have been approved by the Commission as HERS providers to oversee HERS raters providing Title 24 field verification and diagnostic testing.

At the time Energy Star Homes were approved in 2002 and 2003 relevant to this report, CHEERS was the only approved HERS provider.

Recently (March, 2006) the Energy Commission approved certification of CBPCA as a new (third) HERS provider.

About CHEERS®

CHEERS® (California Home Energy Efficiency Rating Services) is a California statewide 501 (C) (3) non-profit organization dedicated to promoting energy efficiency. Founded in 1990, CHEERS® was approved in 1999 by the California Energy Commission as the first home energy rating provider under the Home Energy Rating System Regulations. It has an independent Board of Directors representing utilities, environmental and energy conservation and consulting groups.

CHEERS® trains and certifies home energy Raters for the building industry. Working with builders as homes are being built, CHEERS® Raters—nearly 500 statewide—conduct independent third party tests, verifications and certifications for homebuilders. This process ensures that homes being built meet or exceed the energy efficiency standards established by the state. Last year, CHEERS® Raters completed more than 20,000 ratings and verifications.

A CHEERS® Rater will perform a comprehensive analysis of the home. The analysis includes insulation, windows, heating/cooling system, water heater and lighting. Once verified and certified that the home meets state energy standards, the information is entered into a computer program that calculates an energy rating for the home and, when needed, analyzes all of the possibilities (up to 6,000 variations) for improving the home's energy efficiency. Once the analysis is completed, a detailed rating report listing recommended energy efficiency improvements, (many of which may be financed through an Energy Efficient Mortgage) is submitted.

To make sure energy efficiency ratings are completely objective, Raters are independent contractors that have been trained and certified by CHEERS®. Further, every CHEERS® Rater is required to go through quality assurance reviews, renew their certification and contracts annually with CHEERS®.

CHEERS® maintains a unique online Registry of certification documents that links the homebuilder, rater, and energy analyst to the rating process.

3. Evaluation Methodology Overview

The goals of the Phase II report are to provide gross and net impact savings estimates for the single family and multifamily components of the 2002 and 2003 ENERGY STAR® New Homes Programs. Evaluation of gross and net impacts is a relative measurement, usually compared to a reference or baseline. For this program, the ideal metric of energy savings would be obtained by comparing each Energy Star Home (participant) to its equivalent non-Energy Star home (non-participant). Since equivalent non-Energy Star homes were not constructed, other methods were needed to estimate energy savings.

Discussion of gross and net impacts is conducted in the context of estimated parameters, defined below.

Energy savings Annual energy savings due to exceeding Title 24 building code minimum requirements.

Simple Gross savings Participant energy savings from a summation of tracking database (CHEERS) savings.

Adjusted gross savings Also called **Gross ex post savings**. Simple gross savings adjusted by on-site inspection findings (takes into account differences between planned building characteristics and inspected characteristics).

Net Ex Post savings Participant energy savings due to the program (excludes free ridership).

Net savings Same as Net Ex Post savings in this report.

Free ridership Also called **Naturally Occurring savings.** Participant energy savings that would have occurred absent the program. In this study naturally occurring savings are equivalent to non-participant energy efficiency beyond Title 24 package D requirements.[17] Note that a single program participating home can have partial free ridership.

Net-to-Gross Ratio $NTG = \frac{NetExPost}{GrossExPost}$

Spillover Non-participant energy savings due to the program.

Ex Ante (Net) savings Energy savings estimates *(calculated by RLW)* based on each IOU's per-unit savings estimates. Ex ante savings = (number of actual units approved) x (IOU per-unit savings estimate filed in PIP) x (0.8 NTG factor).

Table 12 shows each of the parameters, data sources, and analysis methods used to estimate the parameters. Details on each of the analysis methods are found in corresponding chapters throughout this report.

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[17] http://www.energy.ca.gov/title24/

Quantity to estimate	**Data sources used**	**Analysis Methods**
SF simple gross savings	CHEERS	Data queries
SF adjusted gross (ex post) savings	On-site inspection data, CHEERS	Title 24 energy modeling, ratio estimation
SF net ex post savings	SF adjusted gross savings, SF RNC baseline study, utility billing data	Difference of differences, billing analysis
SF free ridership	Gross ex post savings, net ex post savings	Gross - Net
SF spillover	SF RNC baseline study, CHEERS	Hypothesis testing
MF simple gross savings	CHEERS	Data queries
MF adjusted gross savings	On-site inspection data, CHEERS	Title 24 energy modeling, ratio estimation
MF net ex post savings	MF builder surveys	SERA
MF free ridership	MF builder surveys	SERA
Ex ante savings	IOU PIPs, CHEERS	NA

Table 12: Parameters Estimated, Data Sources and Analysis Methods

Two distinct approaches were attempted to evaluate the ex post gross and ex post net energy savings resulting from the single family program: an engineering-based "difference-of-differences" approach and a billing data analysis. A less rigorous evaluation method was used for measuring multifamily ex post gross savings due to the unavailability of baseline data. Survey data were collected from builders of multifamily projects for determining construction practices absent the program and overall net program effects. An overview of each of these methods follows, and further details are described throughout this report in the appropriate chapters.

Single Family Gross and Net Ex Post Savings Methodologies

Many of the parameters estimated were used only in intermediate steps to achieve the ultimate goal of the analysis: to estimate net ex post savings

Figure 9 shows a flowchart for single family energy savings calculations using the difference of differences method.

1. Simple Gross Savings were calculated by summing the energy savings of each home from the CHEERS tracking data.
2. On-site inspections were conducted to verify that homes were actually built as planned and modeled in the tracking database.
3. Adjusted Gross savings were estimated using ratio estimation analysis to extrapolate the as-built findings to the population of participants.

4. Ex Ante Savings were calculated for each utility based on number of units (homes) completed in each program year and each utility's PIP estimates at the per-home level.
5. Net Energy Savings were estimated using the "difference of differences" methodology.
6. Other parameters, such as free ridership and NTG ratio were calculated.

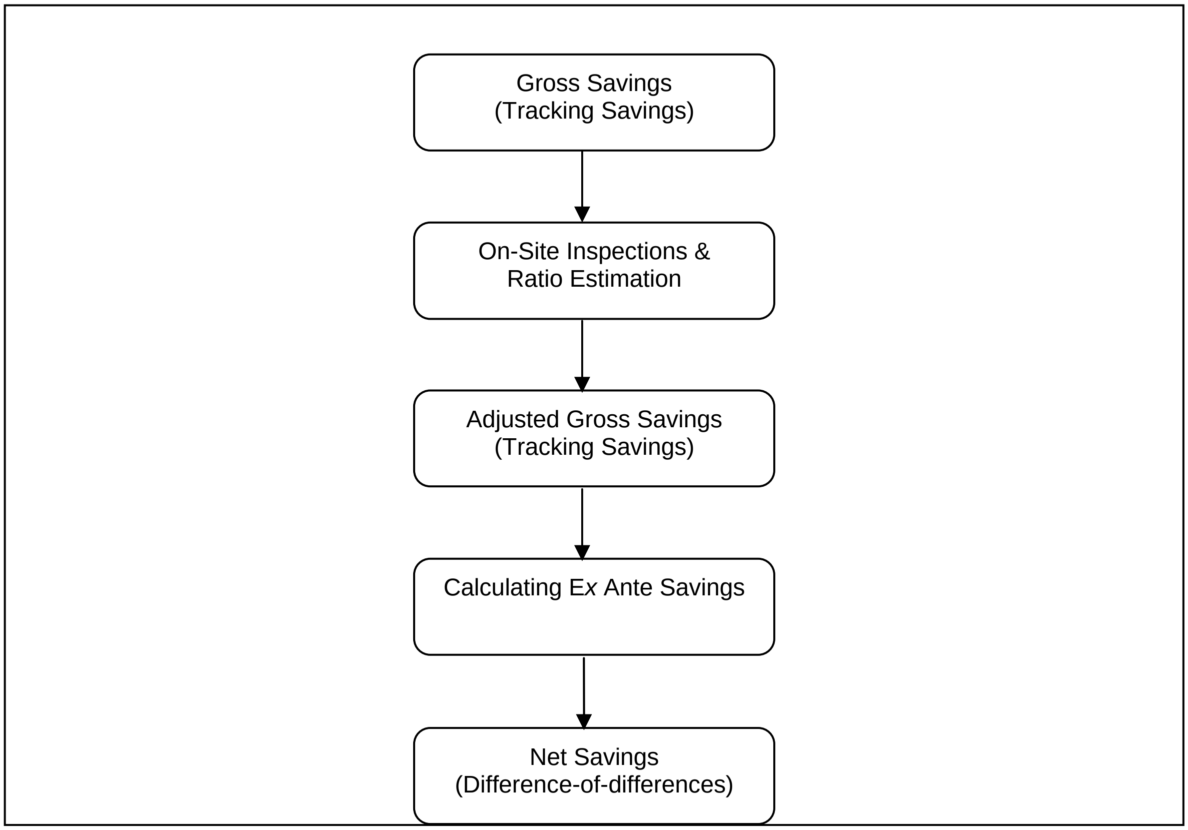

Figure 9: Single Family Gross and Net Energy Savings Calculation Flowchart

In addition to the above Difference of Differences analysis, a billing analysis was conducted to attempt to measure actual changes in energy consumption. Customer billing data was collected from the utilities for both participants and non-participants (homes in the baseline study). Details of this analysis method and its challenges can be found in the Single Family Billing Analysis chapter.

Multifamily Gross and Net Savings

Figure 10 shows a flowchart for multifamily energy savings calculations.

1. Simple Gross Savings were calculated by summing the energy savings of each home from the CHEERS tracking data.
2. On-site inspections were conducted to verify that homes were actually built as planned and modeled in the tracking database.

3. Adjusted Gross savings were estimated using ratio estimation analysis to extrapolate the as-built findings to the population of participants.
4. Ex Ante Savings were calculated for each utility based on number of units completed in each program year, and each utility's PIP estimates at the per-unit level.
5. Net Energy Savings were estimated by applying the Net-to-Gross ratio determined by surveys with multifamily builders.

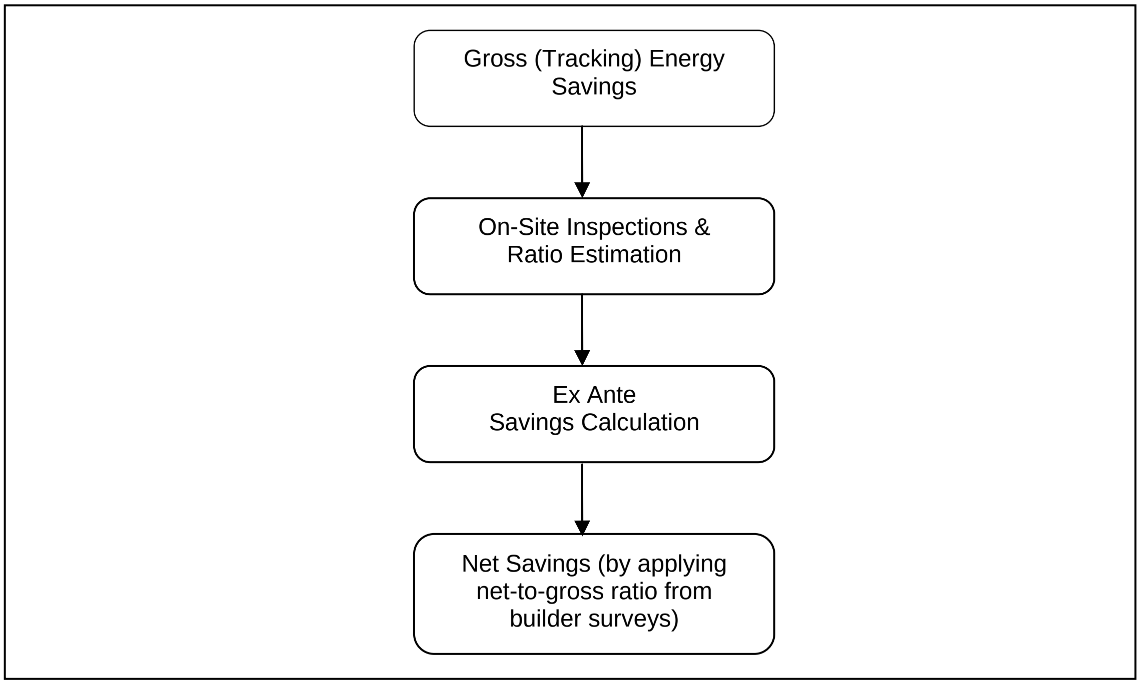

Figure 10: Multifamily Gross and Net Energy Savings Calculation Flowchart

A billing analysis was not conducted for multifamily projects.

Calculating Ex Ante Savings

For program years 2002 and 2003 the utilities filed their Annual Earning Assessment Proceeding (AEAP) report, which summarize program accomplishments and energy savings. The values included in the AEAP report often become the ex ante value used for program impact evaluation. However, RLW was not able to use the AEAP energy saving values because, for this particular program, the AEAP energy savings values are only estimates and are inclusive of energy savings resulting from both completed structures and committed structures (project planned for completion at some future date). The evaluation, on the other hand, considers realization of energy savings only for structures considered complete.18 Therefore it was necessary for RLW to calculate the ex ante energy savings using only the total number of completed and approved units, the per unit

[18] For the purpose of the evaluation, "completed" was defined by the final C-HERS inspection date, designated in CHEERS by a date and "approved".

savings found in each utility's Program Implementation Plan, and a 0.8 NTG ratio. Specifically:

> Ex ante savings = (number of actual units approved) x (IOU per-unit savings estimate filed in PIP) x (0.8 NTG factor).

Data Sources

There were several key data sources used by RLW to conduct this evaluation. The first data source is the California Home Energy Efficiency Rating System (CHEERS) Registry. RLW worked closely with CHEERS throughout the study to obtain extracts from the CHEERS Registry. Registry data includes detailed building characteristics information for participant structures. For a large number of the participant structures in the CHEERS Registry, RLW also obtained the original Micropas or EnergyPro Title 24 files. These files were provided by the implementers.

Another key data source used for this study is the 2004 Residential New Construction Baseline Study[19] (the baseline study). It is important to note that this study grouped CEC climate zones into five Regional Market Share Tracking (RMST) climate zones as shown in Figure 11. Furthermore, the ESH program defines **coastal** regions as CEC climate zones 1-7, and **inland** regions as CEC climate zones 8-16. As a result there are three distinct types of climate zones discussed throughout this report:

1. CEC climate zones 1 – 16
2. RMST climate zones 1 – 5 from the residential new construction baseline study
3. ESH program inland and coastal climate regions

[19] 2004 California Residential New Construction Baseline Study (Itron, 2004).

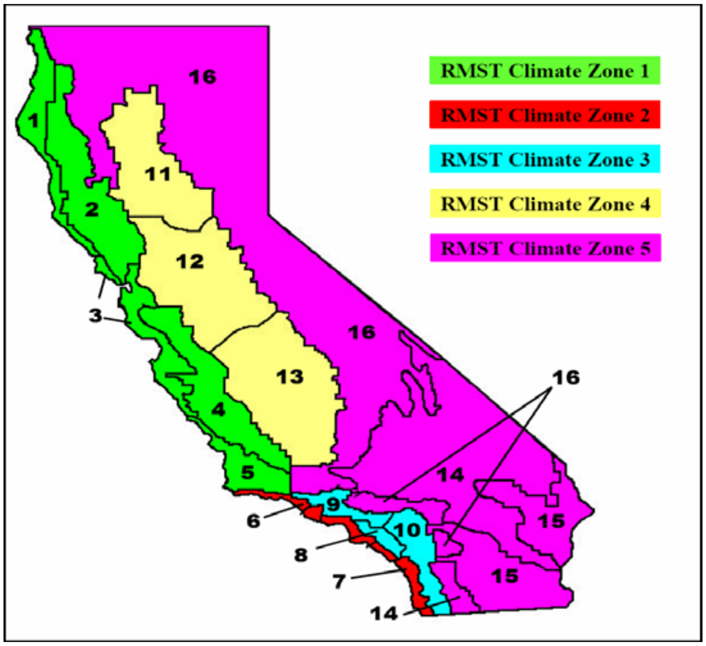

Figure 11: California Energy Commission 16 Climate Zones and 5 RMST Climate Zones

The baseline study's authors provided RLW with raw data collected by building surveyors, as well as structure-specific Title 24 output generated in the process of conducting the study.

For the billing analysis, billing data was acquired from each of the investor owned utilities (IOUs). Several thousand participant single family homes' billing data was collected covering an eighteen month period, when available. Billing usage data was also collected for the non-participant (baseline) homes.

Lastly, program implementation planning (PIP) estimates of unit-level gas and electric savings from each utility were obtained. RLW required this information in order to determine the *ex* ante program savings.

4. Single Family, Multifamily, and High Rise Specific Results, Conclusions and Recommendations

Background

The ESH program, and this evaluation, are entirely based on EnergyPro and Micropas energy modeling software. If the software models are inaccurate or biased, than the results of the program and this evaluation will be inaccurate or biased. This is a potential weakness of this evaluation.

The tracking database (CHEERS) does not always have accurate data which makes EM&V work less accurate. Inaccuracies may originate with CHEERS, or may originate with the Title 24 modelers who upload the data to CHEERS.

Single Family Energy Savings

Single family net energy savings were calculated based on actual homes completed in calendar years 2002 and 2003; there were 6850 homes. Ex ante estimates were calculated for each utility based on per unit savings estimates and the number of homes actually built in 2002 and 2003.[20] Ex post savings were estimated using the difference-of-differences (DofD) methodology, detailed in this report. The essence of this method is to compare ENERGY STAR® Homes (participants) to standard construction practices (non-participants), determined from a non-participant new construction baseline study, to subtract out naturally occurring savings. The result is ex post (net) savings.

	2002 kWh			2003 kWh		
	Ex Ante	***Ex Post***	***Realization Rate***	***Ex Ante***	***Ex Post***	***Realization Rate***
PG&E	111,864	380,763	340%	543,835	1,818,960	334%
SCE	63,118	78,456	124%	2,350,536	1,431,206	61%
SCG	No est.	73,252	NA	265,800	1,181,588	445%
SDG&E	154,655	-6,114	-4%	543,628	107,880	20%

Table 13: Single Family Electricity Net Savings & Realization Rates

Single family gas savings and realization rates are:

	2002 Therms			2003 Therms		
	Ex Ante	***Ex Post***	***Realization Rate***	***Ex Ante***	***Ex Post***	***Realization Rate***
PG&E	54,228	46,056	85%	276,880	216,725	78%
SCE	No Est.	6,728	NA	No Est.	55,130	NA
SCG	No Est.	461	NA	6,000	6,489	108%
SDG&E	-1,102	9,755	NA	1,221	34,184	2800%

Table 14: Single Family Gas Net Savings & Realization Rates

[20] At the time utilities filed Program information with the CPUC, estimates were based on homes committed (approved applications) within a Program year – not constructed. Since that time, it was determined to conduct this evaluation based on homes actually constructed within a Program year. Due to this accounting change, it was necessary to calculate new ex ante estimates.

Single family net savings are also shown graphically by end-use[21] in Figure 12. Note that the energy units have been converted (from kWh and therms) to source kBTU for comparison purposes. The total height of each bar represents the standard design, or Title 24 Package D energy use. In almost all homes, heating and water heating are fueled by natural gas, while cooling is electric. Several results are evident.

- The three end-uses consume roughly equal amounts of source energy.
- The ESH program's largest net source energy savings are derived from cooling, while the smallest are from water heating.
- Negative natural savings for cooling means that new non ENERGY STAR® Homes on average do not meet Title 24 cooling budget requirements.
- Significant naturally occurring (gas) savings are present for heating and water heating, translating to high gas free-ridership rates.
- The average as-proposed ENERGY STAR® home uses the most energy for water heating among the three end-uses. Most of the program savings in energy use comes from heating and cooling.

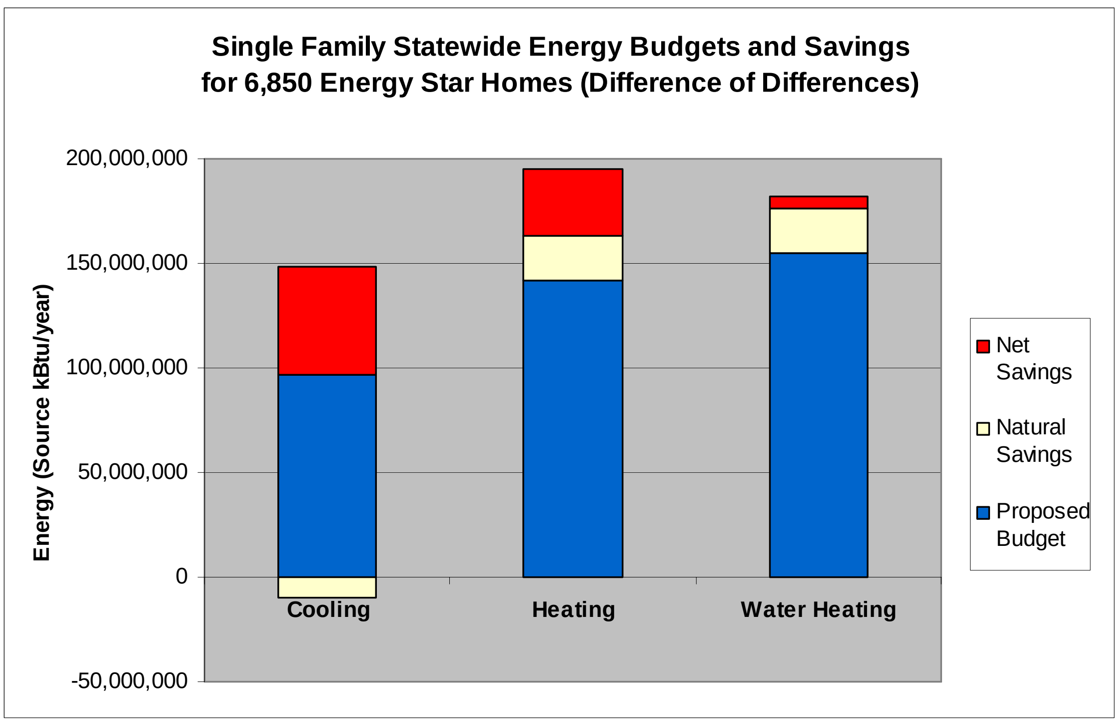

Figure 12: Single Family Net Energy Savings

[21] The builder affected end-uses covered in Title 24 are space heating, space cooling, and water heating.

Single Family Verification Inspections

On-site verification inspections were conducted of 110 single family homes. These inspections revealed that although homes are not built exactly to plan 90% of the time, their energy compliance margins are on average at least as good as planned regardless.[22] Figure 13 shows the compliance margin results for all 110 homes inspected. Many homes were far above 15% or 20% compliance margins required for ENERGY STAR® Homes compliance, especially in inland climate zones.[23]

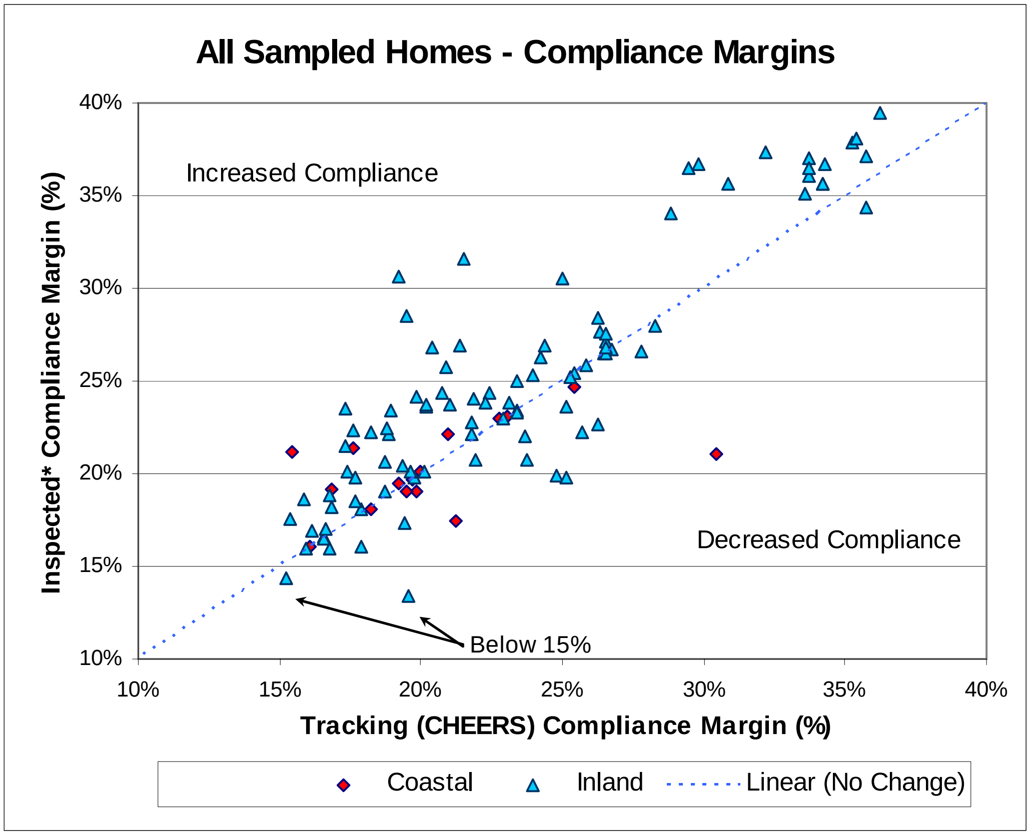

Figure 13: Title 24 Energy Compliance Margins (110 Inspected ENERGY STAR® Homes)

[22] It is important to note that both planned (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. Furthermore, statistical precisions listed in this report are statistically derived and have no component due to variability or bias associated with the modeling software. This study does not attempt to validate or estimate potential biases in energy modeling software currently used for California Title 24 compliance.

[23] The ESH program defines coastal climate zones as CEC climates zone 1-7, and inland as CEC 8-16.

Single Family Cooling, Heating, and Water Heating – Measures, Findings and Observations

1. Modeled energy usage is roughly evenly divided among the three builder affected end-uses (cooling, heating, water heating). End-use energy consumption does vary significantly between climate zones, however water heating is fairly constant throughout the state, while cooling and heating vary significantly by climate zone.
2. Cooling savings are generally realized through the use of higher efficiency (SEER) air conditioners with thermal expansion valves (TXV), smaller/fewer windows, windows with low SHGC, and duct sealing. Other less common measures include window overhangs and radiant barrier.
3. Space heating savings are almost always from improved efficiency of the envelope – not from higher equipment AFUEs. Measures include better insulation, higher efficiency windows (low E, low U-value), and duct sealing.
4. Water heating is a particularly difficult end-use for builders to achieve incremental savings. The reason for this seems clear: the energy factor of traditional non-condensing gas storage water heaters is limited, and the market has already shifted to higher efficiency models. Little incremental savings are possible without going to significantly more expensive condensing water heaters or possibly to tankless units.
5. Non-participant homes are cooling non-compliant, on average. The negative natural savings of non-participants are therefore credited as additional net savings to ENERGY STAR® Homes participants, helping to make cooling the largest net source energy savings category.
6. Non-participant homes are more efficient than Title 24 for both water heating and space heating, resulting in "naturally occurring savings."[24] This translates into especially high free-ridership for water heating.

Single Family Conclusions & Recommendations

1. The existence of building codes (Title 24), building permits, Title 24 energy modeling, inspections, etc. gives the impression of strict enforcement of codes and program requirements, but this may be more perception than reality. The basis of this conclusion is that several hundred homes were found modeled in the wrong climate zone, and that 90% of the RLW inspected homes required remodeling due to differences in as-built building characteristics.
2. The CHEERS database is not always an accurate indicator of how homes are built, but on average the energy impacts are about right.
3. Single family free-ridership was very low (actually negative) for electric savings, but high for gas savings. Note that fuel-type specific free ridership estimates are appropriate as a result of the single family difference of differences analysis.
4. It was not difficult to exceed the 2001 Title 24 by 15%. The "bar" for ENERGY STAR® Homes participation was set modestly as evidenced by the large portion

[24] 2004 California Residential New Construction Baseline Study (Itron, 2004).

single family homes achieving 25%-40% better than Title 24 requirements (Package D) as seen in Figure 13.

5. Often, only minor changes in plans are necessary to achieve ENERGY STAR® Homes status, evident from minor differences between ENERGY STAR® Homes and non-participants in building characteristics.
6. There are more options to comply in inland climate zones than coastal. This is due to larger inland energy budgets, especially for cooling, giving builders/designers "more room to play" to achieve savings.
7. The most recent residential new construction baseline study, utilized for analysis in this report, was insufficient to conduct comprehensive impact evaluation estimates due to an inappropriate sample design.
8. The existence of spillover is expected to exist due to discussions with builders and Program Managers, but this study was unable to measure significant spillover from the 2004 RNC baseline study. Note that this study sampled from housing starts in 2002 – the first year of the ESH program. Since part of the program goals are to change builder practices, estimating market effects may be desired, in which case a more current RNC baseline study is recommended.
9. This study finds evidence that ENERGY STAR® Homes are significantly more efficient than non-participant homes, but there is little evidence that this translates into actual energy savings. Differences in actual energy consumption could be dominated by demographics or possible snap-back effects.[25]
10. It is recommended that the program conduct regulatory reporting of energy savings estimates based on expected completion dates, rather than builder application dates.
11. A cost effectiveness study is recommended once all of the 2002 and 2003 program year participant homes are completed.

Multifamily Energy Savings

Multifamily homes consist of low-rise multifamily projects including low income, market rate for sale, market rate for rent, and special needs. Once again, ex ante program estimates were calculated with consideration to number of dwelling units actually constructed, and each utility's PIP estimates, as described in Chapter 14. Multifamily electricity savings realization rates were much more variable than gas realization rates, primarily driven by widely varying utility PIP estimates. For example, PG&E's 2003 kWh PIP estimate was 6.125 kWh/dwelling unit, while SCE's was 310.0 kWh/dwelling unit.

[25] Snap-back is defined to be a person's increased usage of a service due to their perception that higher efficiency justifies or offsets the increase. For example, using the air conditioner more after the purchase of a high efficiency unit.

	2002 kWh			2003 kWh		
	Ex Ante	*Ex Post*	*Realization Rate*	*Ex Ante*	*Ex Post*	*Realization Rate*
PG&E	461	2,467	535%	3,229	74,133	2296%
SCE	0	0	NA	124,248	7,330	6%
SCG	63,168	115,136	182%	801,624	451,041	56%
SDG&E	75,725	26,796	35%	330,538	66,803	20%

Table 15: Multifamily Electricity Savings (kWh/year)

	2002 Therms			2003 Therms		
	Ex Ante	*Ex Post*	*Realization Rate*	*Ex Ante*	*Ex Post*	*Realization Rate*
PG&E	1,249	1,246	100%	42,308	32,474	77%
SCE	0	0	NA	0	17,379	NA
SCG	8,723	7,994	92%	112,776	104,144	92%
SDG&E	15,034	11,585	77%	46,502	58,435	126%

Table 16: Multifamily Gas Savings (Therms/year)

Figure 14 shows the Title 24 modeled energy usage and gross savings for all participating units. The total height of each bar represents the standard design, or Title 24 Package D energy use. Note that the units have been changed to source kBTU/year for comparison purposes. Modeled energy usage is dominated by water heating which accounts for more energy usage and savings than cooling and heating combined.

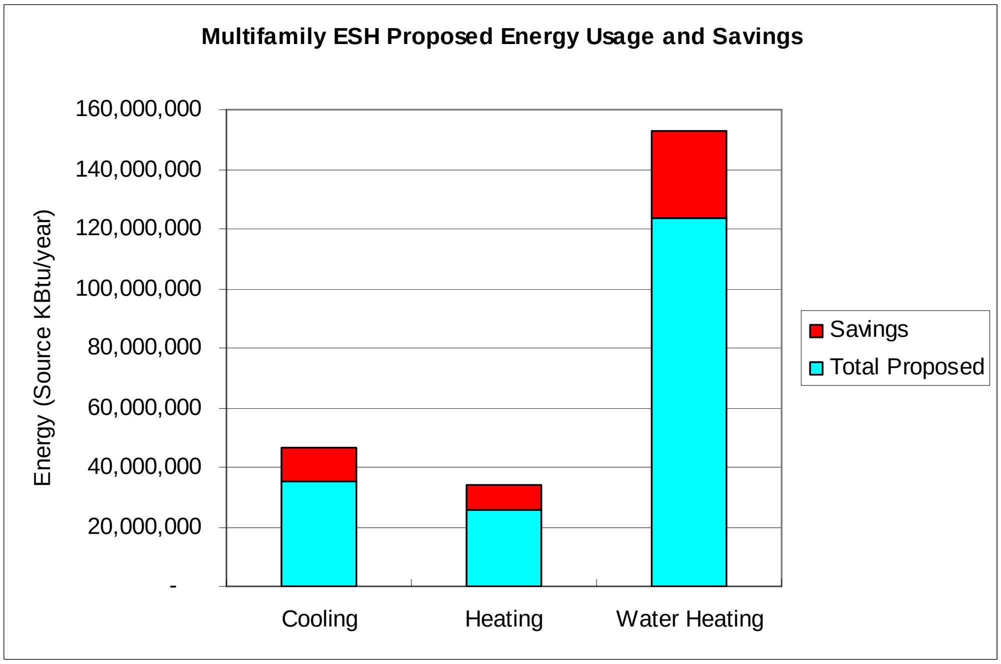

Figure 14: Multifamily Gross Energy Savings by End-Use above Proposed Usage

Multifamily Verification Inspections

A total of 25 projects were inspected with a total of 123 plans[26], since there were multiple plans associated with almost all of the projects. The multifamily on-site inspections revealed that there was not much difference between the inspected characteristics and the plans in the tracking database. Figure 15 shows the computed average compliance margins from the inspected data, and the original plan data. As can be seen from the figure, there is little difference between the two sets of compliance margins. This is true in all climate zones.

Based on these on-site inspection results, there is high correlation between planned and as-built modeled energy usage. As a result, no adjustments to the tracking savings estimates are necessary and the tracking database modeled energy values are considered accurate.

[26] The meaning of "plans" for multifamily projects is variable. For single family, a plan represents a single family home. Due to the flexibility of Title 24 modeling software, a multifamily plan can represent a dwelling unit, a multifamily structure, or a group of structures.

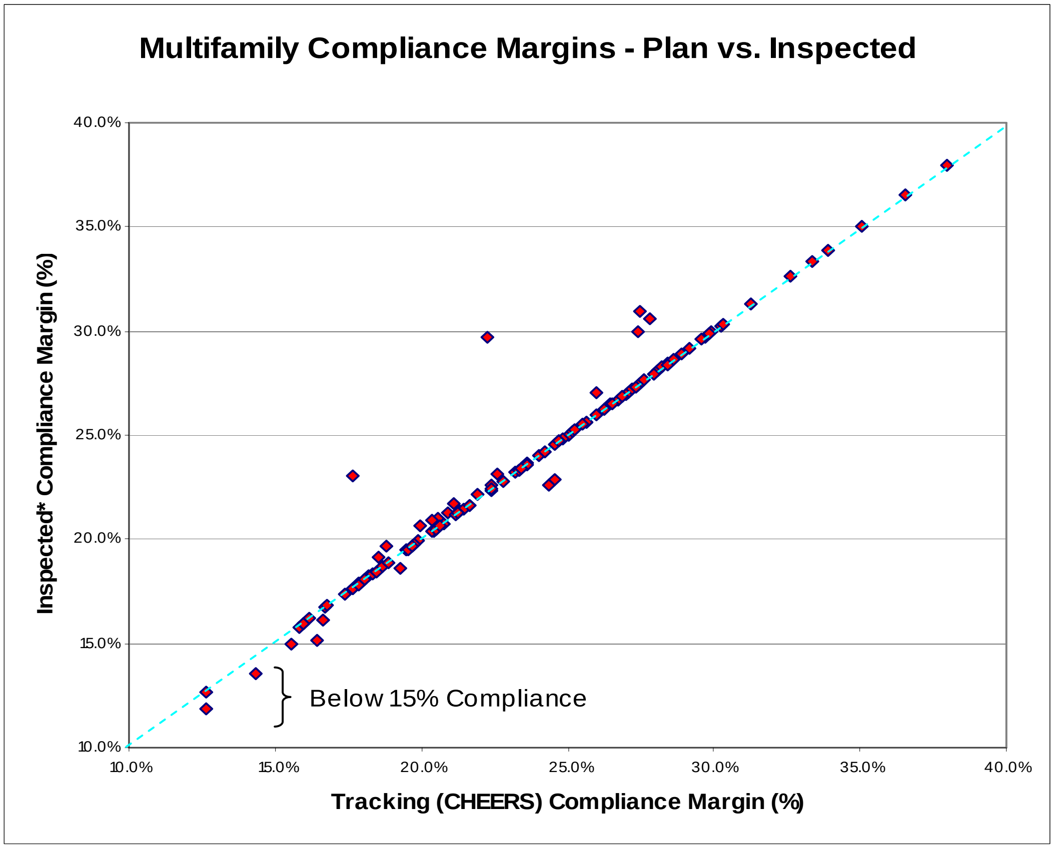

Figure 15: Inspected Multifamily Structures Compliance Margins

Multifamily Conclusions & Recommendations

1. Multifamily projects have very high free-ridership rates (almost 40%) due to multiple loopholes in Title 24 for multifamily structures. These loopholes are intended to be closed with the October 2005 Title 24 code changes. (Many builders were doing nothing different to meet ENERGY STAR® Homes requirements.)
2. C-HERS measures were rarely utilized by multifamily builders.
3. Builder surveys[27] also showed many projects need to exceed Title 24 by 15% for tax incentives/financing reasons (particularly low income housing since these developments are most eligible for tax incentives/financing), further impacting free-ridership.
4. New Title 24 code is expected to have a significant impact (beyond free-ridership) on multifamily projects by closing loopholes and generally tightening requirements. The main reason for this is there have not been multifamily specific energy efficiency code revisions in over 30 years, while single family code revisions have been completed regularly, and as recently as 2001.

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[27] 2006 Statewide Residential New Construction Program Strategy Assessment, CALMAC ID #: PGE0234 (RLW, 2005)

5. Modeled energy usage is dominated by water heating which accounts for more energy usage and savings than cooling and heating combined. Efficient water heating systems should be targeted more aggressively by the program. Consideration should be given to the behavioral aspects of hot water usage when not individually metered.
6. Wide variation in the modeling of multifamily projects makes it difficult to conduct EM&V analysis. Sometimes plans are for single structures, other times for groups of structures.
7. Most multifamily projects were built as planned (unlike single family).

High Rise Energy Savings

There were only three high rise buildings completed during 2002 and 2003 with a total of 200 dwelling units among them. Given the small number of units completed, and that the utilities had no high rise specific ex ante estimates, it's not possible to conduct meaningful quantitative analysis on this segment of the program. However, there are a few general conclusions.

High Rise Conclusions & Recommendations

1. Although three buildings is a small population, their total annual electric savings is negative. Meeting the compliance margin requirement is coming entirely from gas savings measures. After the 2002 program year the implementers became aware of this problem and implemented a new program rule disallowing negative electric savings.
2. High rise should be moved to a different program due to the commercial nature of these projects and different set of market actors.

5. Single Family Gross (Tracking) Savings

Introduction

The starting point for energy savings analysis is the Tracking database (CHEERS) and the associated Gross Savings, defined as the difference between Standard (package D) and Proposed modeled energy consumption.[28]

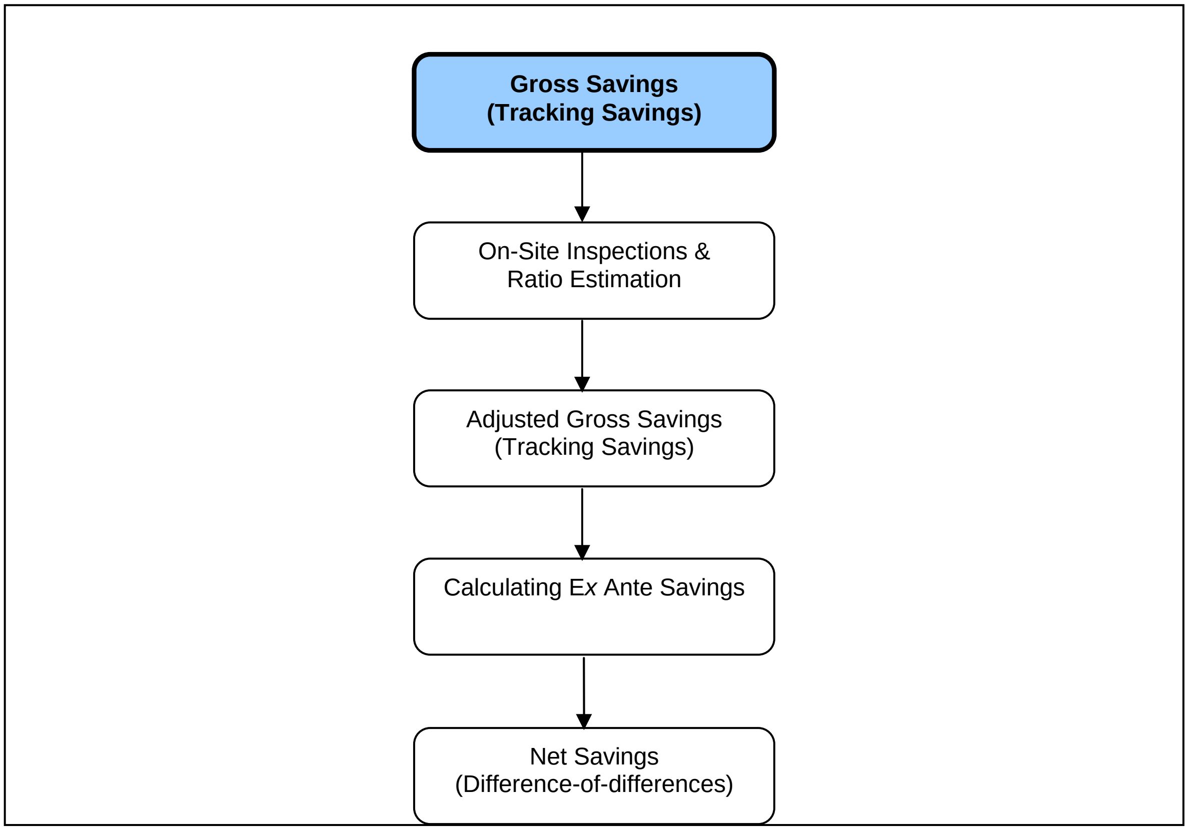

Figure 16: Single Family Gross and Net Energy Savings Calculation Flowchart[29]

Population of ENERGY STAR® Homes

The inclusion or exclusion of homes in the population has a dramatic effect on the total energy savings estimates, therefore a precise definition of the population is necessary. Program energy savings estimates were based on *participant application year*, and their

[28] "Standard" and "Proposed" are terms used by Title 24 energy modeling software. When a new home is modeled, it is compared to a "Standard" home's energy budget, which is determined by a set of prescriptive measures and characteristics (referred to as Package D) specific for that climate zone (e.g. insulation levels, air conditioner SEER, etc.). "Proposed" is the modeled energy consumption of the new home as designed. Gross energy savings is defined as the difference between Standard and Proposed.

[29] See chapter Evaluation Methodology Overview for explanation of the steps.

building plans. More recently, it was determined to credit energy savings in the year each home was *built and passed inspection*, and thus that is the criteria used for this report.

Homes included in the population were:

1. Inspected in 2002 or 2003
2. Structure "status" was labeled "Approved" (i.e. passed inspection)
3. Project program year was 2002, 2003

Note that when, or if, incentives were paid is not a criteria used to determine participation status. Implementing this definition, the population of single family participant homes in 2002 and 2003 contains 6,850 homes:

Utility	Coastal	Inland	Total
PGE	271	2684	2955
SCE	0	2311	2311
SCG	36	396	432
SDGE	888	264	1152
Total	1195	5655	6850

Table 17: Population of Completed 02/03 Participant Homes

Gross (Tracking) Savings

Since Gross Savings is defined as the difference between Standard (package D) and Proposed modeled energy consumption,

Gross Savings of the ENERGY STAR® Homes = $\sum_{i=1}^{N_p}(S_{p_i} - P_{p_i})SF_{p_i}$, where

S_p[30] = Participant CF-1R standard[31] energy use (kBTU/sf-yr)

P_p = Participant CF-1R proposed energy use (kBTU/sf-yr)

SF_p = Conditioned floor area of the home

N_p = total number of ENERGY STAR® Homes

The gross savings for the 2002-2003 programs are provided in Table 18.

[30] The subscript p is used to denote Participants, and np is used for Non-Participants.

[31] "Standard" and "Proposed" are terms used by Title 24 energy modeling software. When a new home is modeled, it is compared to a "Standard" home's energy budget, which is determined by a set of prescriptive measures and characteristics specific for that climate zone (e.g. insulation levels, air conditioner SEER, etc.). "Proposed" is the modeled energy consumption of the new home as designed. Gross energy savings is defined as the difference between Standard and Proposed.

Utility	Units	Tracking Savings (kBTU/year)
PGE	2955	53,466,798
SCE	2311	39,348,833
SCG	432	10,209,890
SDGE	1152	12,079,898
Total	6850	115,105,419

Table 18: Tracking Savings of Completed 02/03 Participant Homes

Details of Computing the Simple Gross

The *Data* table from a CHEERS Registry extract was used to compute values for energy savings. The CHEERS data contains values for energy usage per square foot for heating, cooling, and water heating. It has one value for each possible orientation of the structure; north, south, east, or west. We computed the average of these orientations to arrive at a unique number for each type of end use. This number is the expected savings of the structure from the Micropas or EnergyPro models. For the baseline values for the energy usage per square foot for a structure, we used the CHEERS value called "standard." The average values of the four orientations were compared to the standard to compute the energy savings for a structure.[32]

For each end use, the CHEERS data contains associated fuel types for all structures. We checked all the records in the database (i.e. 6,850 unique structure) to verify that the fuel type for heating and water heating were always gas, or gas fired, and that the fuel type for cooling was always electric. We then aggregated all savings from heating and water heating to arrive at the total gas savings. Similarly, the total electric savings were computed by summing up the cooling savings of all structures. [33]

In order to differentiate the results by coastal and inland differences each home was classified as either coastal or inland using the CEC climate zone it was modeled in. Homes modeled (or built) in CEC climate zones 1-7 were classified as coastal, whereas homes modeled in CEC climate zones 8-16 were classified inland.

[32] In a small percentage of structures, we did not have values for all four orientations. Instead we used the 'PROPOSED' values for energy savings reported in the CHEERS database. In these cases, we subtracted the 'Proposed' values from the 'Standard' in order to arrive at the energy savings for these structures.

[33] The energy savings by fuel type are presented in the Adjusted Gross Energy Savings chapter.

6. Single Family Verification Inspections & Ratio Estimation

Introduction & Background

On-site inspections of 110 single-family ENERGY STAR® Homes were conducted to verify that as-built characteristics and associated energy savings match the plans.[34] Inspected modeled energy savings were compared to the planned modeled energy savings (as reported in CHEERS). If differences in as-built characteristics were found, the next step was to analyze how they may affect the energy savings of the program. This was accomplished with ratio estimation analysis, 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.

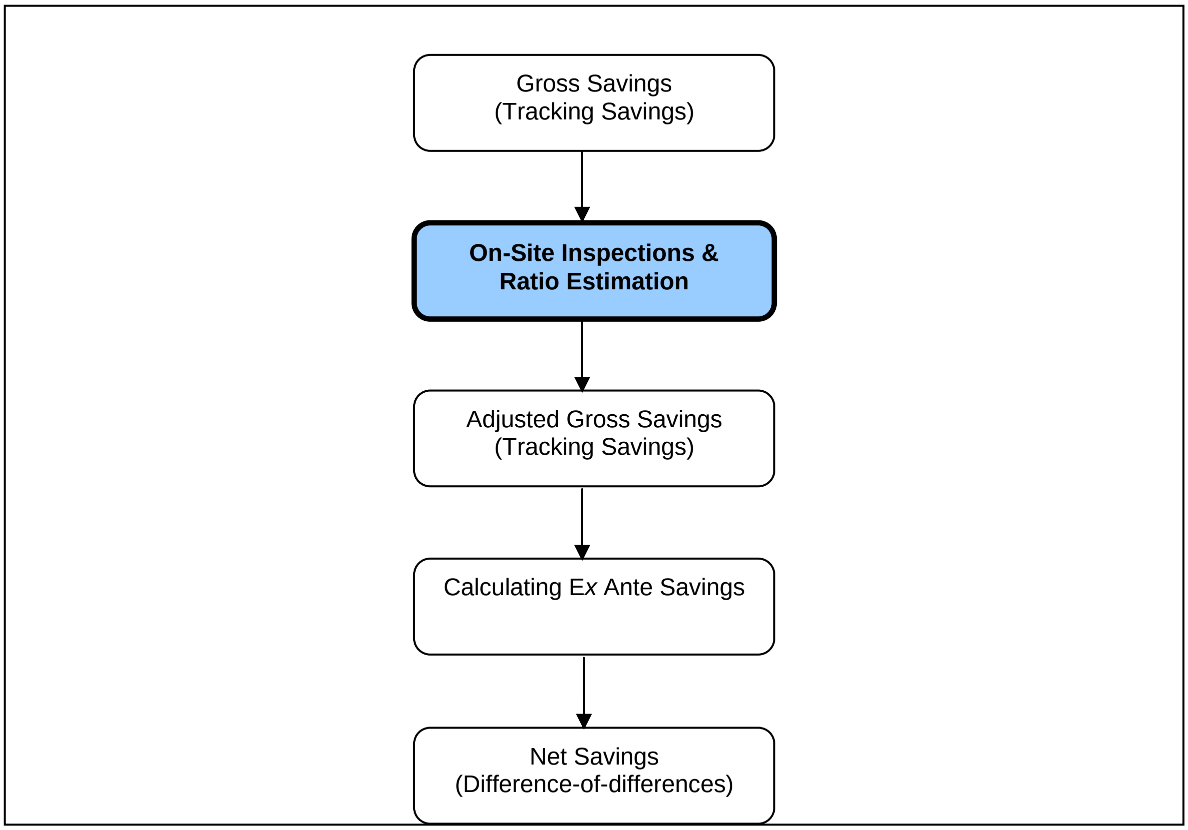

Figure 17: Single Family Gross and Net Energy Savings Calculation Flowchart[35]

To asses the energy impacts, the fundamental method was to compare the on-site inspection results with the Title 24 plans submitted for each home in the sample. If

[34] 'Plans' refers to the Title 24 files submitted to the utility by the participant and approved by the utility. This data is then uploaded to the CHEERS database.

[35] See chapter Evaluation Methodology Overview for explanation of the steps.

building characteristics differences were found, the home's Title 24 energy model was re-simulated.

Purpose

The purpose of the on-site inspections and ratio estimation was to,

1. determine ratio estimators, by coastal and inland climate regions and by end-use, to provide the best estimate for the inspected energy savings.
2. determine the statistical significance of the ratio estimators, by coastal and inland climate regions and by end-use.

Summary of Key Results

The single family on-site inspections revealed that the average energy Compliance Margins were at least as good as the plans.[36] Figure 18 shows the compliance margin results for all 110 homes inspected by RLW. Many homes increased compliance margin, some decreased compliance, and two homes fell below the minimum program requirements (below 15%). Interestingly, many homes were far above the 15% or 20% compliance margins required for ENERGY STAR® Homes compliance, especially in inland climate zones.

[36] 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. Furthermore, statistical precisions listed in this report are statistically derived and have no component due to variability or bias associated with the modeling software. This study does not attempt to validate or estimate potential biases in energy modeling software currently used for California Title 24 compliance.

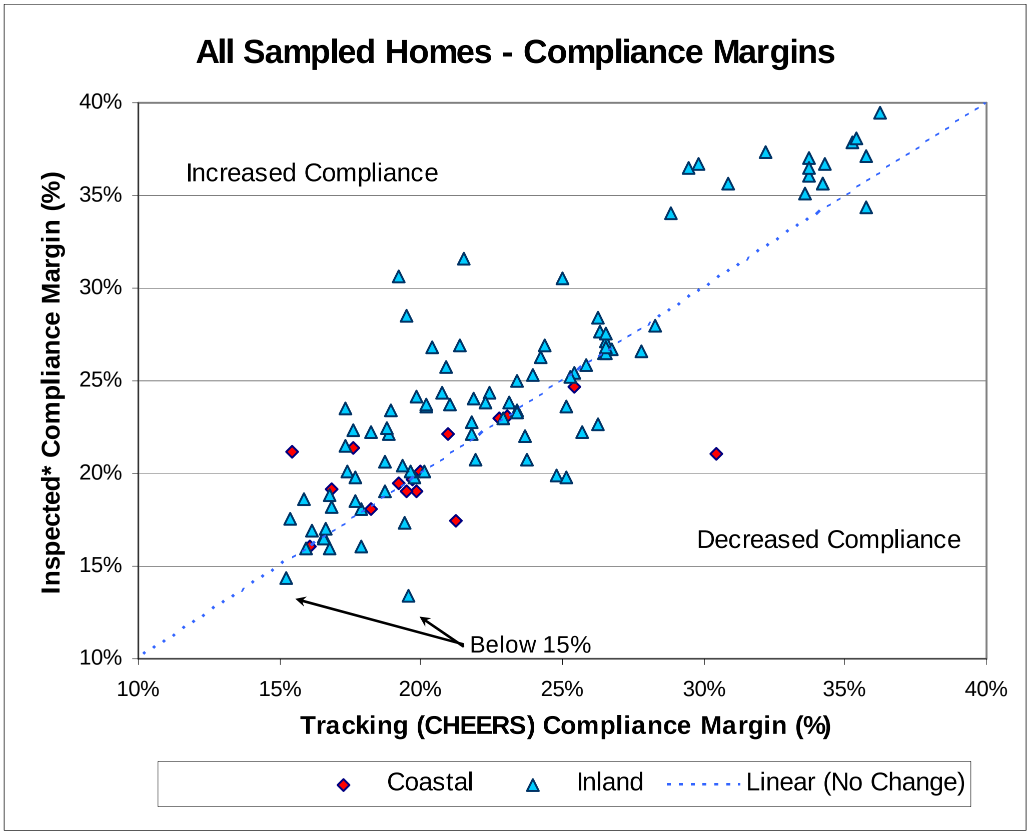

Figure 18: Title 24 Energy Compliance Margins (110 Inspected ENERGY STAR® Homes)

The on-site inspection results were further analyzed by inland and coastal climate zones and end-uses (heating, cooling, water heating). Given the sample size of 110 homes, *ratio estimation was conducted at the climate zone and end-use level, on a statewide basis*. Utility specific b-ratios were not created. The results in Table 19 show that b-ratios vary from 0.93 to 1.15 depending on end-use and climate zone.

Climate Zone	End-Use	Sample Size	**B Ratio**	Standard Error	Lower Bound	Upper Bound	Statistically Significant*
Coastal	Cooling	16	**0.95**	0.10	0.78	1.13	No
	Heating	16	**1.10**	0.08	0.96	1.24	No
	Water Heating	16	**0.93**	0.06	0.83	1.03	No
Inland	Cooling	94	**1.15**	0.03	1.11	1.19	Yes
	Heating	94	**1.04**	0.01	1.02	1.06	Yes
	Water Heating	94	**1.01**	0.02	0.99	1.04	No

Table 19: B-Ratio Estimators

Interpreting B-Ratios

B-ratios less than one indicate less energy savings than planned, while b-ratios greater than one yield increased savings. For example, a b-ratio of 0.95 for coastal cooling indicates that coastal ENERGY STAR® homes on average only achieved 95% of the claimed cooling savings, while the inland cooling b-ratio of 1.15 indicates ES homes on average achieved 115% of the claimed cooling savings in inland regions.

Other Inspection Findings

The inspections also revealed important process findings. Most homes' plans did not match the on-site findings, and re-simulations of the energy models were required for 90% of the inspected homes. Usually the differences in characteristics were few in number, but for a few homes so many differences were found that some of our inspectors wondered if they were at the correct house. *While homes are not built exactly to plan 90% of the time, their energy savings seem to be at least as good as planned, regardless.*

The ratio estimators, or b-ratios, are used to calculate the adjusted savings, shown in **Table 19**, due to differences between as-built findings over plans. A detailed discussion of ratio estimation techniques can be found in **Appendix A – Ratio Estimation**.

On-Site Inspection Methodology

Figure 19 shows the basic steps in the on-site inspections and how the results were used to inform various portions of this report. The primary goal of the inspections is to verify the presence of the measures, in this case the building characteristics that when combined produce an ENERGY STAR® home. The other primary purpose of the inspections is to use as-built data to improve the gross savings estimates.

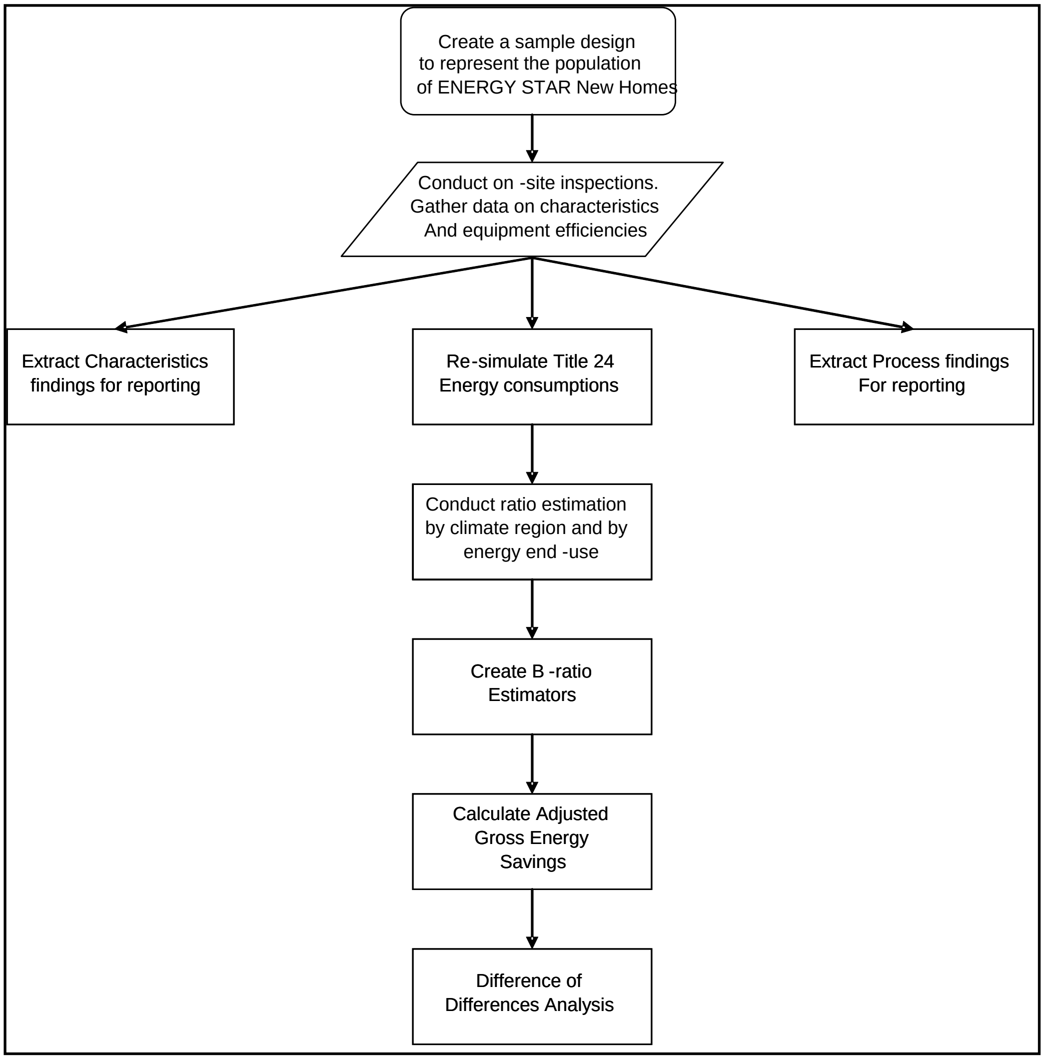

Figure 19: Steps in on-site inspections and analysis of results

Sample Design

A sample of 110 homes were selected from the five Regional Market Share Tracking (RMST) climate zones. Consideration was given as to how this sample should be drawn with the goal of best characterizing how and where ENERGY STAR® Homes are actually being built, and the impacts of their energy savings. The sample design was finalized using a random proportional sample by RMST climate zone.

RMST Climate Zone	Sample Size	Percent
1	5	4.5%
2	11	10.0%
3	35	31.8%
4	47	42.7%
5	12	10.9%
Total	110	100.0%

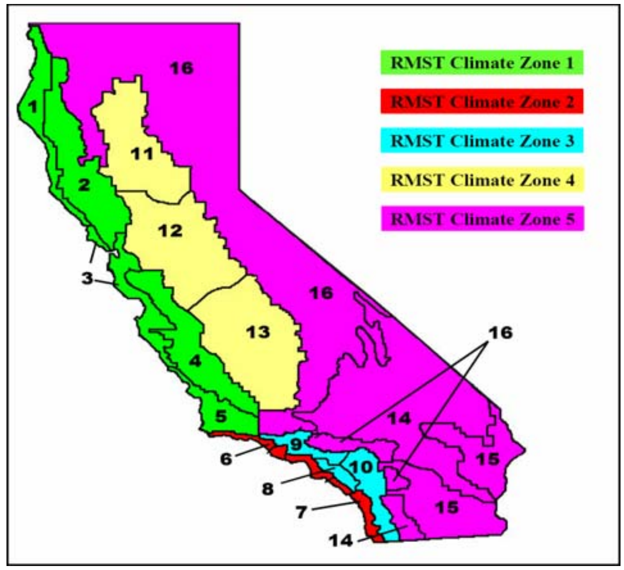

Table 20: CEC and RMST Climate Zone Map

On-Site Inspection Limitations

It was not possible to verify all building characteristics with 100% precision. For example, measuring window SHGC, window U-values, duct sealing, insulation levels in closed walls, and a few other characteristics was not possible. In a few cases some data, particularly for windows, was obtained from homeowner info packages.

Good data on equipment ratings/efficiencies was collected as all equipment is required to have product information labels.

On-Site Verification Characteristics Findings

Generally homes were found to be built slightly more energy efficient than was originally planned. Ninety percent of the inspected homes were found to have one or more characteristics different from their Title 24 plans which required the home to be re-modeled.

The main findings that caused changes in energy consumption were: total window area, equipment efficiencies, radiant barrier, thermal expansion valves, overhangs, and hot water re-circulating timers.

The following graphs and tables show the results for the key characteristics. Results are shown by home, although Home IDs have been suppressed.

Figure 20, Figure 21, and Figure 22 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 plan vs. inspection 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.

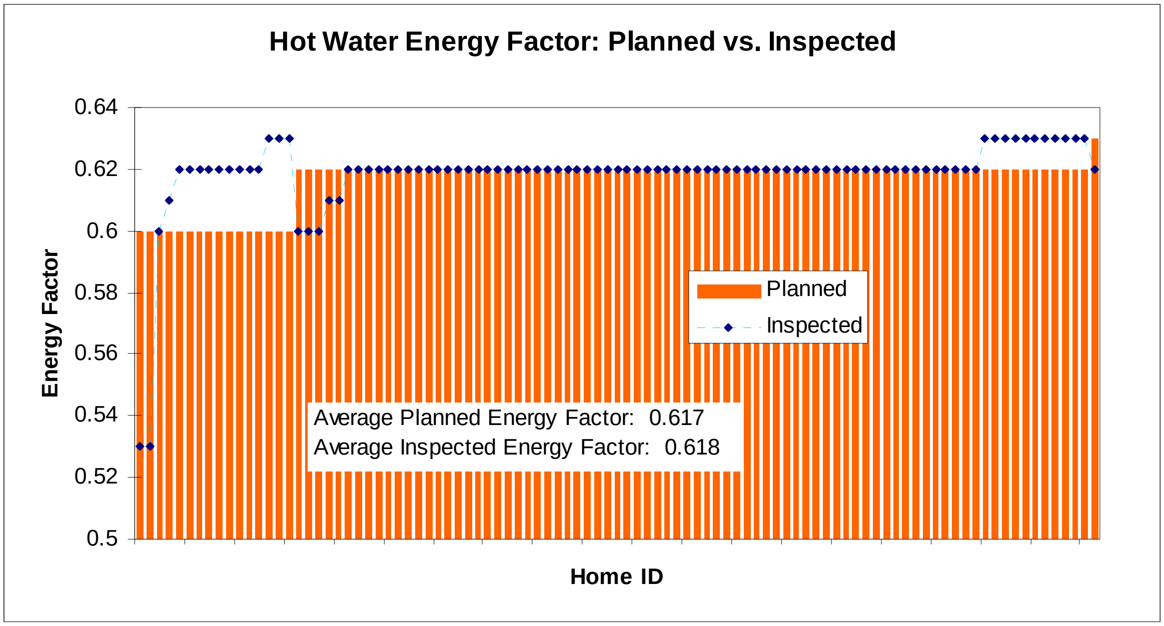

Figure 20: Planned vs. Inspected hot water heater energy factor (Home IDs suppressed)

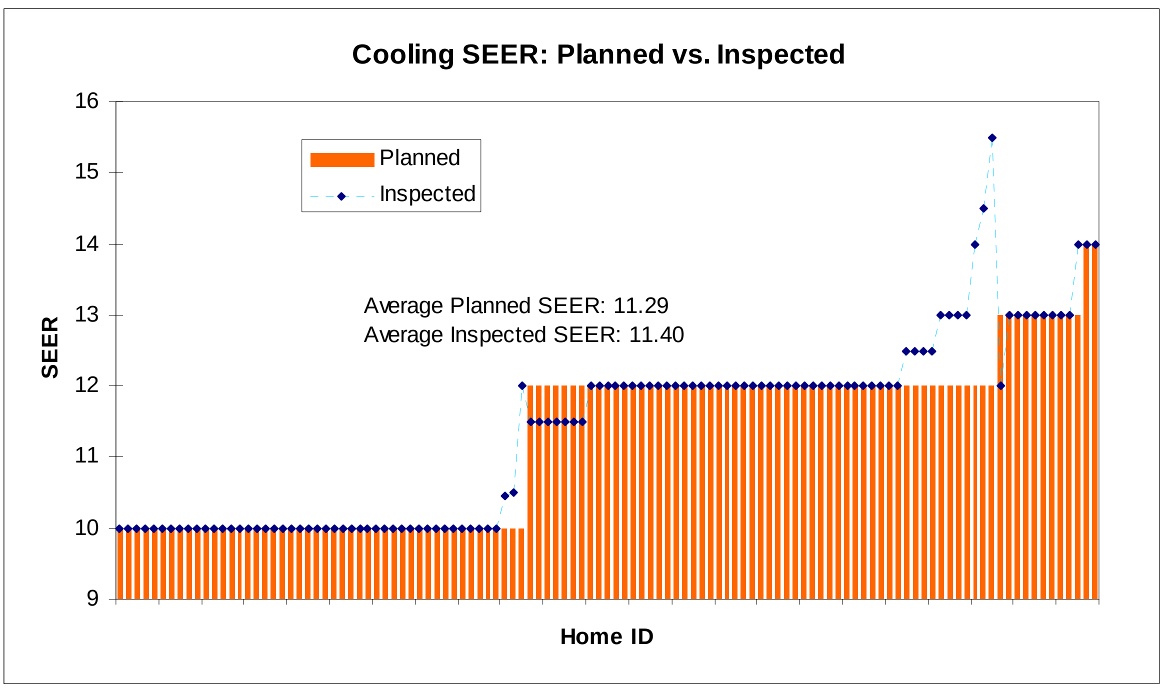

Figure 21: Planned vs. Inspected Cooling SEER

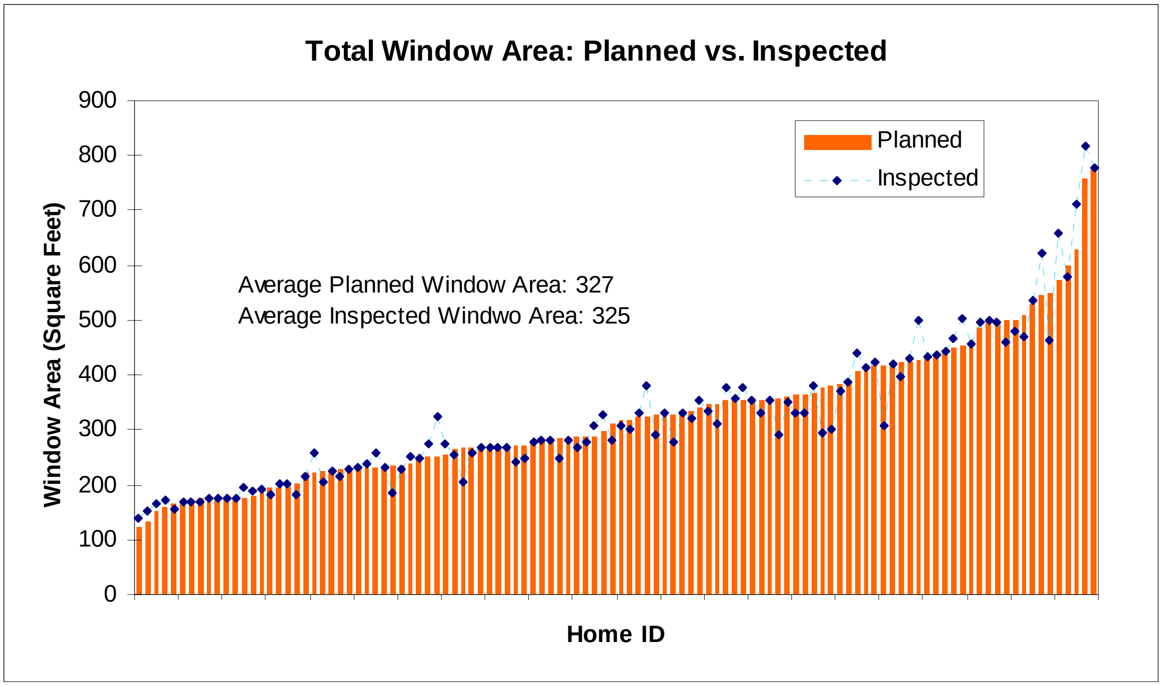

Figure 22: Planned vs. Inspected Total Window Area

Table 21 shows other inspection data in a 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.

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	

Table 21: Planned vs. Inspected Measures (Window Overhangs, Thermal Expansion Valves (TXV), Radiant Barrier, Hot Water Recirculation Controls

As can be seen, single family homes are rarely built as planned, however the average impact on energy seems to be a slight overall *improvement* in energy efficiency. More thorough (and costly) inspections could be done to further quantify differences between plans and as-built findings, but given the results it may not be cost effective to do so.

Title 24 Re-modeling Simulations

RLW Analytics has certified HERS raters on staff and we conduct many Title 24 energy simulations every year.

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 homes require remodeling?

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

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

However, some of these should have been caught by the C-HERS rater if the home was actually inspected,[37] and the changes could reduce energy efficiency. Of the homes RLW inspected, 51 (or 46%) were physically inspected by a C-HERS rater, which suggests the inspection process may not always be providing the intended guarantee of compliance.

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

A key goal of the inspections was to analyze how the findings may impact the energy savings of the program through the Difference-of-differences analysis. As can be seen in the flowchart Figure 19, first the on-site findings needed to be applied to adjust the population. This section explains how this was done.

It is important to note that the ENERGY STAR® Homes Program is based on Compliance Margins, as calculated by Title 24 modeling software such as EnergyPro and Micropas. Compliance Margin is the percentage of energy reduction as compared to a Standard home, of the same size and in the same California climate zone. Therefore Compliance Margin can be affected by changes in the Standard or Proposed modeled energy densities.

Figure 23 shows that the inspected energy savings is closely tied to the planned estimates.

[37] Every measure in each home that is "Approved" is not required to be inspected by a C-HERS rater. Production builders are only required to inspect one out of seven single family homes of the same plan in a project.

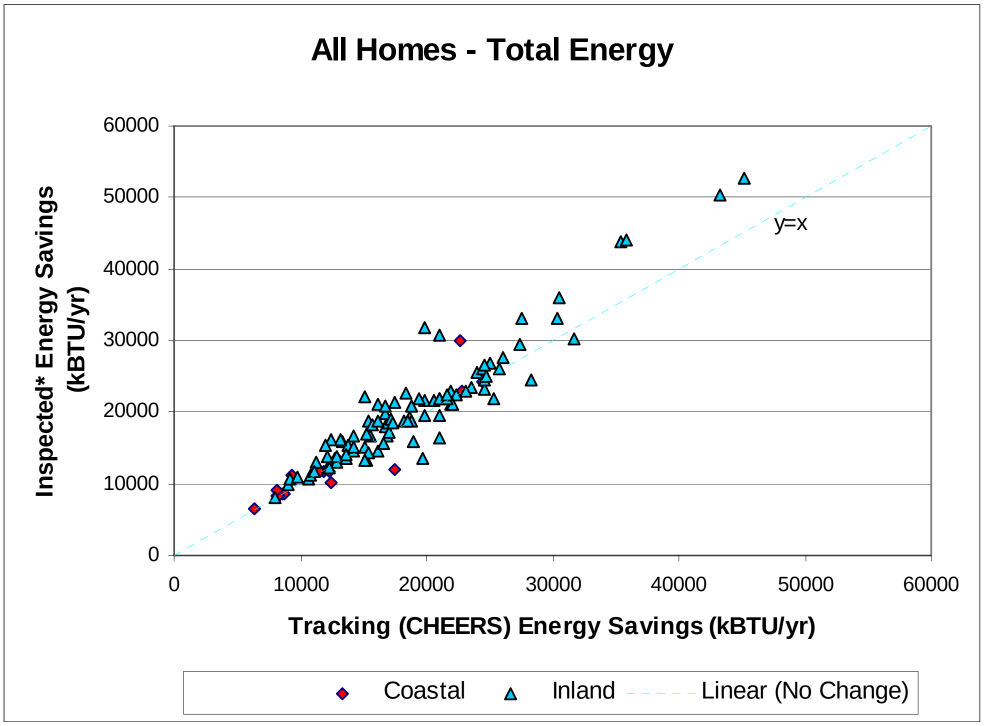

Figure 23: All Inspected Homes – Tracking vs. Inspected Total Energy

Figure 24 through Figure 29 show the Ratio Model Estimate { y=bx } of the energy savings as a function of tracking energy savings, by energy end-use, and by coastal vs. inland climate zones.

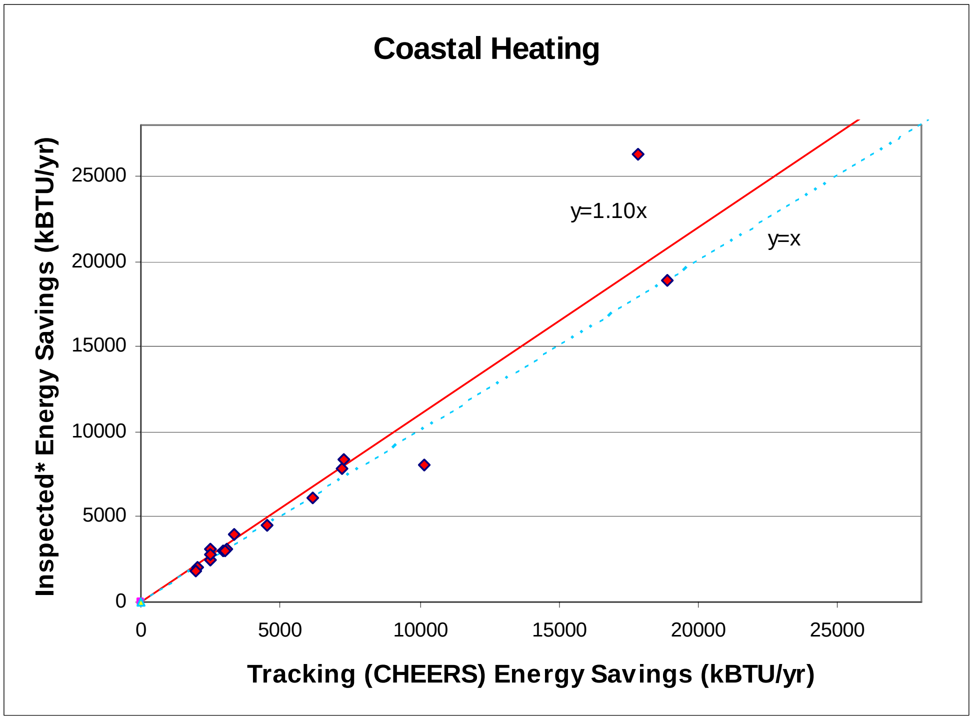

Figure 24: Coastal Heating - Tracking vs. Inspected Energy

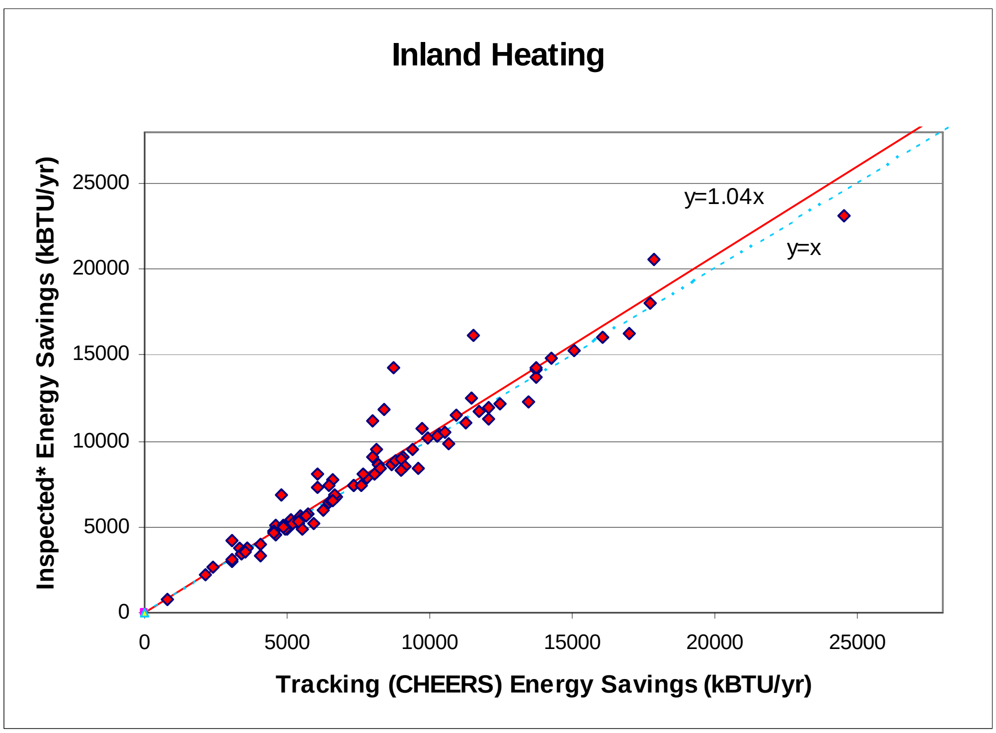

Figure 25: Inland Heating - Tracking vs. Inspected Energy

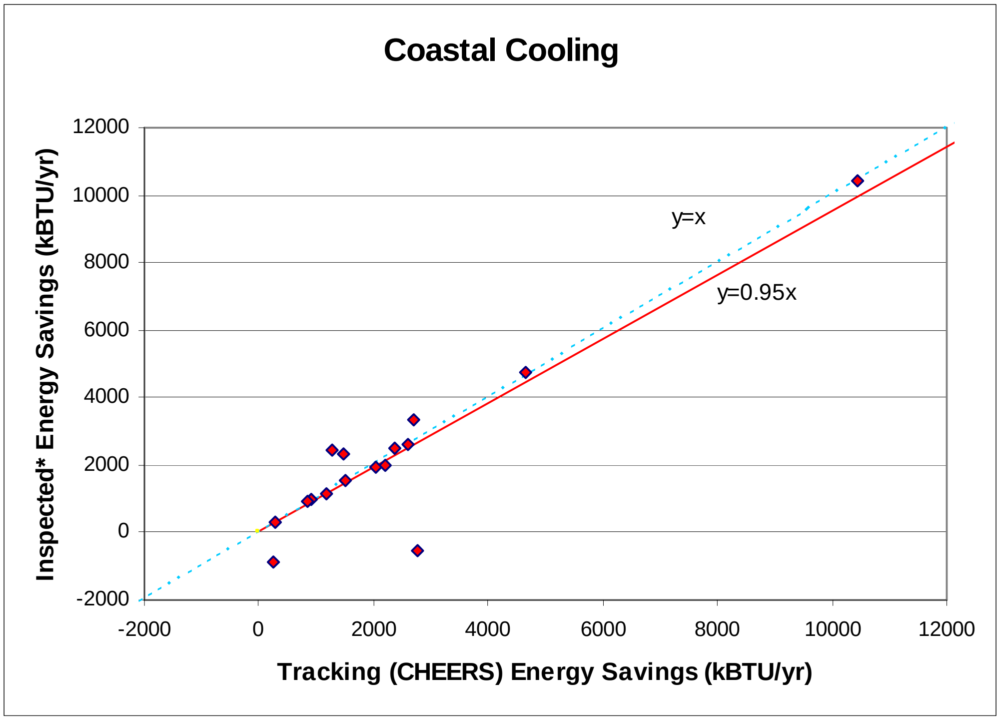

Figure 26: Coastal Cooling - Tracking vs. Inspected Energy

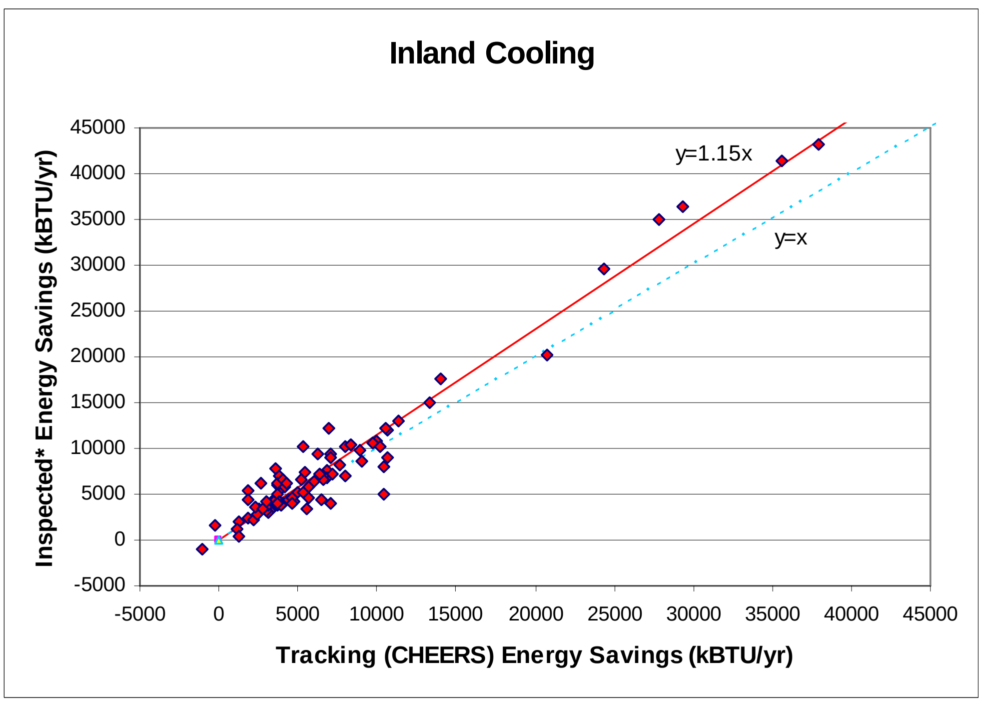

Figure 27: Inland Cooling - Tracking vs. Inspected Energy

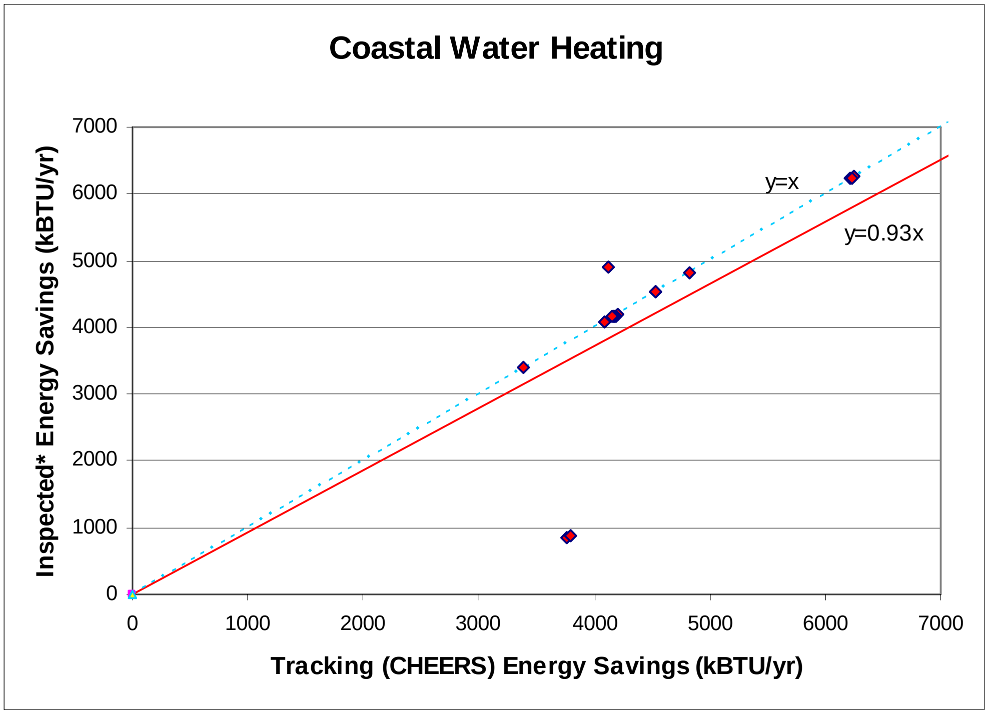

Figure 28: Coastal Water Heating - Tracking vs. Inspected Energy

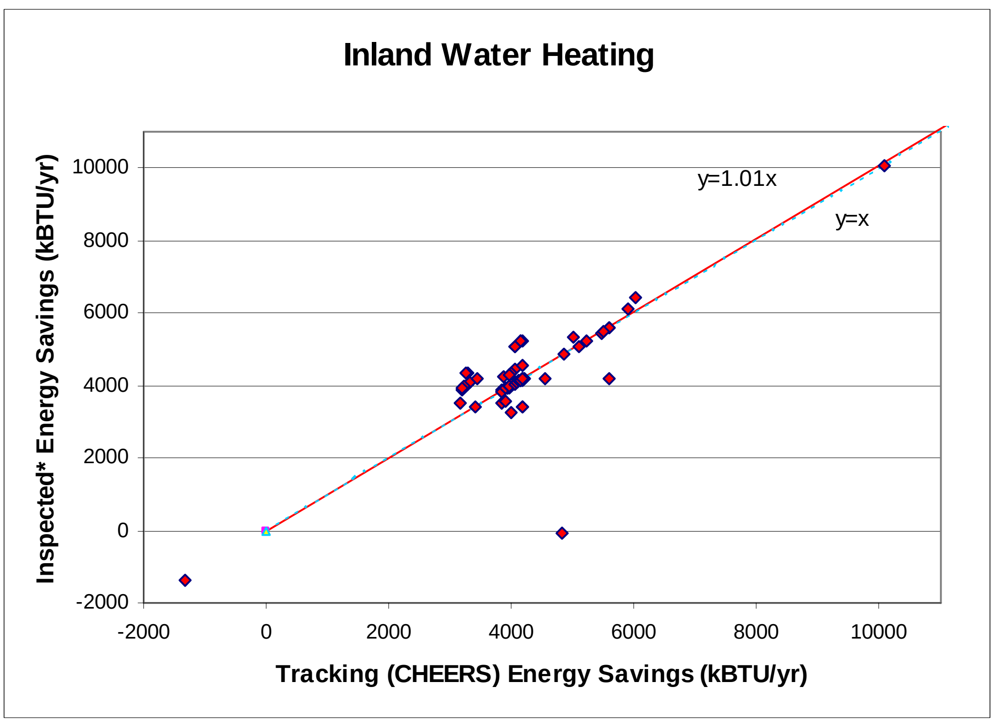

Figure 29: Inland Water Heating - Tracking vs. Inspected Energy

Model Based Ratio Estimation Methodology to Expand On-Site Inspection Results to the Population of ENERGY STAR® Homes

Model Based Ratio Estimation techniques were used to estimate the “true” energy savings due to differences in planned vs. inspected building characteristics. The idea of ratio estimation is to look at the ratio between two quantities which are expected to be highly correlated, which in our case are “planned energy savings” and “inspected energy savings”. A thorough description of ratio estimation can be found in the Appendix, or in the 2004 California Evaluation Framework, Chapter 13.

Weighting

Since the sample was randomly and proportionally drawn within each RMST climate zone, the assumption is being made that the coastal sample homes are representative of the coastal participants, and the inland sample homes are representative of the inland participant homes. The samples were weighted to the total population using strata based on the conditioned floor area of each home.

Interpreting the Inspection Results

It is important to note that both planned 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 energy modeling software, such as EnergyPro or Micropas. Potential bias in the modeling software would impact both planned and “inspected” energy savings. Furthermore, statistical precisions listed in this report are statistically derived and have no component due to variability or bias associated with the modeling software. This study does not attempt to validate or estimate potential biases in energy modeling software currently used for California Title 24 compliance.

As an example, **Figure 25: Inland Heating - Tracking vs. Inspected Energy**, gives the impression that Tracking (Planned) Energy Savings is a very accurate indicator of true energy savings. This may or may not be true. This interpretation would only be correct if the modeling software provides an accurate and unbiased estimate of energy savings based on building characteristics.

In summary, interpretation of these results must be done in context of the methodology. The “ruler” (Title 24 energy modeling software) used to measure program qualification, is the same ruler used to then measure program effectiveness. If the “ruler” is off, there is no way to know.

7. Adjusted Gross Energy Savings

Introduction

Adjusted gross savings are determined by application of the b-ratio estimators determined by on-site inspections, described in the previous chapter.

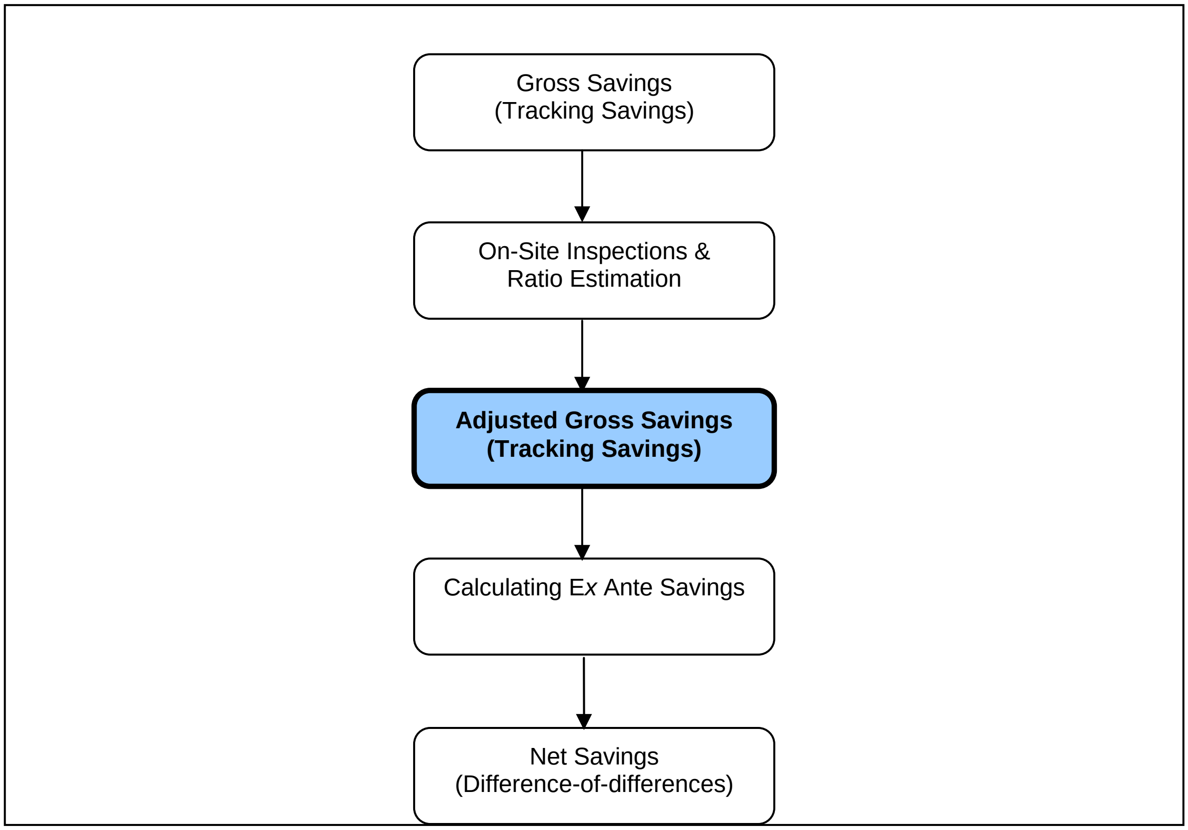

Figure 30: Single Family Gross and Net Energy Savings Calculation Flowchart

Summary of Key Findings

The overall impact of the inspection energy savings adjustments is an *average 6% increase* in Gross energy savings, as can be seen in Table 22.

Utility	Units	Tracking Savings (kBTU/year)	Adjusted Savings (kBTU/yr)	Percent Change
PGE	2955	53,466,798	56,277,704	5.3%
SCE	2311	39,348,833	42,434,887	7.8%
SCG	432	10,209,890	11,449,272	12.1%
SDGE	1152	12,079,898	12,336,011	2.1%
Total	6850	115,105,419	122,497,874	6.4%

Table 22: Tracking Savings and Adjusted Savings of Completed 02/03 Participant Homes

Note that the Adjusted Tracking Savings are calculated at the end-use and region level, using ratio estimation. Table 23 further breaks out the Adjusted Tracking Savings by year, utility and climate region.

Utility	Year Completed	Climate Region	Number Homes	Adjusted Savings (kBTU/year)	% of total
PGE	2002	Coastal	19	462,430	0%
		Inland	455	8,301,169	7%
	2003	Coastal	252	4,545,038	4%
		Inland	2,229	42,969,066	35%
SCE	2002	Inland	91	1,930,766	2%
	2003	Inland	2,220	40,504,121	33%
SCG	2002	Coastal	6	51,987	0%
		Inland	21	651,417	1%
	2003	Coastal	30	231,430	0%
		Inland	375	10,514,437	9%
SDGE	2002	Coastal	247	2,173,881	2%
		Inland	3	36,381	0%
	2003	Coastal	641	5,844,394	5%
		Inland	261	4,281,355	3%
Total	2002/03		6,850	122,497,874	100%

Table 23: Adjusted Tracking Savings by Utility, Year, and Climate Region

Methodology for Calculating Adjusted Savings

For the purposes of calculating adjusted energy savings, we have applied all b-ratios using ratio estimation for all program participants. Even though not all b-ratios are statistically significant at the 90% confidence level, they still represent our best estimate of the true as-built energy savings for program participants.

	Coastal Tracking Savings (kBTU/yr)	Inland Tracking Savings (kBTU/yr)	**Total Gross Tracking Savings (kBTU/yr)**	Coastal b-ratios	Inland b-ratios	Coastal Adjusted Savings (kBTU/yr)	Inland Adjusted Savings (kBTU/yr)	**Total Gross Adjusted Savings (kBTU/yr)**
Cooling	2,206,618	34,660,348	**36,866,966**	0.95	1.15	2,102,629	39,911,649	**42,014,278**
Heating	5,717,687	45,204,935	**50,922,622**	1.10	1.04	6,284,056	46,948,648	**53,232,705**
Water Heating	5,293,152	22,022,679	**27,315,830**	0.93	1.01	4,922,475	22,328,416	**27,250,891**
Total	13,217,456	101,887,962	**115,105,418**			13,309,161	109,188,713	**122,497,874**

Table 24: B-Ratio Estimation Effect on Gross Savings

Figure 31 shows the total single family adjusted gross energy savings relative to proposed energy, by end-use. The full height of the bar represents “standard” design, as defined by Package D in Title 24 modeling software. It is evident that the adjusted gross energy savings are a significant part of the totals; however, as will be seen in Chapter 8, some of the gross savings are naturally occurring, dramatically impacting net savings.

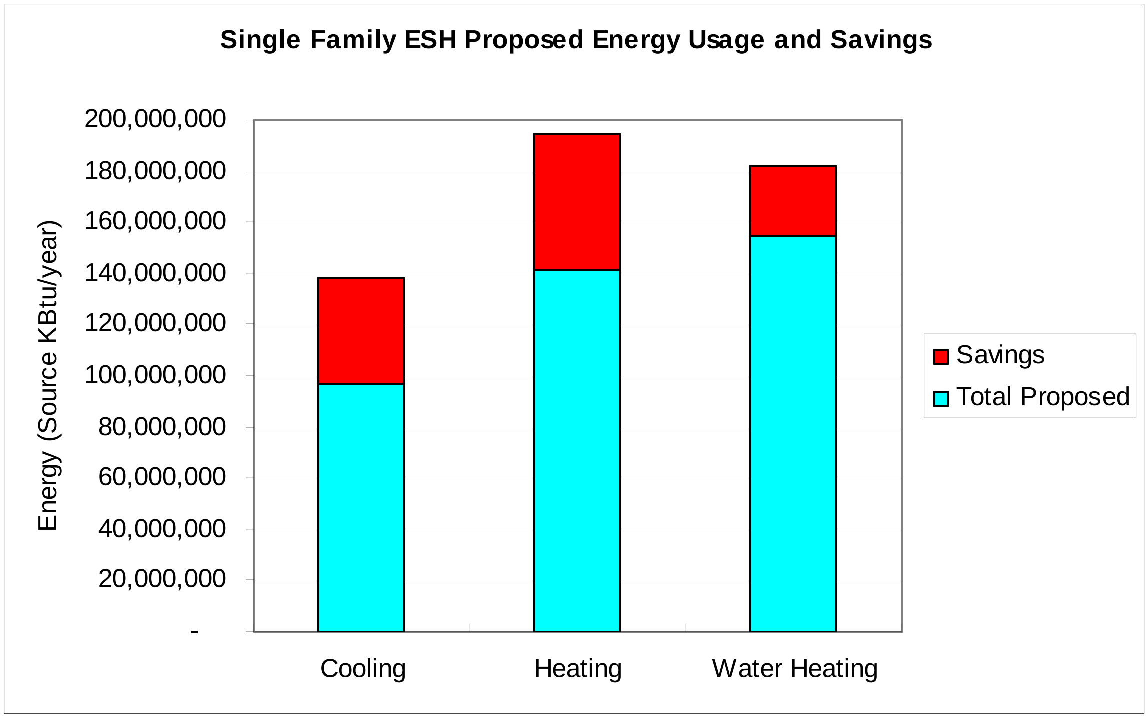

Figure 31: Single Family ENERGY STAR® Homes Adjusted Gross Energy Savings with Total Proposed Energy

8. Single Family *Ex* Ante Savings

This chapter presents the approach to calculating the ex ante savings estimate.

Introduction

Normally, evaluation studies measure the actual energy impacts of a program and compare the results to the savings estimates provided by the program implementer. The implementer's estimate of savings is most often referred to as the "*ex* ante" value, while the evaluator's best estimate of savings is referred to as the "*ex* post".

For this program there was no *ex* ante estimate provided by the implementers, therefore it was necessary to work with them in order to produce an *ex* ante estimate. The ex ante estimate is important because it allows the evaluation results to be compared to something meaningful.

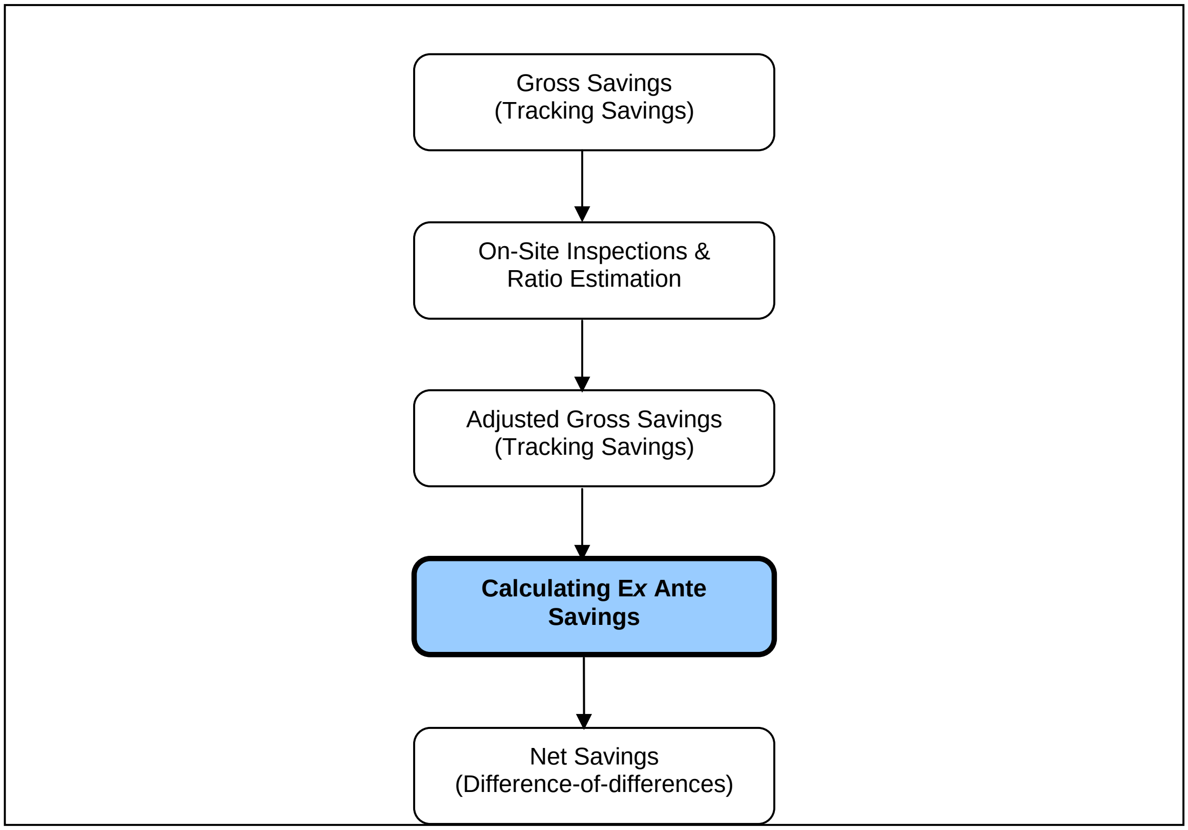

Figure 32: Single Family Gross and Net Energy Savings Calculation Flowchart

Single Family Ex Ante Results

Table 25 shows the total gross and net ex ante values by utility and by year.

	2002				2003			
	Gross Ex Ante		Net Ex Ante		Gross Ex Ante		Net Ex Ante	
	kWh	Therms	kWh	Therms	kWh	Therms	kWh	Therms
PG&E	139,830	67,785	111,864	54,228	679,794	346,100	543,835	276,880
SCE	78,897	None	63,118	None	2,938,170	None	2,350,536	None
SCG	None	None	None	None	332,250	7,500	265,800	6,000
SDG&E	193,319	(1,377)	154,655	(1,102)	679,535	1,526	543,628	1,221
Total	**412,046**	**66,408**	**329,637**	**53,126**	**4,629,749**	**355,126**	**3,703,799**	**284,100**

Table 25: Gross and Net Ex Ante Values by Utility and Year

Methodology

The approach to calculating the ex ante values first required data from each utility. RLW worked with each of the four implementers to obtain their planning estimates of energy savings for single family participant homes. The estimates were provided for both 2002 and 2003 program years, and often included different estimates for regional differences (coastal vs. inland) and compliance margin (15% vs. 20%). Table 26 and Table 27 present the per unit savings values provided to RLW by the utilities, for 2002 and 2003 respectively. In some cases savings values were not provided (denoted by "NA"), either because there were no plans to build homes in the particular category (example, 2002 SCG), or because savings cannot be claimed by the utility (example, 2002 SCE Therm savings).

	2002 Per Unit kWh Savings			Per Unit Therm Savings	
Utility	Compliance	Coastal	Inland	Coastal	Inland
PG&E	SF 15%	295		143.22	
	SF 20%				
SCG	SF 15%	NA		NA	
	SF 20%				
SDG&E	SF 15%	770	1043	-6	35
	SF 20%	NA	NA	NA	NA
SCE	SF 15%	450	867	NA	
	SF 20%	NA	NA		

Table 26: 2002 SF Per Unit kWh and Therm Savings Estimates by Utility

	2003 Per Unit kWh Savings			Per Unit Therm Savings	
Utility	Compliance	Coastal	Inland	Coastal	Inland
PG&E	SF 15%	274		139.5	
	SF 20%				
SCG	SF 15%	NA	885.9	NA	19.6
	SF 20%	NA	NA	NA	NA
SDG&E	SF 15%	699.4	885.9	-5.6	19.6
	SF 20%	NA	NA	NA	NA
SCE	SF 15%	630	1153	NA	
	SF 20%	NA	1494		

Table 27: 2003 SF Per Unit kWh and Therm Savings Estimates by Utility

Using the CHEERS Registry, RLW determined the number of homes "approved" in each of the two evaluation years, 2002 and 2003. Since the registry data does not indicate whether the home is a 15% or 20% compliance margin participant, RLW was not able to distinguish between the two. In one case (SCE 2003 inland kWh savings per unit) the average of the 15% and 20% savings estimates was used). Figure 33 shows the number of homes considered "approved", or complete, by evaluation year and the IOU PIP estimates. The number of completed homes times the unit savings is equal to the gross ex ante. Totals are shown in the bottom gray cells, 6,850 participant homes were approved in 2002 and 2003, thus these homes constitute the evaluation population for the 2002 and 2003 single family program.

Utility	Year Completed	Climate Region	"Approved" Homes	PIP kWh Savings/Home	PIP Therms Savings/Home
PGE	2002	Coastal	14	295	143
		Inland	460	295	143
	2003	Coastal	215	274	140
		Inland	2,266	274	140
SCE	2002	Coastal	0	630	NA
		Inland	91	867	NA
	2003	Coastal	0	630	NA
		Inland	2,220	1,324	NA
SCG	2002	Coastal	6	None	NA
		Inland	21	None	NA
	2003	Coastal	30	None	NA
		Inland	375	886	20
SDGE	2002	Coastal	247	770	-6
		Inland	3	1,043	35
	2003	Coastal	641	699	-6
		Inland	261	886	20
Totals	**2002**	**Coastal**	**267**	**NA**	**NA**
		Inland	**575**		
	2003	**Coastal**	**886**	**NA**	
		Inland	**5,122**		

Figure 33: Number of Approved Homes and Average Savings

Lastly, RLW applied a factor of 0.8 to account for free-ridership. The 0.8 factor is the value used for program planning purposes as the deemed net-to-gross for this particular program. Thus, the ex ante is the net ex ante, just as the ex post presented in the next chapter is the net *ex* post. Table 28 shows the net ex ante savings for each evaluation year, 2002 and 2003, as well as by utility and fuel. The increase in total savings between 2002 and 2003 is a result of the number of homes completed, 1,043 and 5,807 respectively (see Figure 33).

	2002 Net Ex Ante		2003 Net Ex Ante	
	kWh	**Therms**	**kWh**	**Therms**
PG&E	111,864	54,228	543,835	276,880
SCE	63,118	None	2,350,536	None
SCG	None	None	265,800	6,000
SDG&E	154,655	(1,102)	543,628	1,221
Total	**329,637**	**53,126**	**3,703,799**	**284,100**

Table 28: Net *Ex* Ante Savings

9. Net Savings: Difference-of-differences Analysis

Introduction

Net Savings are the ultimate goal of the impact analysis. In this section, we combined all the previous results and applied the "difference-of-differences" analysis, the essence of which is to compare ENERGY STAR® Homes (participants) to standard construction practices (non-participants). The previous chapters were concerned with gross savings, defined as the difference between Standard (package D) and Proposed modeled energy consumption. Net Savings are defined as the gross savings less naturally occurring savings (the natural savings of similar non-participants over the industry standard practice). Data was used on the standard and proposed energy usages for all non-participant homes from the RNC baseline database, and compared the savings of the non-participants to the savings of the ENERGY STAR® participant homes. Their difference becomes the estimate of net savings.

Net Savings = [Gross participant savings] – [naturally occurring savings]

The calculation methodology can be found in Appendix B.

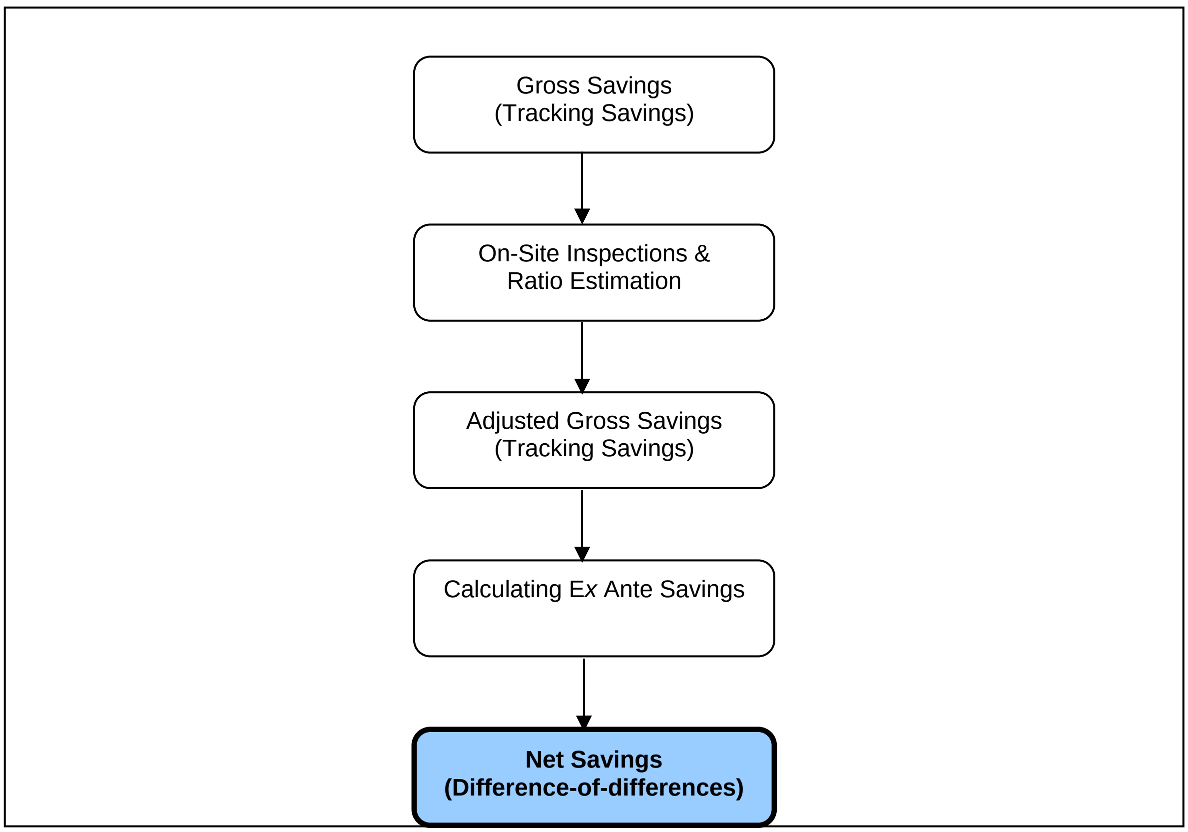

Figure 34: Single Family Gross and Net Energy Savings Calculation Flowchart

Summary of Results

The following two tables show the net to gross ratios for kWh and Therms respectively. The Gross Ex Post is the Simple Adjusted Gross Savings result for each year. The Net Ex Post is the Difference-of-differences result.

Electricity NTG ratios vary widely across IOUs and program years, from -0.20 to 2.25. The statewide electric NTG ratio is 1.51 for 2002, and 1.21 for 2003, implying negative free-ridership both years. This is consistent with the new construction baseline study used for the analysis, and is a direct result of negative naturally occurring cooling savings among non-participants.[38] That is, on average, non-participant homes do not meet Title 24 package D cooling energy budgets. In fact, the non-participant baseline study found that 27% of homes surveyed did not meet Title 24 energy requirements period.

	Gross Ex Post 2002	Net Ex Post 2002	NTG RATIO 2002	Gross Ex Post 2003	Net Ex Post 2003	NTG RATIO 2003
PGE	168,922	380,763	2.25	1,031,724	1,818,960	1.76
SCE	92,391	78,456	0.85	1,669,846	1,431,206	0.86
SCG	55,687	73,252	1.32	858,507	1,181,588	1.38
SDGE	31,160	-6,114	-0.20	197,678	107,880	0.55
Total	**348,160**	**526,358**	**1.51**	**3,757,756**	**4,539,634**	**1.21**

Table 29: kWh Net to Gross Ratios By Year

Gas NTG ratios are more consistent across IOUs and program years. <u>The statewide gas NTG ratio is 0.63 for 2002 and 0.44 for 2003, implying high average free ridership of 53%.</u> This is a direct result of high naturally occurring savings in the two gas end-uses, heating and especially water heating.

	Gross Ex Post 2002	Net Ex Post 2002	NTG RATIO 2002	Gross Ex Post 2003	Net Ex Post 2003	NTG RATIO 2003
PGE	70,344	46,056	0.65	369,529	216,725	0.59
SCE	9,850	6,728	0.68	234,109	55,130	0.24
SCG	1,334	461	0.35	19,578	6,489	0.33
SDGE	18,913	9,755	0.52	81,022	34,184	0.42
Total	**100,441**	**63,000**	**0.63**	**704,239**	**312,528**	**0.44**

Table 30: Therms Net to Gross Ratios By Year

Single Family Energy Savings

Single family net energy savings were calculated based on actual homes completed in calendar years 2002 and 2003; there were 6850 homes. Ex ante estimates were

[38] As determined by the 2004 California Residential New Construction Baseline Study (Itron, 2004). Non-participant homes exceeded cooling budgets primarily in inland climate zones. Some homes made up the deficit with energy savings in other areas (heating or hot water), but the study found that 27% of homes surveyed were not Title 24 compliant. The compliance of another 30% could not be determined within the error bounds of the data collected.

calculated for each utility based on per unit savings estimates and the number of homes actually built in 2002 and 2003.[39] Ex post savings were estimated using the difference-of-differences (DofD) methodology, detailed in this report. The essence of this method is to compare ENERGY STAR® Homes (participants) to standard construction practices (non-participants), determined from a non-participant new construction baseline study, to subtract out naturally occurring savings. The result is ex post (net) savings.

	2002 kWh			**2003 kWh**		
	Ex Ante	***Ex Post***	***Realization Rate***	***Ex Ante***	***Ex Post***	***Realization Rate***
PG&E	111,864	380,763	340%	543,835	1,818,960	334%
SCE	63,118	78,456	124%	2,350,536	1,431,206	61%
SCG	No est.	73,252	NA	265,800	1,181,588	445%
SDG&E	154,655	-6,114	-4%	543,628	107,880	20%

Table 31: Single Family Electricity Net Savings & Realization Rates

Single family gas savings and realization rates are:

	2002 Therms			**2003 Therms**		
	Ex Ante	***Ex Post***	***Realization Rate***	***Ex Ante***	***Ex Post***	***Realization Rate***
PG&E	54,228	46,056	85%	276,880	216,725	78%
SCE	No Est.	6,728	NA	No Est.	55,130	NA
SCG	No Est.	461	NA	6,000	6,489	108%
SDG&E	-1,102	9,755	NA	1,221	34,184	2800%

Table 32: Single Family Gas Net Savings & Realization Rates

The results of the net savings analysis are also presented in the bar-chart below. The total height of each bar represents the standard design, or Title 24 Package D energy use. Energy savings are divided into two parts – the naturally occurring savings, and the net savings calculated using the difference-of-differences method. Statewide all three end-uses consume roughly equal amounts of source energy. In almost all homes, heating and water heating are natural gas fueled, while cooling is electric. The ENERGY STAR® Homes program's largest net source energy savings are derived from cooling, while the smallest are from water heating. Also note that the negative natural savings for cooling indicates that new non ENERGY STAR® Homes do not meet minimum Title 24 requirements, on average.

Several results are evident.

- The three end-uses consume roughly equal amounts of source energy.
- The ESH program's largest net source energy savings are derived from cooling, while the smallest are from water heating.
- Negative natural savings for cooling means that new non ENERGY STAR® Homes on average do not meet Title 24 cooling budget requirements.

[39] At the time utilities filed Program information with the CPUC, estimates were based on homes committed (approved applications) within a Program year – not constructed. Since that time, it was determined to conduct this evaluation based on homes actually constructed within a Program year. Due to this accounting change, it was necessary to calculate new ex ante estimates.

- Significant naturally occurring (gas) savings are present for heating and water heating, translating to high gas free-ridership rates.
- The average as-proposed ENERGY STAR® home uses the most energy for water heating among the three end-uses. Most of the program savings in energy use comes from heating and cooling.

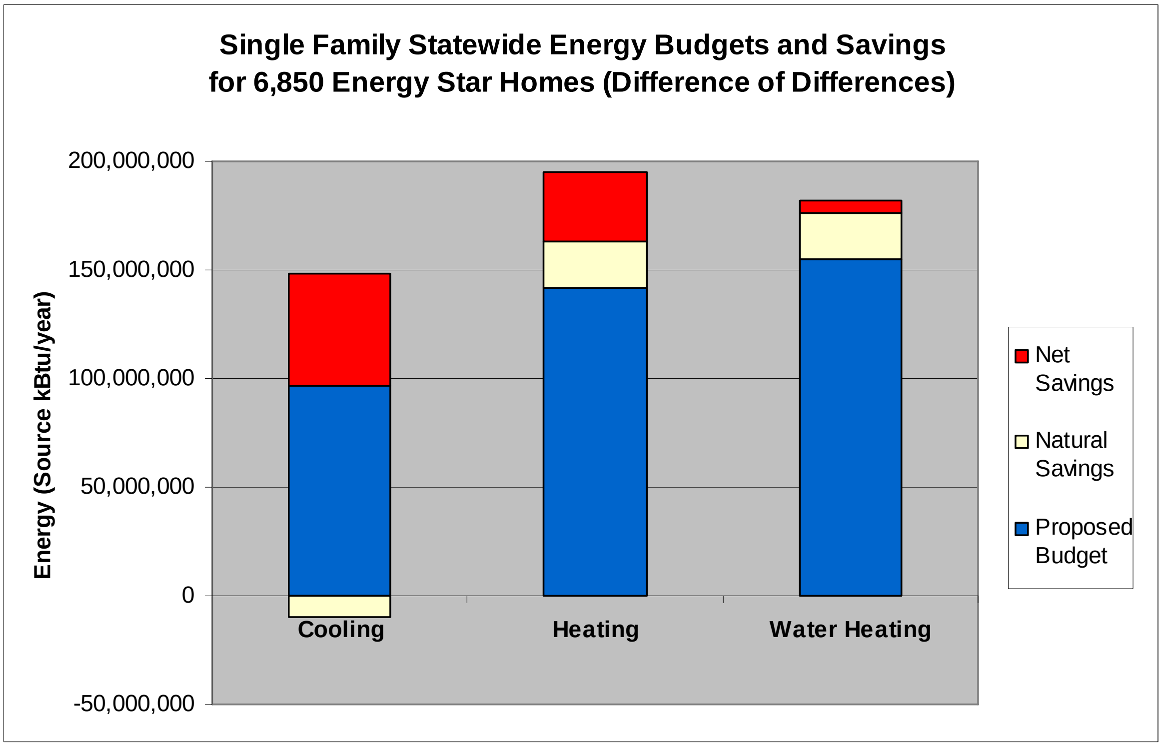

Figure 35: Single Family Net Energy Savings

10. Single Family Spillover

Spillover, defined as program induced Non-Participant energy savings, is generally difficult to assess since impact evaluation efforts tend to focus on Participants. Although there are many possible ways to attempt to assess spillover, this study focused on builders with a combination of participant and non-participant projects which may have spillover from one project to the other. Although a more exhaustive spillover study may yield different results, our analysis was not able to detect any spillover effects using the data available through the RNC baseline study. That is, no significant energy differences were found between different groups of Non-Participants as defined in our analysis. As a result, all 575 baseline homes were used in the Difference-of-differences analysis. Details of the spillover analysis methodology follow. The Itron baseline study data was segmented into four distinct groups of non-participants:

- Partial-Participant Non-Participants (100)
- Possible Partial-Participant Non-Participants (135)
- True Non-Participants (297)
- Unknown status Non-Participants (43)

Partial-participant non-participants were defined to be non-participant builders that also had participant projects that were managed and constructed from the same office. Possible partial-participant non-participants were defined to be non-participant builders that also had participant projects, but the participant projects were managed and constructed from a different office of the same builder company. True non-participants were defined to be non-participant builders that had no participation in energy efficiency programs in the last four years, and unknown status non-participants were non-participants that could not be definitively assigned to one of the above three categories. Of the 575 homes in the baseline study data, we designated 100 homes as partial-participant non-participants, 135 as possible partial participant non-participants, 297 as true non-participants, and 43 as unknown status non-participants.

The spillover analysis attempted to estimate energy savings differences between Partial Participant Non-Participants (100) and True Non-Participants (297). The analysis was also repeated by grouping the Partial Participant Non-Participants (100) and Possible Partial Participant Non-Participants (135), and comparing this group to the True Non-Participants.

To determine the non-participant spillover energy savings attributable to the program, we utilized the “Difference-of-differences” approach to compare the performances of two distinct groups (i.e. the Partial-Participant Non-Participants to the True Non-Participants). The Difference-of-differences analysis utilized for this analysis is the same as that previously discussed, but with one exception - the participant group was replaced by the group of partial participant non-participants in order to measure the possible spillover.

The specifics of the approach are similar to the Difference-of-differences description outlined in Appendix C. We first applied weights to the data on partial participant non-participants so that the sample data from this group can be extrapolated to the population of the same group. We then used case weights to the other group of true non-participants in order to extrapolate the true non-participant sample data to a population that is similar in composition to the population of partial non-participants.

The results of the comparisons found the total spillover savings to be negative for both groupings of partial participants. However, the difference in savings between the two groups was found to be very small and insignificant in both the comparisons. We additionally performed statistical tests to compare the mean energy savings of these two groups of non-participants. We could not reject the null hypothesis that the difference in savings between the two groups is significantly different from zero, and therefore we did not estimate any spillover savings using this method.

11. Single Family Building Characteristics Comparisons

This section compares the building and efficiency characteristics of the single-family homes participating in the 2002 ENERGY STAR® New Homes Program to the homes included in the 2004 Residential New Construction Baseline Study. This chapter only focuses on the major elements of residential construction effecting building energy efficiency and consumption.

Sample Sizes

Table 33 shows the number of homes that have been included in the following analysis. The data is presented by RMST zone, and in total. In total, 575 non-participants were used, while 10,965 participants[40] were used to make the following comparisons.

RMST Zones	Non-participants	Participants
RMST 1	42	515
RMST 2	88	1266
RMST 3	127	5442
RMST 4	277	3005
RMST 5	41	737

Table 33: Number of Homes Included in Analysis

Conditioned Floor Area

Table 34 compares the average conditioned floor area in ENERGY STAR® and non-participant homes by climate zone. ENERGY STAR® Homes are on average about 131 square feet smaller than non-participant homes. The most dramatic differences are in zone 1 (north coastal) and zone 5 (desert and mountain areas), where ENERGY STAR® Homes are 383 and 576 square feet smaller, respectively. In general however, the differences are quite small, suggesting that home size is roughly equivalent between participants and non-participants.

Climate Zone	ESTAR Conditioned Floor Area	NP Conditioned Floor Area
RMST CZ1	2,147	2,530
RMST CZ2	2,833	2,848
RMST CZ3	2,498	2,699
RMST CZ4	2,296	2,432
RMST CZ5	1,929	2,505
Overall	**2,427**	**2,558**

[40] At the time this building-characteristics analysis was conducted, program year was used to determine participant population.

Table 34: Conditioned Floor Area by Climate Zone

Domestic Hot Water

Table 35 compares ENERGY STAR® home participant and non-participant domestic water system types by climate zone. Overall, instantaneous systems are slightly more prevalent in ENERGY STAR® homes. The most dramatic difference is in Zone 1 (Northern Coastal), where nearly 40% of participant water heaters and only 5% of non-participant water heaters are instantaneous. It may be that these systems are utilized more in coastal zones because of there are limited opportunities to exceed Title 24 using cooling improvements, owing to small cooling budgets in coastal areas.

Only 6% of water heaters are "Large", Large water heaters are storage type systems greater than 75 gallons. Large systems conform to a different efficiency metric and are rated in recovery efficiency rather than energy factor.

Climate Zone	ESTAR Participants			Non-Participants		
	Storage	Instantaneous	Large	Storage	Instantaneous	Boiler
RMST CZ1	63%	37%	0%	95%	5%	0%
RMST CZ2	89%	0%	11%	97%	0%	3%
RMST CZ3	90%	2%	9%	98%	2%	0%
RMST CZ4	97%	0%	3%	100%	0%	0%
RMST CZ5	100%	0%	0%	100%	0%	0%
Overall	**91%**	**3%**	**6%**	**99%**	**1%**	**0%**

Table 35: Tank Types by Climate Zone

Table 35 shows average storage tank size for participants and non-participants by climate zone.[41] Overall, storage water heaters in ENERGY STAR® Homes have slightly smaller tanks than storage water heaters in non-participant homes.

Climate Zone	ESTAR Storage Tank Size	NP Storage Tank Size
RMST CZ1	50	51
RMST CZ2	51	57
RMST CZ3	49	55
RMST CZ4	46	50
RMST CZ5	49	51
Overall	**48**	**52**

Table 36: Storage Tank Size by Climate Zone

[41] When calculating the average tank sizes, we have restricted the calculations to storage water heaters only.

The efficiency of a storage water heater is indicated by its energy factor (EF). This number includes both the conversion of the fuel source to hot water and the standby losses - heat lost through the tank surfaces. In general, smaller water tanks are more efficient than larger ones because there is less standby loss. The energy factor combines tank volume, internal insulation, recovery efficiency and standby loss. The higher the energy factor the more efficient the water heater.

Table 37 shows the average energy factor for storage water heaters in ENERGY STAR® Homes and non-participants by climate zone.[42] Overall, storage water heaters in ENERGY STAR® Homes are more efficient than non-participant storage water heaters.

Climate Zone	ESTAR Energy Factor	NP Energy Factor
RMST CZ1	0.60	0.60
RMST CZ2	0.60	0.57
RMST CZ3	0.61	0.58
RMST CZ4	0.62	0.59
RMST CZ5	0.61	0.59
Overall	**0.61**	**0.59**

Table 37: Average Energy Factor by Climate Zone

Heating Equipment

The efficiency of a furnace is measured by its AFUE (annual fuel utilization efficiency). The federal appliance standards require that furnaces have a minimum rating of 0.78 (at least 78% efficient).[43] Furnaces with an AFUE of 0.90 or better qualify for the ENERGY STAR® label.

Table 38 compares the average AFUE in ENERGY STAR® Homes to baseline homes by climate zone.[44] Overall, both ENERGY STAR® Homes and baseline homes have an average AFUE of 0.82. In the coastal zones (zone 1 and zone 2), the baseline homes, on average, have slightly more efficient furnaces than ENERGY STAR® Homes, whereas in the Central Valley (zone 4) and the mountain and desert areas (zone 5), the furnaces in ENERGY STAR® Homes are slightly more efficient than those found in baseline homes.

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[42] We have omitted 6 baseline homes in calculating the average non-participant energy factor. These 6 homes had water heater tank sizes of 100 gallons, yet were rated in Energy Factor. The maximum tank size is 75 gallons for efficiency ratings using energy factor.

[43] ENERGY STAR Program Website, www.energystar.gov

[44] We have omitted 2 baseline homes when calculating the average AFUE. One had a radiant heater and the other had a boiler. Since ENERGY STAR Homes have only furnaces or heat pumps, we omitted these 2 baseline homes.

Climate Zone	ESTAR Average AFUE	NP Average AFUE
RMST CZ1	0.82	0.87
RMST CZ2	0.80	0.82
RMST CZ3	0.80	0.80
RMST CZ4	0.84	0.82
RMST CZ5	0.85	0.81
Overall	**0.82**	**0.82**

Table 38: Average AFUE by Climate Zone

Cooling Equipment

Table 39 shows the percentage of ENERGY STAR® participant and baseline homes with a cooling system by climate zone. Overall and in every climate zone, ENERGY STAR® participant homes are more likely to have a cooling system. However, for compliance purposes Title 24 assumes all homes have air-conditioning, even if they do not. Using a "no cooling" option in Title 24 software modelers can indicate no cooling, however use of the "no cooling" option is not always practiced since using it has no bearing on compliance. Therefore, the prevalence of air-conditioning in the participant sample is very inconclusive, and in fact not likely to be correct. Since the baseline data is based on actual on-sites it is more likely to be accurate than data coming from the CHEERS database.

Climate Zone	% of ESTAR Homes With Cooling	% of NP Homes With Cooling
RMST CZ1	35%	28%
RMST CZ2	100%	70%
RMST CZ3	100%	91%
RMST CZ4	100%	99%
RMST CZ5	100%	100%
Overall	**97%**	**87%**

Table 39: Incidence of Cooling System by Climate Zone

Thermostatic expansion valve (TXV) technology helps the cooling system operate more efficiently when the refrigerant charge falls below its target charge. In theory, the TXV may never come into use if the cooling equipment maintains proper refrigerant charge. Consequently, thermostatic expansion valves are reported to help increase the time an air conditioner functions at its peak efficiency, even when the refrigerant charge is incorrect.

Table 40 presents the percentage of cooling systems with a TXV by climate zone for ENERGY STAR® Homes and non-participant homes with cooling. Overall and in all climate zones except zone 2 (south coastal), cooling systems in ENERGY STAR® Homes are significantly more likely to have a TXV installed.

Climate Zone	ESTAR % of Cooling Systems With TXV	NP % of Cooling Systems With TXV
RMST CZ1	40%	18%
RMST CZ2	0%	39%
RMST CZ3	30%	9%
RMST CZ4	88%	6%
RMST CZ5	87%	57%
Overall	**47%**	**18%**

Table 40: Cooling Systems with TXV by Climate Zone

Air conditioning efficiency is measured by Seasonal Energy Efficiency Ratio, or SEER—the greater the value the better the efficiency. The federal minimum requirement is 10 SEER, however in January 2006 this changed to 13 SEER. Overall, ENERGY STAR® Homes and non-participant homes have air conditioners of approximately the same efficiency, as shown in Table 41. In zone 1 (north coastal) and zone 4 (central valley), ENERGY STAR® Homes have more efficient air conditioners than do non-participant homes.

Climate Zone	ESTAR Average SEER	NP Average SEER
RMST CZ1	11.7	10.6
RMST CZ2	10.0	10.3
RMST CZ3	10.3	10.6
RMST CZ4	12.0	11.0
RMST CZ5	11.5	11.6
Overall	**10.8**	**10.9**

Table 41: Average SEER by Climate Zone

Radiant barriers are materials that are installed in buildings to reduce summer heat gain and winter heat loss, thereby reducing building cooling and heating energy usage. The potential benefit of attic radiant barriers is primarily in reducing air-conditioning cooling loads in warm or hot climates. Radiant barriers usually consist of a thin sheet or coating of a highly reflective material (usually aluminum), which is applied to one or both sides of a number of substrate materials. A radiant barrier is a C-HERS measure that can be used by builders to gain additional compliance credits.

Table 42 shows the percentage of ENERGY STAR® Homes and non-participant homes with a radiant barrier. About 6% of ENERGY STAR® Homes and 4% of non-participant homes have a radiant barrier. It may be that builders are using radiant barriers in CZ1 due to the low saturation of air-conditioning. Without the presence of air-conditioning they are unable to use air-conditioning related measures to exceed code, so instead they are required to install other measures, such as radiant barriers. On the other hand, use of radiant barriers in mild climate zones would not likely produce significant improvement over the baseline, owing to moderate cooling loads in coastal zones. Furthermore, while use of radiant barriers in any zone will result in Title 24 efficiency improvements, energy savings would not be great since most of the homes don't even have cooling systems, where most of the radiant barrier savings are derived. Higher than average saturation of radiant barriers in CZ5, the hottest of the five zones, makes sense due to the added difficult of compliance in hot climate zones. However, as the table shows, both participants and non-participants are installing barriers in this zone, so this does not seem to be a program driven measure, but rather a cost effective climate zone driven compliance action.

Climate Zone	ESTAR % of Homes with Radiant Barrier	NP % of Homes with Radiant Barrier
RMST CZ1	36%	14%
RMST CZ2	0%	0%
RMST CZ3	3%	1%
RMST CZ4	5%	2%
RMST CZ5	18%	21%
Overall	**6%**	**4%**

Table 42: Percentage of Homes with Radiant Barrier by Climate Zone

Table 43 shows the percentage of conditioned floor area utilizing a radiant barrier in participating and non-participating homes. Overall, about 5% of the conditioned floor area in both participating and non-participating homes utilizes a radiant barrier.

Climate Zone	ESTAR % of Area with Radiant Barrier	NP % of Area with Radiant Barrier
RMST CZ1	34%	18%
RMST CZ2	0%	0%
RMST CZ3	2%	2%
RMST CZ4	5%	1%
RMST CZ5	19%	25%
Overall	**5%**	**5%**

Table 43: Percentage of Conditioned Floor Area with Radiant Barrier by Climate Zone

Fenestration

The fenestration aspect (windows, doors and skylights) of an efficient home largely results from a whole-building design approach.[45] Efficient windows, doors and skylights can save up to 15% from reduced heating, cooling and lighting usage.

The California Energy Commission sets both maximum U-values and maximum area ratios in Title 24 standards. Table 44 summarizes the standards by Title 24 climate zone (manual D).

Climate Zone	RMST CZ	U-Value	SHGC	Max Area
1	1	0.65	NA	16%
2	1	0.65	0.4	16%
3	1	0.75	NA	20%
4	1	0.75	0.4	20%
5	1	0.75	NA	16%
6	2	0.75	NA	20%
7	2	0.75	0.4	20%
8	3	0.75	0.4	20%
9	3	0.75	0.4	20%
10	3	0.65	0.4	20%
11	4	0.65	0.4	16%
12	4	0.65	0.4	16%
13	4	0.65	0.4	16%
14	5	0.65	0.4	16%
15	5	0.65	0.4	16%
16	5	0.65	NA	16%

Table 44: Summary of 2001 Title 24 Standards for Fenestration by T24 Climate Zone

Part of the performance approach may include optimizing the window to floor area ratio in order to maximize energy efficiency. Overall and in each climate zone, ENERGY STAR® Homes have a larger average window to floor area percentage than non-participant homes.

Climate Zone	ESTAR Window to Floor Area	NP Window to Floor Area
RMST CZ1	19%	17%
RMST CZ2	19%	16%
RMST CZ3	16%	15%
RMST CZ4	17%	16%
RMST CZ5	16%	14%
Overall	**17%**	**16%**

[45] Whole-Building Design Approach, also referred to as integrated design, is when the building HVAC system has been sized according to the load requirements as determined by a computer simulation model, rather than only basing the size of the HVAC system on building size or rule of thumb procedures.

Table 45: Window to Floor Area by Climate Zone

Fenestration has a U-value and solar heat gain coefficient (SHGC) that measures the rate of heat loss and how well a product prevents heat from entering. The U-value ratings generally fall between 0.20 and 1.20. The lower the U-value, the greater a product's resistance to heat flow, and the better it's insulating properties, and is therefore more efficient. The SHGC measures how well a product blocks heat caused by sunlight. The SHGC is expressed as a number between 0 and 1. The lower the SHGC, the less solar heat it transmit, and is therefore more efficient. .

Table 46 summarizes average U-values and SHGC for glass doors, windows and skylights in ENERGY STAR® and non-participant homes by climate zone. Overall and in all climate zones, windows in ENERGY STAR® homes are more efficient than windows in non-participant homes. This is especially true for the SHGC, which shows ENERGY STAR® Homes to have a much better value than non-ENERGY STAR® homes, 0.35 and 0.45 respectively.

Climate Zone	ESTAR U-Value	NP U-Value	ESTAR SHGC	NP SHGC
RMST CZ1	0.43	0.46	0.46	0.48
RMST CZ2	0.36	0.49	0.34	0.52
RMST CZ3	0.41	0.44	0.36	0.47
RMST CZ4	0.36	0.39	0.33	0.42
RMST CZ5	0.35	0.38	0.34	0.42
Overall	**0.39**	**0.42**	**0.35**	**0.45**

Table 46: Average Window U-Value and SHGC by Climate Zone

Insulation

The insulation level of exterior opaque surfaces has profound effects on the energy efficiency of a home. The prevailing residential construction in California is a wood frame home with fiberglass batt insulation in the cavities of the wall and floor framing. Ceiling, roof and wall assemblies are also insulated with blown-in "rock wool" type insulation; however this is less common in California construction. The "R-value" of an insulation material is a measure of the level of thermal resistance of the material. The higher the R-value of a material, the greater is its' ability to resist heat flow, and is therefore more efficient.

Table 47 shows the average R-value for wall insulation by climate zone. Overall and in all climate zones with the exception of zone 4 (central valley), wall insulation R-Values in ENERGY STAR® Homes are on average less than those in non-participant homes. The greatest difference is occurring in zone 1 (north coastal), where the average wall insulation R-Value is 16.1 for non-participants and 12.9 for ENERGY STAR® Homes. Overall however, there is little difference in wall insulation levels.

Climate Zone	ESTAR Wall R-Value	NP Wall R-Value
RMST CZ1	12.9	16.1
RMST CZ2	13.0	13.9
RMST CZ3	13.1	13.3
RMST CZ4	13.5	13.4
RMST CZ5	13.0	13.6
Overall	**13.2**	**13.7**

Table 47: Wall Insulation Average R-Value by Climate Zone

Table 48 summarizes ENERGY STAR® Home and non-participant average R-values for roof insulation by climate zone. Overall, ENERGY STAR® Homes have slightly less roof insulation than non-participant homes. ENERGY STAR® Homes in zone 1 (north coastal) and zone 4 (central valley) have more insulation than their non-participant counterparts. Here again, the overall difference in roof insulation is minimal.

Climate Zone	ESTAR Roof R-Value	NP Roof R-Value
RMST CZ1	36.2	32.8
RMST CZ2	25.4	29.8
RMST CZ3	30.6	30.1
RMST CZ4	33.8	31.5
RMST CZ5	27.9	32.0
Overall	**30.8**	**31.2**

Table 48: Roof Insulation Average R-Value by Climate Zone

12. Single Family Billing Analysis

Introduction

The goal of this Billing Analysis study is to investigate the billing data from the utilities, and compare the actual electricity and gas usage of participant ENERGY STAR® new homes to non-participants. By comparing the amount of gas and electricity consumed by non ENERGY STAR® Homes to the amount consumed by, controlling for housing features such as floor area and number of stories, we can get an estimate of the difference that ENERGY STAR® Home's status makes in final energy usage of a home or set of homes.

Study Objectives

The primary objective of this part of the study is to supplement the Difference-of-differences (DofD) calculation of program savings with a case study of the realized savings in those 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. As such, this section aims to be a useful tool in identifying areas for future investigation.

Summary of Findings

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

Detailed Billing Analysis Results

The results from the billing analysis are reported in Table 49 for the electricity data and Table 50 for the gas results. The high variability of the billing data, when not controlling for important demographic characteristics produced very few results statistically significantly different from zero. However, a closer look yields some interesting insights into what is going on.

Climate Zone	***n (nonparts)***	***n (particpants)***	***NonPart Usage (kWh/sf/yr)***	***Part Usage (kWh/sf/yr)***	***Percent Savings***	***Significant @ 90%?***
CEC 6	76	34	3.475	2.713	**21.9%**	NO
CEC 8	95	124	3.207	3.662	**-14.2%**	YES
CEC 10	24	1557	3.782	3.350	**11.4%**	NO
CEC 12	141	1180	3.613	3.776	**-4.5%**	NO
CEC 13	25	45	4.554	4.716	**-3.5%**	NO
CEC 14	36	138	4.955	3.607	**27.2%**	YES

Table 49: Electricity Billing Analysis Results

CEC Zone 6 – Despite high percent savings, this climate zone did not show significant results. This was due in part to the small number of participants vis-à-vis other climate zones, and partially due to the unusually high variation observed in the non-participant sample. Despite the lack of statistical significance, we feel there is a strong indication that electricity savings were realized in climate zone 6.

CEC Zone 8 – CEC 8 had relatively large samples of participants and non-participants, and showed negative savings (i.e. the ENERGY STAR® Homes used more electricity than the non-ENERGY STAR® Homes) that were statistically significant. A possible explanation of this result is explored below in the discussion of single- and multi-story structures.

CEC Zone 10 – The small number of non-participants, 24, contributed to a lack of significance in CEC 10. A larger sample size would be able to establish savings with more certainty, but there is good indication from these results that electricity savings were realized in CEC 10.

CEC Zones 12 & 13 – These groups showed savings amounts that were very close to zero. There appears to be little difference between ENERGY STAR® Homes and non-ENERGY STAR® Homes in electricity usage in these zones. While the results from 13 are likely simply a result of small sample sizes, CEC 12 has more than enough data to produce significant results if there were indeed significant differences. A possible explanation for the lack of significance in the zone 12 sample is discussed below in the discussion of single- and multi-story structures.

CEC Zone 14 – The participant group showed significant and large positive electricity savings over the corresponding non-participants.

Climate Zone	***n (nonparts)***	***n (participants)***	***NonPart Usage (therms/sf/yr)***	***Part Usage (therms/sf/yr)***	***Percent Savings***	***Significant @ 90%?***
CEC 6	20	34	0.284	0.233	**17.9%**	NO
CEC 8	82	118	0.219	0.203	**7.4%**	NO
CEC 10	20	1257	0.163	0.183	**-11.8%**	NO
CEC 12	185	1344	0.226	0.190	**16.0%**	YES
CEC 14	29	64	0.328	0.231	**29.5%**	YES

Table 50: Gas Billing Analysis Results

CEC Zone 6 – Despite high percent savings, this climate zone did not show significant results. This was likely due to the small number of participants vis-à-vis other climate zones. Despite the lack of statistical significance, we feel there is a strong indication that gas savings were realized in climate zone 6.

CEC Zone 8 – CEC 8 had relatively large samples of participants and non-participants, and though it showed some gas savings, they were not statistically significant. We are unable to determine if there is a demographic basis for this result, or if there was simply little realized gas savings in climate zone 8.

CEC Zone 10 – The statistically non-significant negative savings results in CEC 10 are partially attributable to the small non-participant sample size and by the single-/multi-story analysis discussed below. We do not feel there is enough evidence to declare that there were negative savings realized in CEC 10.

CEC Zones 12 & 14 – Both climate zones' participants showed significant and large gas savings over their non-participant counterparts.

Single- and Multi-Story Houses

Ideally, billing analysis would be conducted controlling for relevant housing characteristics (such as size, occupancy, income of occupants, etc.) as much as possible. Beyond floor area, which is controlled for by using ratio estimation of energy per square foot, the only other housing characteristic we have data for is the number of stories. We only had enough data to conduct a comparison using the number of stories in four CEC climate zones: 8, 10, 12, and 14. However, the results shed light on a possible explanation of the savings results in other climate zones.

There was good evidence that energy usage varied with the number of stories of the homes.[46] For electricity, single-story non-participant homes used more electricity than their multi-story counterparts at a 90% level of significance. For participants, this difference was 90% significant in zones 10, 12, and 14, and significant at the 80% level of confidence in zone 8. Similarly, in zones 10 and 14 both participant and non-participant homes had significant differences in gas usage between single- and multi-story homes. Zone 12's non-participant single-story homes used more gas than the zone's multi-story non-participants, but the participant structures exhibit no significant difference. With the sole exception of CEC 12's participant groups, single story homes used more energy per square foot than multi-story structures in all four climate zones, across both participant classes.

For the most part, the difference between single- and multi-story homes was greater for non-participant homes than it was for participant homes. That is, the impact of having a multi-story structure as opposed to a single-story structure was greater for the less-efficient non-ENERGY STAR® Homes than it was for the ENERGY STAR® Homes. The result of this difference is that ENERGY STAR® Home's savings are greater when we compare single-story ENERGY STAR® Homes to single-story non-ENERGY STAR® Homes than when making the same comparison between multi-story ENERGY STAR® Homes and non-ENERGY STAR® Homes. As Table 51 shows, single-story comparisons of electricity usage show higher savings than multi-story comparisons.

ClimateZone	House Type	n (nonparts)	n (particpants)	NonPart Usage (kWh/sf/yr)	Part Usage (kWh/sf/yr)	Percent Savings	Significant @ 90%?
CEC 8	Single	20	11	4.414	4.107	**7.0%**	NO
CEC 8	Multi	75	113	2.847	3.636	**-27.7%**	YES
CEC 10	Single	7	785	4.440	3.452	**22.2%**	YES
CEC 10	Multi	17	772	3.294	3.282	**0.4%**	NO
CEC 12	Single	40	639	4.270	3.940	**7.7%**	NO
CEC 12	Multi	101	541	3.284	3.655	**-11.3%**	YES
CEC 14	Single	16	91	5.718	3.835	**32.9%**	YES
CEC 14	Multi	20	47	4.141	3.268	**21.1%**	NO

Table 51: Single-/Multi-Story Comparison of Electricity Billing Analysis

When pooled, the ENERGY STAR® Homes in climate zone 8 had negative and significant savings compared to the non-ENERGY STAR® Homes (Table 49). When split into single- and multi-story units, we see that this negative savings is dominated by the low electricity

[46] Due to the small number of 3-story homes in our samples, 2- and 3-story homes were merged into the single category of multi-story homes.

usage of multi-story non-participant homes. The single-story ENERGY STAR® Homes show positive savings over their non-ENERGY STAR® Homes counterparts.

The low savings seen in zones 10 and 12 when houses were pooled are also shown to have been pulled down by low energy usage among multi-story non-ENERGY STAR® Homes. Even in zone 14, where savings are high for both types of ENERGY STAR® Homes, the single-story homes exhibit significantly more savings than the multi-story homes.

The same trend can be seen in the gas billing data in Table 52. Multi-story non-participant homes used significantly less gas than their single-story counterparts, and pulled the total savings for climate zones 10, 12, and 14 down.

ClimateZone	House Type	n (nonparts)	n (particpants)	NonPart Usage (therms/sf/yr)	Part Usage (therms/sf/yr)	Percent Savings	Significant @ 90%?
CEC 8	Single	17	13	0.279	0.286	**-2.7%**	NO
CEC 8	Multi	65	105	0.200	0.187	**6.6%**	NO
CEC 10	Single	5	661	0.189	0.192	**-1.8%**	NO
CEC 10	Multi	15	596	0.147	0.177	**-19.9%**	NO
CEC 12	Single	68	702	0.259	0.176	**32.3%**	YES
CEC 12	Multi	117	642	0.209	0.201	**3.7%**	NO
CEC 14	Single	12	39	0.390	0.253	**35.0%**	YES
CEC 14	Multi	17	25	0.272	0.208	**23.6%**	YES

Table 52: Single-/Multi-Story Comparison of Gas Billing Analysis

Methodology

The first step of the billing analysis was to weather-normalize the usage figures. The CEC climate zones are very large, and houses within a climate zone may face very different weather from houses located elsewhere in the climate zone. Furthermore, although we received two years worth of billing data, not all of the homes were occupied for the full two years, and thus some may have data from 2003 while others may not. In order to correct for both these spatial and temporal differences among houses within a climate zone, we used the Princeton Scorekeeping Model (PRISM) approach to normalize the energy usage figures in our data to the square-footage-weighted average weather in each home's CEC climate zone for the period 1995-2005. Appendix F – Billing Analysis Data, Methodology, and Weather Normalization has more information on the weather-normalization process.

Once the weather-normalized energy-usages were calculated for each house in the data, we used stratified ratio estimation to weight each participant and non-participant sample to the population of all ENERGY STAR® Homes built in the 2002-2003 period and to produce an estimate of the energy usage per square foot in each sample group. A more detailed description of the stratified ratio-estimation procedure and its reasoning can be found in Appendix A – Ratio Estimation.

Conclusion and Recommendations for Further Study

The data available for the billing analysis of the 2002-03 ENERGY STAR® Homes was insufficient to allow RLW to accurately estimate energy savings by this method. However, the analysis as conducted did bring to light a number of issues that could be investigated more fully in future evaluations:

The CHEERS registry extract may not be a perfectly reliable source of housing characteristic information

RLW found more than 700 of 6850 had erroneous zip code or climate zone information in the CHEERS registry extract. Furthermore, the billing analysis was limited by several hundred homes missing key housing characteristic information. It is unclear whether these are errors with CHEERS, with the data extraction process, or are errors in the data provided to CHEERS by the utility plan check agencies. The true number of errors may be greater, and should be investigated in more detail as the CHEERS registry is the tracking database for the ENERGY STAR® Homes Program and its accuracy is essential for any impact analyses.

A better baseline sample is necessary for analyses at the climate zone level

The sample design that Itron used to conduct their residential new construction baseline study resulted in a non-participant population that was distributed across RMST zones proportional to the amount of new construction in those zones. Unfortunately, the sample design did not take into account the CEC climate zones the homes were in, and the resulting sample is not a good representation of construction by CEC zones. In RLW's analysis of ENERGY STAR® Homes, it was found that there are large differences in energy uses between homes in different CEC zones within a given RMST zone.

A relative-measure-based analysis, such as Differences of Differences can reasonably get around this by performing cross-zonal comparisons. Any attempt to quantify actual fuel savings at the climate zone level, such as billing analysis, will be severely hindered by the inability to compare participants to non-participants in similar climates. Future impact analyses would benefit greatly from a non-participant sample representative of the sixteen CEC climate zones, or at least those zones representing the majority of new construction.

There is evidence that savings are being realized in some climate zones

There was evidence that savings in actual electricity usage were seen in ENERGY STAR® Homes in CEC climate zones 6, 10 and 14. Gas savings were realized by ENERGY STAR® Homes in CEC zones 6, 12, and 14. RLW feels this is solid evidence of the program's success in these areas.

Savings are not seen in other climate zones

The zones where savings were found to be close to zero or negative, however, raise the question as to whether the program's design-focused approach ends up translating into realized usage savings. RLW has come to four possible explanations of these results, any combination of which may be producing the observed energy usage figures:

1. There is a *demographic* bias in the participant population vis-à-vis the non-participant sample. If the way ENERGY STAR® Homes are marketed or where developers choose to build ENERGY STAR® Homes result in differences in occupancy, income, or habits of the inhabitants, this could explain demonstrably more efficient homes using more electricity and gas in day-to-day life. For instance, there may be a higher percentage of families in ENERGY STAR® Homes—perhaps some of the major ENERGY STAR® Homes developments in the non-savings climate zones are close to schools. A thorough process-level investigation of who is buying ENERGY STAR® Homes, and why, would be very useful for quantifying this impact. In general, collecting more demographic information on ENERGY STAR® Homes and non-ENERGY

STAR® Homes homeowners (especially information on occupancy) would be very beneficial for sifting program effects from demographic effects.

2. There is a *behavioral* bias in the participant population. It is possible that the results are explained by a "snap-back" effect. Perhaps people who own an ENERGY STAR® Home are less conservative in their energy usage decisions because they own a more efficient house. Such behavioral bias could be ascertained by conducting homeowner surveys, asking whether owners know they live in an ENERGY STAR® Homes, and whether that affects their energy usage decisions.
3. There could also be a *self-selection* bias in ENERGY STAR® Homes owners. Perhaps people that use the most energy, and thus have the most to gain financially, actively seek out ENERGY STAR® Homes, although we think this is highly unlikely given the tightness of the California home market at the time of the program. The presence of such self-selection may also be found through homeowner survey instruments.
4. The Title 24 modeling system may be flawed. The discrepancy between D of D results and billing analysis results could also be due to the Title 24 modeling software not accurately reflecting the energy usage of the modeled homes either due to software errors or user-input errors. A study focusing on comparing the modeled energy usages to measured end-usages in practice that can control for demographic characteristics could help to recalibrate the modeling software.

Regardless of the reason, these results highlight the importance of demographics in determining the realization rate of energy savings. As such, it is important to consider the impact these results may have on the Difference-of-differences estimation of program savings. The discrepancy between as-designed program savings and as-used program savings highlights the need to supplement as-designed estimates with information on how energy is actually used in practice.

There is a difference in actual savings between single- and multi-story homes

Single-story ENERGY STAR® Homes use less energy than their non-ENERGY STAR® Homes counterparts while multi-story ENERGY STAR® Homes use as much or more than multi-story non-ENERGY STAR® Homes in the same climate zone. This result could arise from any combination of the four reasons outlined above, but certainly has an impact on estimates of energy savings from the ENERGY STAR® Homes Program. The fact that multi-story non-ENERGY STAR® Homes use about as much energy as single- and multi-story ENERGY STAR® Homes indicates that perhaps the Title 24 models are not giving non-ENERGY STAR® Homes enough credit for energy savings achieved by using a multi-story design over a similar single-story design. Again, further study is necessary to firmly establish the reasons behind these results.

13. High Rise Energy Savings

Background

Multifamily high rise buildings (four or more stories) are considered separately from low-rise multifamily buildings (one to three stories) since high rise buildings are subject to different requirements under California Title 24 building codes. As a result, high rise buildings have separate modeling requirements and different program requirements.

Summary

There were a total of three high rise apartment buildings that were credited with energy savings under the California ENERGY STAR® Homes Program. Since there were only three high rise buildings, it was determined that conducting field verification of energy saving characteristics would not be a wise use of EM&V funding for this program cycle. Therefore, Title 24 reports were reviewed for compliance margin requirements and to assign savings to gas or electricity. Ex ante estimates were calculated using actual number of dwelling units completed and IOU multifamily per unit kWh and therm savings estimates. Ex post estimates were calculated using Title 24 gross savings and the average multifamily NTG ratio of 0.625. The results are shown in Table 53, Table 54, Table 55, and Table 56.

	2002 kWh			2003 kWh		
	Ex Ante	***Ex Post***	***Realization Rate***	***Ex Ante***	***Ex Post***	***Realization Rate***
PG&E	2,016	-6,601	-327%	0	0	NA
SCE	0	0	NA	0	0	NA
SCG	0	0	NA	0	0	NA
SDG&E	0	0	NA	21,040	648	3%
Total	2,016	-6,601	-327%	21,040	648	3%

Table 53: High Rise Electric savings

	2002 Therms			2003 Therms		
	Ex Ante	***Ex Post***	***Realization Rate***	***Ex Ante***	***Ex Post***	***Realization Rate***
PG&E	5,466	4,566	84%	0	0	NA
SCE	0	0	NA	0	0	NA
SCG	0	0	NA	0	0	NA
SDG&E	0	0	NA	2,960	5,174	175%
Total	5,466	4,566	84%	2,960	5,174	175%

Table 54: High Rise Gas savings

Utility	Program Year	Dwelling Units	Annual Source Energy Savings (Kbtu)	Annual Site Electric Savings (KWh)	Annual Site Gas Savings (Therms)
SDGE	2003	100	838,447	1,037	8,278
PGE	2002	28	255,357	(2,120)	2,770
PGE	2002	42	367,241	(8,442)	4,536
Total		170	1,461,045	(9,524)	15,585

Table 55: Gross High Rise Buildings' energy savings

Although three buildings is a small population, it is worth noting that *the total annual electricity savings are negative*. The compliance margin requirement is being satisfied entirely by gas saving measures. After the 2002 program year the implementers became aware of this problem and implemented a new program rule. The rule stated that in order to comply for the program there could be no negative electric savings, while the project must also be at least 15% better than the standard. More details of each project are show in Table 56.

Utility	Project Name	Program Year	City	Conditioned Floor Area (square feet)	Dwelling Units	Climate Zone	Compliance Margin	Annual Source Energy Savings (Kbtu)	Annual Site Electric Savings (KWh)	Annual Unit Site Electric Savings (KWh/unit)	Annual Site Gas Savings (Therms)	Annual Site Unit Gas Savings (Therms/unit)
SDGE	Villa Harvey Mandel	2003	San Diego	42,453	100	7	21.7%	838,447	1,037	10	8,278	83
PGE	Housing Alliance Project	2002	Castro Valley	27,108	28	3	16.9%	255,357	(2,120)	(76)	2,770	99
PGE	Northgate Apartments	2002	Oakland	44,514	42	3	17.0%	367,241	(8,442)	(201)	4,536	108
Total					170			1,461,045	(9,524)	(56)	15,585	92

Table 56: Three high rise buildings and savings per dwelling unit

In the future, if a significant number of high-rise buildings apply to the program, it may be appropriate to conduct on-site inspections and verification of the energy saving measures and building characteristics.

Complete energy compliance margin calculations and details can be found in Appendix C.

14. Multifamily Gross (Tracking) and Net Savings

Introduction

Similar to single family, the energy savings analysis of multifamily homes is based upon the Tracking database (CHEERS). The associated Gross Savings for multifamily homes is similarly defined as the difference between Standard and Proposed[47] modeled energy consumption.

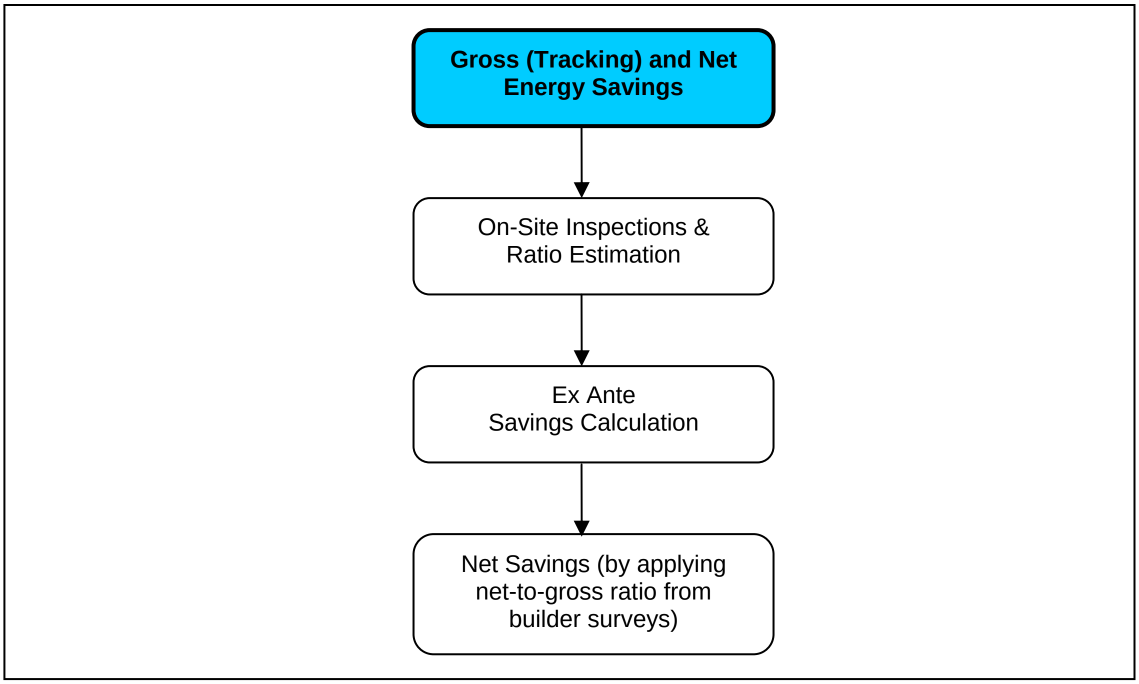

Figure 36: Multifamily Gross and Net Energy Savings Calculation Flowchart

Gross (Tracking) and Net Savings

The tracking database (CHEERS) reports all energy figures in source kBTU. Table 57 shows gross and net multifamily savings by utility. Net savings were calculated by applying the NTG ratio to the gross tracking savings.

MF Net Savings = NTG x (MF Gross Savings)

The NTG ratio was determined through interviews conducted by SERA.

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[47] "Standard" and "Proposed" are terms used by Title 24 energy modeling software. When a new home is modeled, it is compared to a "Standard" home's energy budget, which is determined by a set of prescriptive measures and characteristics specific for that climate zone (e.g. insulation levels, air conditioner SEER, etc.). "Proposed" is the modeled energy consumption of the new home as designed. Gross energy savings is defined as the difference between Standard and Proposed.

Utility	Structure IDs	Dwelling Units	Tracking Savings (Source kBTU/yr)	NTG (from SERA)	Net Savings (Source kBTU/yr)
PGE	113	675	6,649,016	0.625	4,155,635
SCE	28	501	2,900,669	0.625	1,812,918
SCG	367	4,186	27,209,307	0.625	17,005,817
SDGE	250	1,919	12,735,169	0.625	7,959,480
Total	758	7,281	49,494,161	0.625	30,933,851

Table 57: Gross and Net Savings of Completed 02/03 Multifamily Dwelling Units

Structure ID is a variable in the CHEERS database which can represent a dwelling unit, a building, or a group of buildings, depending on how the builder modeled the project. One recommendation of this report is that at least minimal uniformity in modeling be implemented to assist the program implementers and plan check agencies.

In Table 58 the net savings have been broken out by utility and year, and converted to site kWh and therms savings.

Net Savings	2002 kWh	2003 kWh	2002 Therms	2003 Therms
PG&E	2,467	74,133	1,246	32,474
SCE	0	7,330	0	17,379
SCG	115,136	451,041	7,994	104,144
SDG&E	26,796	66,803	11,585	58,435
Total	144,400	599,308	20,825	212,433

Table 58: Net Multifamily kWh and Therms Savings by Year

Comparison of Multifamily End-Uses

The CHEERS data in source kBTU is useful for comparison of end-uses across fuel types. Figure 37 shows gross energy savings by end-use. The total height of each bar represents the standard design, or Title 24 Package D energy use. The savings represents the energy savings resulting from the proposed design. Water heating is the dominant energy end-use, and also the source of the majority of energy savings.

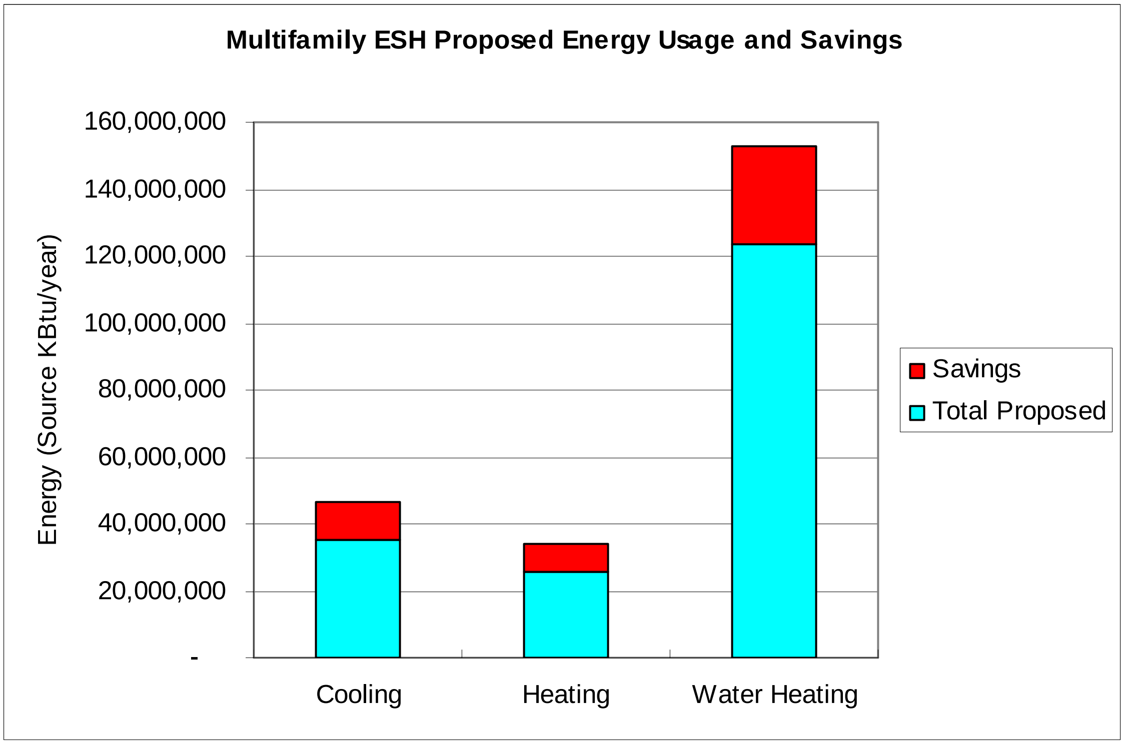

Figure 37: Multifamily Gross Energy Savings by End-Use above Proposed Usage

End Use	Total Proposed	Savings	Total Standard
Cooling	35,350,511	11,487,257	46,837,768
Heating	25,613,584	8,440,210	34,053,794
Water Heating	123,291,707	29,566,694	152,858,401
Total		49,494,161	233,749,963

Table 59: Multifamily Gross Energy Savings by End-Use above Proposed Usage

Population of Multifamily ENERGY STAR® Homes

The definition of an ENERGY STAR® Homes multifamily program participant is: multifamily structures in projects that were accepted into the ENERGY STAR® Homes Program, completed construction, and passed inspection all occurring in 02/03. Note that when, or if, incentives were paid is not a criteria used to determine participation status. As a result, we are using the CHEERS database to define the population of participant structures by filtering on program Year (= 02 or 03), Last inspection Date (= 02 or 03), and Status (= approved).

Implementing this definition, the population of multifamily homes in 2002 and 2003 contains 758 unique structures. The frequency distribution of these multifamily structures, by utility and climate region, is presented in Table 60.

Utility	Coastal	Inland	Total
PGE	89	24	113
SCE	1	27	28
SCG	97	270	367
SDGE	208	42	250
Total	395	363	758

Table 60: Population of Completed 02/03 Multifamily Structures

These 758 structures are associated with 52 unique projects. The frequency distribution of these projects, by utility and coastal/inland climate region, is presented in the table below.

Utility	Coastal	Inland	Total
PGE	5	3	8
SCE	1	4	5
SCG	9	16	25
SDGE	8	6	14
Total	23	29	52

Table 61: Population of Projects Associated with Above Multifamily Structures

Gross (Tracking) Savings Methodology

Since Gross Savings is defined as the difference between Standard and Proposed modeled energy consumption,

Gross Savings of the ENERGY STAR® Homes = $\sum_{i=1}^{N_p}(S_{p_i} - P_{p_i})SF_{p_i}$, where

S_p[48] = Participant CF-1R standard energy use (kBTU/sf-yr)

P_p = Participant CF-1R proposed energy use (kBTU/sf-yr)

SF_p = Conditioned floor area of the home

N_p = Total number of multifamily structures

Details of Computing the Simple Gross

Similar to single family, we primarily used the *Data* table in the CHEERS database to compute values for energy savings. The CHEERS data contains values for energy usage per square foot for heating, cooling, and water heating. It has one value for each possible orientation of the structure; north, south, east, or west. We computed the average of these orientations to arrive at a unique number for each type of end use. This number is the expected savings of the structure from the Micropas or EnergyPro models. For the baseline values for the energy usage per square foot for a structure, we used the CHEERS value called "standard." The average values of the four orientations were compared to the standard to compute the energy savings for a structure.[49]

[48] The subscript p is used to denote Participants, and np is used for Non-Participants.

[49] In a small percentage of structures, we did not have values for all four orientations. Instead we

The CHEERS data contains associated fuel types for all structures. We checked that for all the records that are in our database (i.e. 758 unique structure ids), the fuel type for water heating is always gas, or gas fired. Additionally, the fuel type for cooling is always electric for these structures. The fuel type for heating is "Gas" for a vast majority of the plans, and is "Electric" for the others. There were 15 multifamily plans in our data that used multiple heating appliances with mixed fuel types. The fuel types for these plans were recorded as "Gas" for some appliances and as "Electric" for some others. Each plan was examined individually to identify the predominant heating fuel type (Electric or Gas). We assigned a unique heating fuel type to each of these structures based on the fuel types (cited in the plan) used by the majority of the appliances. The savings were aggregated for gas heating and water heating to arrive at the total gas savings of all structures. Similarly, the total electric savings were determined by summing up the cooling savings and electric heating savings of all structures. [50]

In order to differentiate the results by coastal and inland differences each home was classified as either coastal or inland using the CEC climate zone it was modeled in. Homes modeled (or built) in CEC climate zones 1-7 were classified as coastal, whereas homes modeled in CEC climate zones 8-16 were classified inland.

For some structures, we did not have individual proposed values for the four orientations. Instead some 'PROPOSED' values for energy savings were reported in the CHEERS database. In these cases, we subtracted the 'Proposed' values from the 'Standard' in order to arrive at the energy savings for these structures.

used the 'PROPOSED' values for energy savings were reported in the CHEERS database. In these cases, we subtracted the 'Proposed' values from the 'Standard' in order to arrive at the energy savings for these structures.

[50] The energy savings by fuel type are presented in the Adjusted Gross Energy Savings chapter.

15. Multifamily On-Site Verification Inspection Results

Introduction & Background

On-site inspections of 25 multi family projects of ENERGY STAR® Homes were conducted to verify that as-built characteristics and associated energy savings match the plans.[51] Similar to single family, if any difference in as-built characteristics of the multifamily plans was found, the next step was to analyze how they may affect the energy savings of the program. 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 EM&V study.

To assess the energy impacts, the fundamental method was to compare the on-site inspection results with the Title 24 plans submitted for each structure in the sample. If building characteristics differences were found, the structure's Title 24 energy model was re-simulated.

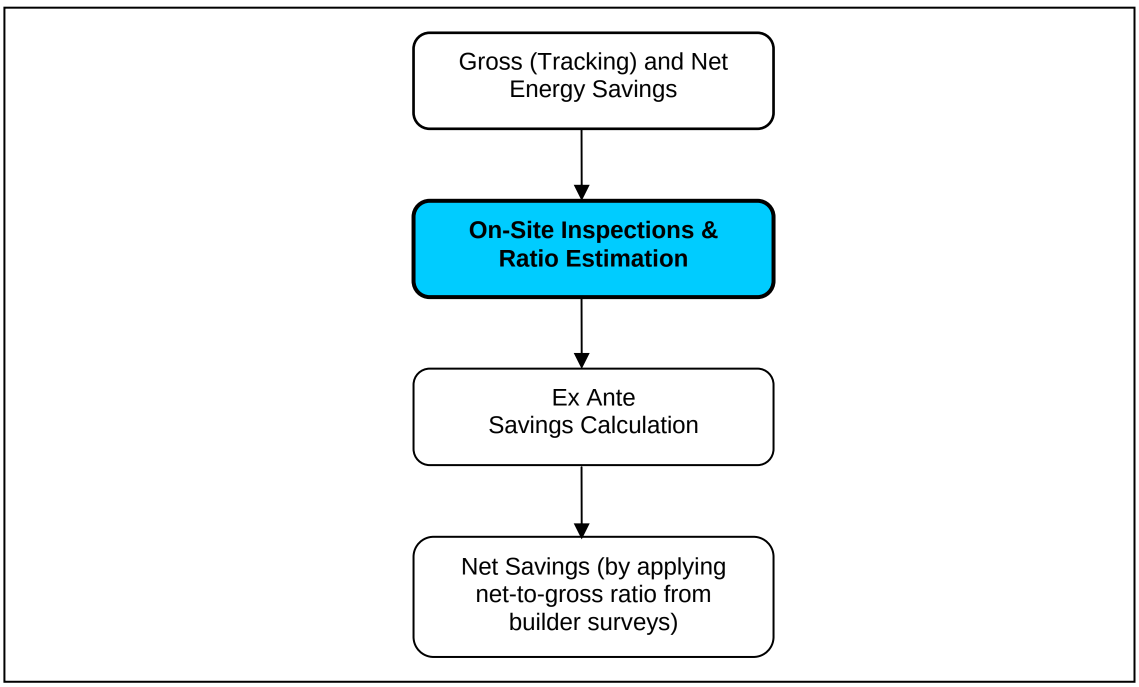

Figure 38: Multifamily Gross and Net Energy Savings Calculation Flowchart

Summary of Key Results

We inspected 25 projects, and a total of 123 plans, since there were multiple plans associated with almost all of the projects. The multifamily on-site inspections revealed that there was not much difference between the inspected characteristics and the plans in the tracking database. Figure 39 shows the computed average compliance margins from

[51] Plans refer to the Title 24 files submitted to the Program, and entered in the CHEERS database.

the inspected data, and the original plan data. As can be seen from the figure, there is little difference between the two sets of compliance margins. This is true in all climate zones.

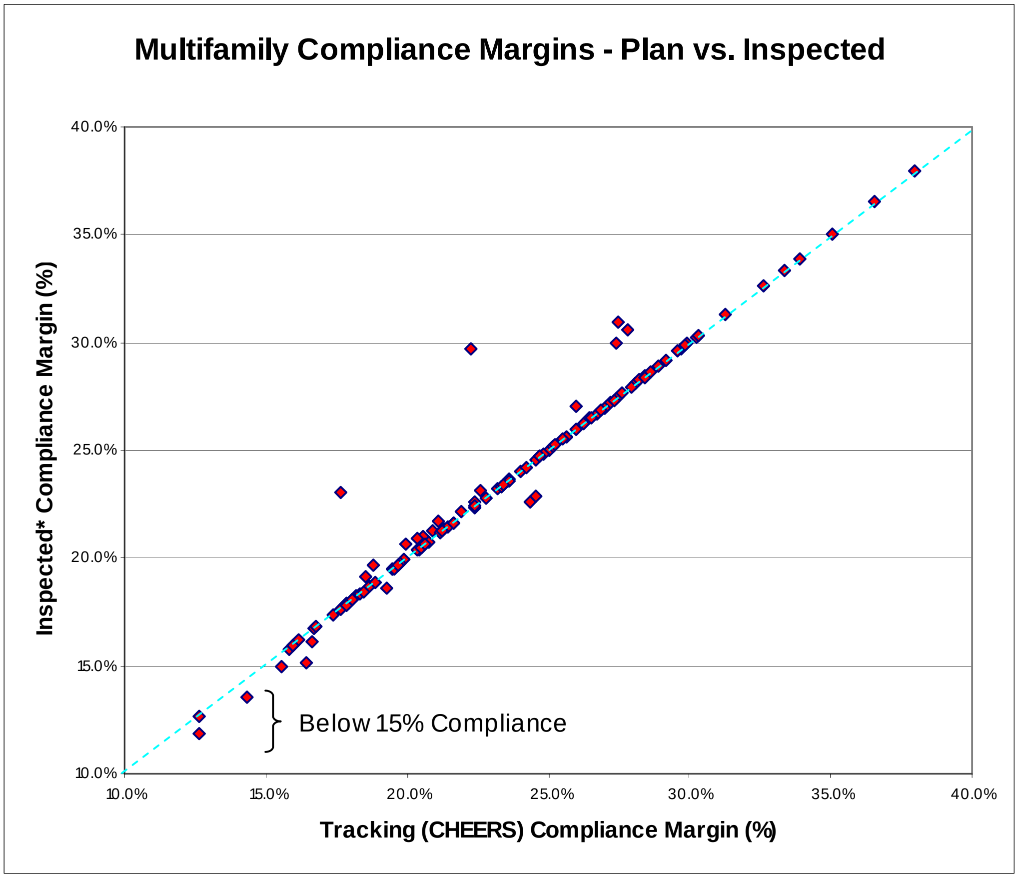

Figure 39: Inspected Multifamily Structures Compliance Margins

Based on these on-site inspection results, there is high correlation between planned and as-built modeled energy usage. *Ratio estimation was therefore not performed, and no adjustments to the tracking savings estimates are necessary. The tracking database modeled energy values are considered accurate.*

Curiously, three plans missed the 15% minimum compliance margin requirement to meet ENERGY STAR® Homes Program requirements. It's unclear how they qualified.

16. Multifamily *Ex* Ante Savings

This section presents the approach to calculating the *ex* ante savings estimate.

Introduction

Like the single family impact analysis, there was no multifamily *ex* ante estimate provided by the implementers, therefore it was necessary to work with them in order to produce an *ex* ante estimate. The ex ante estimate is important because it allows the evaluation results to be compared to something meaningful.

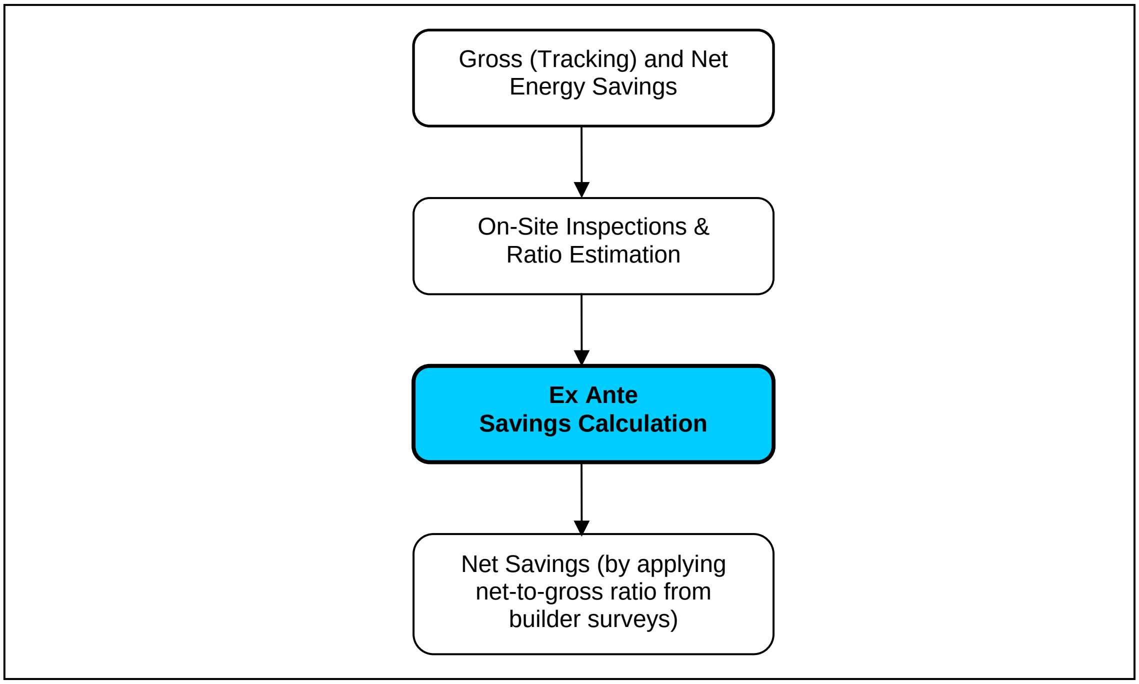

Figure 40: Multifamily Gross and Net Energy Savings Calculation Flowchart

Multifamily Ex Ante Results

The multifamily ex ante (calculated) results are shown below. The methodology used to calculate the ex ante savings follows the method used for single family, and is described below.

	2002				2003			
	Gross Ex Ante		Net Ex Ante		Gross Ex Ante		Net Ex Ante	
	kWh	Therms	kWh	Therms	kWh	Therms	kWh	Therms
PG&E	576	1,562	461	1,249	4,036	52,885	3,229	42,308
SCE	NA	NA	NA	NA	155,310	NA	124,248	NA
SCG	78,960	10,904	63,168	8,723	1,002,030	140,970	801,624	112,776
SDG&E	94,656	18,792	75,725	15,034	413,173	58,127	330,538	46,502
Total	**174,192**	**31,258**	**139,354**	**25,006**	**1,574,549**	**251,982**	**1,259,640**	**201,585**

Table 62: Multifamily Calculated Ex Ante Estimates (Net = Gross x 0.8)

Multifamily Ex Ante Methodology

The approach to calculating the ex ante values first required data from each utility. RLW worked with each of the four implementers to obtain their planning estimates of energy savings for multifamily participant projects. The estimates were provided for both 2002 and 2003 program years, and often included different estimates for regional differences (coastal vs. inland) and compliance margin (15% vs. 20%). Table 63 presents the per unit[52] savings data provided by each implementer. The table presents both kWh and therm savings for each program year. Again, at the time of program planning, these were the implementers' best estimates of how much savings would result per multifamily unit, not project.

	2002		2003	
Utility	**kWh**	**Therm**	**kWh**	**Therm**
PG&E	36	97.6	6.125	80.25
SCG	210	29	263	37
SDG&E	272	54	263	37
SCE	675	NA	310	NA

Table 63: Multifamily Per Unit kWh and Therm Savings Estimates by Utility

Using the CHEERS Registry, RLW determined the number of structures "approved" in each of the two evaluation years, 2002 and 2003. For each approved structure RLW obtained the number of units (dwellings) associated with each structure. Table 64 shows the actual number of completed units. Multiplying the number of units by the per unit savings yields the gross ex ante.

[52] "Unit" for multifamily refers to a dwelling unit with a unique mailing address. Unit and dwelling unit are used interchangeably, and could be an apartment, condominium or townhouse.

Utility	Year Completed	Climate Region	"Approved" Dwelling Units	PIP kWh Savings/ Unit	PIP Therms Savings/ Unit
PGE	2002	Coastal	16	36	98
		Inland	0	36	98
	2003	Coastal	291	6	80
		Inland	368	6	80
SCE	2002	Coastal	0	675	NA
		Inland	0	675	NA
	2003	Coastal	20	310	NA
		Inland	481	310	NA
SCG	2002	Coastal	154	210	29
		Inland	222	210	29
	2003	Coastal	716	263	37
		Inland	3,094	263	37
SDGE	2002	Coastal	232	272	54
		Inland	116	272	54
	2003	Coastal	813	263	263
		Inland	758	263	263
Totals	**2002**	**Coastal**	**402**	**NA**	**NA**
		Inland	**338**		
	2003	**Coastal**	**1,840**	**NA**	
		Inland	**4,701**		

Table 64: Number of Approved Dwelling Units and PIP IOU Estimates

17. Net to Gross (NTG) and Non-Energy Benefits (NEB) Analysis – Skumatz Economic Research Associates (SERA)

Skumatz Economic Research Associates (SERA) was responsible for performing the multifamily net-to-gross analysis and a non-energy benefits analysis for this project. The following chapters summarize the results of their research. Note that both of SERA's analyses only pertain to the multifamily component of the 2002-03 ENERGY STAR program evaluation. The multifamily net-to-gross results, developed by SERA, were applied to the gross multifamily savings estimates developed by RLW. The non-energy benefits analysis was conducted to provide further insight into program benefits and outcomes relative to costs. However, most non-energy benefits are not currently approved features of current cost benefit tests in California, therefore these results are provided for added insight into the 2002-03 program.

Introduction and Context

The overall study incorporates both process and impact evaluation work on the Statewide ENERGY STAR® New Homes Program. This Phase II report provides gross and net impact savings estimates for the single family and multifamily components of the 2002 and 2003 ENERGY STAR® New Homes Programs. Although the single family analysis used two methods to examine gross and net impacts (engineering based approach and billing data analysis), the multifamily analysis discussed in the previous sections used a "simple gross" approach for measuring gross savings resulting from the multifamily Program component.[53]

However, in order to fully assess the net attributable impacts of the multifamily component of the program, Skumatz Economic Research Associates (SERA) conducted two additional analyses:

- **Net to gross analysis**: designed to analyze the direct and indirect energy efficiency and savings–related effects induced in the marketplace attributable to the multifamily component of the California Statewide Energy Star®
- **Non-energy benefits analysis**: designed to inventory and measure the "hard to measure" positive and negative non-energy effects (non-energy benefits in the literature) experienced due to the program, including effects for participants, the utilities, and society and the environment at large.

This chapter summarizes the results of these two analyses. The combined team of RLW Analytics (prime contractor), supported by subcontractor Skumatz Economic Research Associates, (SERA) were tasked with conducting a detailed measurement and verification for the single family and multifamily components of the California Statewide Energy Star® Homes Program. As part of the work, the team reviewed the program literature, and identified the program logic, and itemized a number of researchable questions and indicators. These are presented in Table 65.

[53] The single family net and gross and the assessment of gross savings from the multifamily program was conducted by RLW Analytics, the prime contractor for the project.

In general, RLW was responsible for Single family (SF) and multifamily (MF) impact evaluation, SF and MF process evaluation, and SF net-to-gross analysis. SERA was responsible for MF net-to-gross analysis, and the Non-energy benefits analysis for the program, which informed elements of outcomes B, C, N-Q, S-U, and Y. These results are summarized at the end of the chapter.

Table 65: Outcomes, Indicators, and Measurements for CA-Energy Star® Homes Program

Outcomes	Proposed Indicators
Short Term Outcomes	
A. Increased builder awareness	Percent aware participants and non-participants; track over time
B. Educated market actors	1) Understanding of program elements by builders 2) Understanding of program elements by owners 3) Understanding of ESH benefits by builders 4) Understanding of ESH benefits by owners
C. Number of ESH built / savings attributable to the program	1) Number built; number of homes participating in program 2) Elapsed time to build?
D. Increased public awareness of ESH	1) Advertising “hits” 2) Percent of public aware of ESH
E. Consumer demand for ESH / upgraded homes increases	1)Number of homes participating in program 2) Builder reports on percent of homeowners requesting ESH (weak – few interactions) 3) Realtor reports on percent of homeowners asking about ESH (stronger)
F. Homebuyer purchases ESH	1) Number sold 2) Percent ESH of market for new homes 3) Percent ESH dollars of total new homes $
Intermediate Outcomes	
G. Increased builder acceptance of ESH	1) Number of ESH participating builders 2) Number of ESH homes relative to non-ESH 3) Increasing share of homes by participating builders built to ESH 4) Increasing share of Non-participating builders that build ESH / increasing share of their homes built to ESH 5) Perception of ESH homes, advantages by PNP builders
H, Increased need for C-Hers raters	1) Backlog – time to get rater on-site 2) Costs for raters (higher cost)
I. Rating industry matures	1) Number of raters certified 2) Class sizes 3) Number of rating schools / outlets?

Outcomes	Proposed Indicators
	4) Hits on rating websites? 5) Reduced(?) cost for ratings
J. Advanced home designs	ESH program encourages more innovation in energy efficient homes and features
K. Increased public acceptance / demand for Energy Star Products	1) reported ES sales / appliances holdings by consumers increases 2) Perceptions of quality and other features for ES models 3) Percent of sales of ES models increases
L. Increased demand for EE goods / products / services	1) Percent of models on sales floors (or available) that are ES models 2) Market price differential decreases for ES products 3) Percent of sales of ES models increases
M. Increase availability of EE goods / products / services	1) Percent of models on sales floors that are ES models 2) Percent of sales of ES models increases
N. Homebuyer enjoys lower energy bills	1) bill comparisons to other homes 2) reports from owner about bills vs. expectations 3) kWh usage compared to other comparable homes
O. Builders promote and advertise ESH	1) number of builders actively promoting program 2) advertisements mentioning ESH; builders saying they include in advertisements 3) listings mentioning ESH
P. More non-participating homes built to ESH standards	Percent of NP homes built to ESH
Q. Direct and indirect program savings and environmental benefits provided	Value of non-kWh impacts – omitted program effects
R. Market recognizes value of ESH	1) ESH sell for higher prices 2) Builder reports of premiums 3) Realtor reports of premiums
S. Purchasers recognize benefits and spread word of ESH / word of mouth (awareness / value)	1) Value of NEBs / omitted effects (combined with housing prices) 2) Reports of "spreading the word"
T. Availability of eligible builders / knowledgeable builders (and raters?)	1) Share / number of builders building to ESH standards – inside or outside program 2) Number enrolled in some program? 3) Number of different builders requesting services of raters 4) Number of raters in business 5) Backlog for raters
Longer Term Outcomes	
U. Quality home construction / enhanced home design	1) Percent of market built to enhanced standards
V. Good builder reputation	1) Percent of realtors saying builder has strong reputation (by ESH participants / non partic) 2) Complaints / suits against ESH participating builders compared to others
W. Product differentiation	Builders differentiate their ESH homes in the marketplace as a superior product

Outcomes	Proposed Indicators
X. Increased (builder) profitability	1) Profit ratios for builders to ESH vs. non-ESH designs? 2) Percent of builders building to ESH that say profit margins are higher for ESH homes?
Y. Lower energy consumption and demand	1) energy consumption compared to other homes

Program Description

California's[54] ENERGY STAR® New Homes Program provides financial incentives and education to California builders who construct new residences that exceed the state's mandatory minimum energy efficiency standards. Single family production builders and multifamily developers are the primary Program targets. The State's Title 24 energy code[55], set by the California Energy Commission (CEC), establishes the energy efficiency standards for residential and non-residential new buildings. Participating builders that exceed California's Title 24 residential standards by 15% or more receive cash incentives, training and marketing support. In the 2002 incarnation of the program, participating multifamily developers whose compliance level is at least 15% and less than 20% received $150 per unit; those at 20% or higher compliance received $250 per unit.

Given that the ENERGY STAR® New Homes Program is a new construction Program, the cycle for the program – from decision to construction – involves a long lead time. Recognizing that, program participants were given 24 months from the time they are accepted into the Program to complete construction. In some cases, Program managers also provide 3 month extensions to participants requesting additional construction time. This complicates the process of associating program years with participants. 2002 participants could have completed projects as late as December 31, 2004, or possibly longer if time extensions were granted to any of the participant builders. This evaluation considers projects that were completed and approved in 2002 and 2003.[56]

Overview of Data Collection Approach

The information to support these analyses were gathered using detailed structured telephone interviews conducted with developers, builders and owners of multifamily projects in the State of California who had constructed a multifamily building in 2002 or 2003. These interviews covered three key topics:

- Process evaluation topics (data collected via SERA interview for efficiency, analyzed by RLW);
- Net to gross topics, and program attribution issues,
- Non-energy effects.

[54] This description summarizes information from the main body of the report, as summarized by RLW Analytics.

[55] http://www.energy.ca.gov/title24/

[56] A separate report – the 2004-05 EM&V study – will evaluate homes completed in 2004 and 2005, yet the homes included in the evaluation will be a hybrid of 2002, 2003, and 2004-05 Program year homes.

A total of 37 surveys were completed, 23 with participants, and 14 with non-participants. The 23 completions with participants represent virtually all of the 25 total 2002-2003 participants in the multifamily component of the program. Instruments and completions are discussed in greater detail in the following sections.

Survey Instrument

SERA developed the survey used for the participant and non-participant firms with input and approval from RLW Analytics, the PG&E project manager, and representatives from the other utilities. The survey instrument measured the multifamily developers' project background, awareness of and participation/non-participation in the Energy Star® program, general practices, program influence, free-ridership (only in the case of participants), market effects, and non-energy benefits (NEBs).

Experienced personnel administered the survey via telephone. The customary practice called for a maximum of five attempts per record, at different times during business hours. When the appropriate person was contacted, participants were asked to focus on a multifamily building project that had been built / developed between the years 2002 and 2003 and had participated in the Energy Star® Homes program. Non-participants were also asked to focus on a multifamily building project that had been built / developed between the years 2002 and 2003, but one that did *not* participate in the program.

Summaries of the topics included in the participant and non-participant surveys are presented in Table 66.

Table 66: Topics Addressed in MF Participant and Non-Participant Interview Guides

Topics in Participant Interview Guide
Process: • Roles, type of project • Awareness of ESH program, sources of information, reasons for participating, barriers • Assessment of approval process, rater, use of consultant, and other steps • Program strengths and weaknesses • Assessment of impact on marketability Net-To-Gross (NTG) • Energy performance relative to standard construction, program influence in efficiency / performance • Free ridership / likelihood of installing equipment / equipment performance / efficiency changes compared to situation without program; estimated energy savings attributable to program • Related effects, behavioral changes due to installation of higher efficiency equipment through program • Market effects within projects, by participants at other projects, and changes in efficiency and standard construction by non-participants attributable to the influence of the program Non-energy benefits (NEBs) • Positive and negative impacts from program; value of individual NEB categories in relative terms • Overall total NEBs, positive and negative relative valuations via comparison, willingness to pay, and other measurement methods • Use of NEBs in "selling" the dwelling

Firmographics and Attitudes • Changes in knowledge and attitude indicators • Number of employees, CA/non-CA share of work, number of units built / owned / managed in CA, share by territory
Topics in Non-Participant Interview Guide
Process: • Roles, type of project • Awareness of ESH program, sources of information, reasons for NOT participating, barriers • Difficulty in meeting threshold efficiency levels in building • Use of Title 24 consultant Net-To-Gross (NTG) • Baseline energy savings relative to energy code, frequency their projects exceed Title 24 by 15%, relative efficiency level of their projects relative to Title 24 over time, normal building practices / efficiency level • Influence of ESH program on energy performance of projects • Cost differences for meeting / exceeding Title 24 • Role of awareness of ESH in likelihood of installing higher efficient equipment • Related effects, behavioral changes due to installation of higher efficiency equipment generally • Effects of ESH on non-participants / market place, if any Non-energy benefits (NEBs) • Positive and negative impacts from installation of energy efficient equipment in MF, values of individual NEB categories in relative terms • Overall total NEBs, positive and negative relative valuations via comparison, willingness to pay, and other measurement methods • Use of NEBs in "selling" the dwelling Firmographics and Attitudes • Changes in knowledge and attitude indicators • Number of employees, CA/non-CA share of work, number of units built / owned / managed in CA, share by territory

Data from both participants and non-participants were used to estimate the NTG and NEB results.[57] The steps involved in these analyses are presented in the remainder of this chapter.

Sample Design and Completions

In order to assess California's Energy Star® program for multifamily building development, samples of both participating and non-participating builders and developers were surveyed.

Source for Participant Sample: The participant sample was drawn from a database of twenty-five firms that participated in the Energy Star® program in the years 2002 and 2003 with the name, address, phone number, and contact information of each business.

[57] The process questions were analyzed by RLW and the results are presented elsewhere in this report.

Participant Completions: From this sample of twenty-five builder / developers that were participants in 2002-2003, twenty-three surveys were completed. This is more than 90% of the participants for the relevant program year.

Sources for Non-Participant Sample: Non-participants were defined as multifamily builders, developers, or owners that had never participated or had not participated in 2002-2003. The initial sampling approach was not fully successful; therefore, the non-participant sample was drawn from several locations.

- RLW Analytics provided a database with firms who had participated in the Energy Star® Multifamily Home program in any one of the years since the program had been implemented. Those who had not participated in the years 2002 and 2003 were considered "non-participants" for that time frame. Recognizable duplicates in this sample were eliminated and the list was randomized.
- Non-participants were also drawn from a sample acquired through a search engine quest, using the key words "California Multifamily General Contractor." In contacting these businesses, an immediate screener was used to establish if they were involved in residential multifamily construction. The vast majority of the firms on this list were not involved in the necessary activity of building residential multifamily constructions. If the firm was involved in such construction, then the interviewer began administering the survey.
- Further non-participants were found by asking responding firms if they had any suggestions of other firms involved in multifamily construction who may possibly be contacted as well. Fourteen non-participant surveys were completed from these samples.

Non-Participant Completions: The total non-participant sample could not be determined. Assuredly the 14 non-participants represent a relatively small portion of the non-participants for 2002-2003; however, non-participants in this year tended to be participants in other years. This fact, and the fact that this analysis occurred several years after the Program (compromising their recollections of standard practices), complicated the identification and analysis of non-participant data.

Therefore, a total of 37 surveys were completed, 23 with participants, and 14 with non-participants. The 23 completions with participants represent virtually all of the 25 total 2002-2003 participants in the multifamily component of the program. The summary is presented in Table 67.

Table 67: Multifamily Population and Completes

	2002-2003 Participants	Non-Participants
Population	25	Unknown
Respondents	23	14
Percent	92%	n/a

18. Program Attribution – Multifamily Net To Gross Analysis – Skumatz Economic Research Associates (SERA)

Introduction

The Multifamily component of the California ENERGY STAR® New Homes program has important market transformation elements. It uses a combination of incentives and education to encourage multifamily developers to incorporate ENERGY STAR® appliances and recommended whole building design features that cause the building to exceed Title 24 energy standards by 15% or 20% or more. The program works to achieve this in several ways:

- Direct effects: The incentives and education are designed to encourage increased efficiency in a first generation of participating / rebated projects.
- Indirect Participant Effects: The experience and the education provided by the program are designed to help encourage participants to incorporate energy efficient design practices into succeeding projects (including non-participating projects).
- Indirect Market / Non-Participant Effects: In addition, the program's logic would postulate that even non-participant developers could be encouraged to incorporate more efficient practices into their projects because of the combined forces of:
    - competition with other developers,
    - demand in the market,
    - indirect education on the benefits and costs, and on efficient design practices,
    - incorporation of Energy Star® homes elements into revised "standard practice" for multifamily buildings,[58] and
    - increased availability (and potentially improved "price points") for energy efficient equipment in the marketplace.

The Net-To-Gross (NTG) analysis is designed to identify and measure those effects listed above that occur, and occur *due to the presence of the program*. Specifically, to provide information on the performance attributable to the program, the gross savings estimates developed through the impact evaluation and gross savings estimation work described in earlier chapters need to be adjusted by the net-to-gross (NTG) ratio. This ratio is constructed to provide appropriate adjustment for the program's net effect – specifically, to estimate the impact of the program *above and beyond what would have happened without the program*.

Importance of Indirect / Market Effects for Market Transformation Programs

The Energy Star® Homes Programs – both multifamily and single family components – rely on indirect effects on the market and market actors to realize the bulk of the interim and longer-term program effects. A review of the Energy Star® program logic identifies indirect activities, outputs, and outcomes including the following:

[58] For participant and non-participant developers / builders

- Increased builder and public awareness of Energy Star® Homes – including and beyond direct participants
- Educated market actors
- Promotion and advertising of Energy Star® Homes
- More non-participating homes built to Energy Star® Homes standards
- Increased product acceptance and demand for Energy Star® products
- Increased availability of Energy efficient goods, products, and services
- Enhanced home designs and home construction practices in the market, with product differentiation and profitability for builders
- Increased need for (and maturation of) Energy Star® infrastructure, including builders, raters, etc.

Indirect effects are key to the design and success of a market transformation program such as Energy Star® Homes. For this reason, it is critical to measure both:

- the direct effects due to the program – that is, the energy efficiency actions by direct participants that were induced by the program, and
- the indirect and induced effects on participating actors beyond participating projects, and the energy efficiency changes induced in the market by the program, ideally including changes in energy efficiency of non-participating homes, changes in education and actions of non-participant market actors, changes in equipment availability, etc.

The first factor is reflected in the analyses of "free ridership" discussed in upcoming sections. The measurement work on "market effects" described in the following sections measure key elements of the induced and indirect effects, and both methods and results for these key elements of net-to-gross are discussed in the following sections.

Key Caveats and Considerations

Analytical Approach

There have been relatively few efforts to measure the net-to-gross impacts for these types of multifamily initiatives.[59] The NTG work is more difficult for this program than for many others because of two key factors:

- The key decision-makers are developers, and to some extent, builders, and owners. The decision-making may be more fragmented, so questions about the project and motivations for decisions may be difficult to answer.
- Asking about Energy Star® Homes programs are difficult because it is not a single measure that is being rebated, but a set of design practices and measures that combined, lead to at least 15% savings beyond code. Gaining feedback on the savings and impacts compared to a similar project that didn't use these Energy

[59] SERA conducted NTG analyses of 4 related programs (2 MF and 2 Energy Star® efforts) in New York State, for example.

Star® elements necessarily requires an estimate compared to a hypothetical "similar" non-Energy Star® project that doesn't exist.

In the detailed interviews that were conducted, attempts were made to talk with the most relevant decision maker(s). In addition, respondents were asked a variety of questions meant to understand behaviors and decisions relative to Energy Star® elements. Also, as described below, corroborating information was asked in order to confirm responses and understand different nuances about the influences on decisions to incorporate Energy Star® elements into the project. Finally, we talked to both participating and non-participating developers in order to get a better handle on baseline practices in the absence of the program. These efforts have been designed to provide reasonable estimates of the NTG ratio for the program, and the direct and indirect effects from the Energy Star® activities undertaken as part of the Statewide Program. These estimates are important to identify the range of the impact that the program has had on energy efficiency in multifamily buildings, above and beyond what would have occurred without the program.

2002-2003 Program Year Elements Leading to High Free Ridership

The results showed that the participating multifamily projects have very high free-ridership rates (about one-half). This reflects the fact that the 2002-2003 program operated under a period when there were a series of loopholes in Title 24 for multifamily structures. In fact, the on-site and interview work illustrated the fact that many builders were doing nothing different to meet ENERGY STAR® Homes requirement. The primary Title 24 loopholes associated with multifamily housing were:

- Builders indicated[60] that many projects need to exceed Title 24 by 15% for tax incentives / financing reasons (particularly for low income housing).
- The energy modeling programs included several baselines and assumptions that had the effect of allowing multifamily units to meet 15% for program purposes with few to no changes in standard practices.
  Specifically, this included the use of a single-family baseline of 16% -20% wall glazing area. However, multifamily unit layouts are usually limited to one or two walls for installing windows. Multifamily units could easily meet, for example, 8% glazing and receive a "credit" toward meeting 15% improvement over the energy budget. In addition, the program always assumed individual 40 gallon water heaters in each multifamily unit . If a project used a central water heater, it could easily meet the 15% improvement without making any design or equipment changes.

Given the tax benefits and the modeling issues, many of the builders did not need to (nor did they) make any changes beyond what they were going to do anyway in order to meet the qualifications for the Energy Star® Homes Program. This means that the evaluation work will expect to find high free-ridership, and this was one of the results from the project. The builders are building to 15% savings for reasons other than the program and its incentives.

[60] From the Strategy Assessment surveys conducted by RLW Analytics.

The tax-related and modeling loopholes were closed with the October 2005 Title 24 code changes, and this will have a significant impact on the free-ridership estimates associated with later program years.

The sections below describe the steps and analyses used to estimate the net to gross ratio and its components.

Defining Net To Gross (NTG)[61]

Translating gross program-tracked energy and demand savings into just that share that can be specifically attributed to the program is a complex problem in evaluation. Net program impacts reflect gross changes adjusted to account for the combination of two main effects:

- Net effect: a reduction in the gross effect for "free ridership", or that share of program participants that would have undertaken the efficiency behavior or implemented the efficiency measure(s) even without the influence of the program or its market interventions.
- Market effects: an additive adjustment to gross impacts, accounting for the indirect and induced effects from the program, including positive impacts and efficiency increases that the program may have on market actors and actions above and beyond direct program participants.

Given that the evaluation is attempting to measure changes due to the program, and specifically effects above and beyond what would have happened without the program, free ridership (or net effects) is a key component.

- **Free ridership** addresses the set of program participants that would have purchased the energy efficient measure, or adopted the behavior, even without the influence of the program – that is, the program was not instrumental in the participant purchasing / installing the energy efficient measures or using advanced design. Given that the smallest this factor can be is zero, this factor always reduces the gross savings attributable to the program.

The Market Effects (ME) factor, on the other hand, attempts to measure the indirect and induced impacts that the program caused in the market through the indirect and multiplier-type influences from the program. These indirect market effects are an especially important part of the program's intended effects, and derive from the array of market

[61] For additional information on the approach and background, see: Sebold, et.al., "A Framework for Planning and Assesssing Publicly Funded Energy Efficiency", Study ID PG&E-SW040, March, 2001, referred to as "California Framework Study"; Skumatz, Lisa A., Ph.D., John Gardner, and Charles Bicknell (SERA), "Techniques for Getting the Most from an Evaluation: Review of Methods and Results for Attributing Progress, Non-Energy Benefits, Net to Gross, And Cost-Benefit, Proceedings of the EEDAL conference, Turin Italy, May 2005, and Skumatz, Lisa A., Ph.D., Dan Violette, and Rose Woods, "Successful Techniques For Identifying, Measuring, And Attributing Causality In Residential Programs", proceedings from the 2004 American Council for an Energy Efficient Economy (ACEEE), Summer Study, Asilomar, CA; ACEEE Washington DC.

transformation activities undertaken in the Program. There are several components of these indirect and induced market effects:[62]

- **ME Component 1 / within-project effects**:[63] This term consists of additional energy efficiency measures installed or practices incorporated by the builder in a participating building – but not incentivized / included in the program – that were installed because of the influence of the program or the education / awareness provided by the program. These are energy efficient measures or design practices that are not included in the program records or accounted for in program savings computations.

- **ME Component 2 / outside project effects**:[64] This market effects component reflects additional (eligible and non-eligible) efficiency equipment and design features installed by participating builders / contractors in non-participating projects. The measures are not incentivized through the program. This factor accounts for the increase in efficient measures / practices adopted because of the influence of the program even without direct incentives. Indirect Effects: However, that experience and the education provided are designed to help encourage participants to incorporate energy efficient design practices into succeeding projects (including non-participating projects).

- **ME Component 3 / non-participant effects**:[65] This factor incorporates non-program measures purchased / installed by non-participants that were inspired to purchase the energy efficient measures or use the advanced practices because of program advertising or because more efficient measures are in the market due to program actions. Indirect Market Effects: In addition, the program's logic would postulate that even non-participant developers could be encouraged to incorporate more efficient practices into their projects because of the combined forces of:
  - ⇒ competition with other developers,
  - ⇒ demand in the market,
  - ⇒ indirect education on the benefits and costs, and on efficient design practices, and
  - ⇒ increased availability (and potentially improved "price points") for energy efficient equipment in the marketplace.[66]

NTG Formulae: Net program impacts were computed by applying adjustment factors for the effect of free riders and market effects to the gross savings estimates for the program. The basic equation for the Net-to-Gross (NTG) ratio is:

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[62] There can also be "Other" Market effects which can occur through several pathways. For example, manufacturers may change the efficiency of their products, and/or retailers and wholesalers may change the composition of their inventories to reflect the demand for more efficient goods created through an energy efficiency program. Another example might be new building codes or appliance standards adopted in part due to the demonstration of technologies through an energy efficiency program.

[63] For resource acquisition programs, the parallel to this term would be "inside project spillover".

[64] For resource acquisition programs, the parallel to this term would be "outside spillover".

[65] For resource acquisition programs, the parallel to this term would be "non-participant spillover".

[66] In this analysis, stocking behaviors and increased availability in that sense are measured only indirectly through non-participant effects.

NTG ratio = (Net Factor) x (Market Effects Factor)

The net factor equals the attributed fraction of savings, or the value one minus those savings deemed to be free riders.

Net Factor = [1 – (free ridership)]

The market effects factor is a combination of the three market effects components that may influence actions taken outside of the program. The market effects factor is the sum of one and the market effects components:

Market Effects Factor = [1 + (ME Component 1 + ME Component 2 + ME Component 3)]

NTG Data, Computations, and Results

The data were collected as part of the participant, and to some degree, the non-participant interviews conducted as part of the project.[67] The participant interviews provided direct data – self-reported – on free ridership, market effects, and baseline information. The non-participant surveys were used to provide information on non-participant market effects components and to provide context for standard practice.[68]

The results for individual attribution questions are provided in the following paragraphs. The computations were conducted and the information summarized below provides feedback on the major trends and results related to net-to-gross (NTG) and its component factors.

Computing Free Ridership Factors: The questionnaire(s) included several variations of the core question to ascertain the share of the energy savings counted by the program that can be attributed to the effects of the program. Variations providing indications as to free ridership values are summarized below:

- If they had not participated in the program, the likelihood they would have installed all the same energy efficiency measures: 60.2% free ridership
- If they had not participated in the program, the likelihood they would have installed some of the same energy efficiency measures: 74.2% free ridership
- Minimum, maximum, and best estimate of the overall energy savings above Title 24 that were achieved due to the influence of the Program: 41.5%-51.9%.
- Whether the builder already had a need (outside of the Program) to exceed Title 24 by 15% or more: 68% stated yes.

[67] The survey development and the interviews were conducted by Skumatz Economic Research Associates, Inc. (SERA).

[68] Both survey instruments are included in the Appendices.

To provide more robust information from participants, we asked corroborating information as well. This corroborating information is summarized as follows:

- About 29% of participants said the program influenced their decision to increase energy efficiency beyond code "very much." About 35% indicated the program influenced their decision "not at all."
- About 14% said the program was not at all important in their decision to design and build the project to exceed Title 24 by 15%; another 14% said it was somewhat important, and 57% indicated it was very important.

If corroborating factors indicated the program was very influential on the savings achieved, we placed more weight on a lower free ridership factor. If the program was adjudged not influential, more weight was placed on a higher free ridership value.

Free ridership was computed by using the responses to the direct free ridership question battery, adjusted to take into consideration the results from the "corroborating factors". If the corroborating factors indicated the following, the lower free ridership values were selected.

- For those respondents that stated the program was "very important", but provided a high free ridership factor, the information was considered inconsistent.
- For those that stated the program had a high influence, bur provided a high free ridership value, the information was considered inconsistent.

Using these methods, we were able to derive an estimate of free ridership. The computations resulted in an estimate of 50% free ridership factor (0.50). This result indicates that approximately half of the savings from program records may not be strictly attributable to the program.[69]

Computing Market Effects / Indirect Factors: Three types of indirect market effects are traditionally attributable to market transformation programs. These estimates are derived as follows.[70]

- **Within Project Market Effects:** This includes additional energy efficiency measures and design practices installed at the (participating) site that are not covered by the program but are installed because of the influence of the program. However, the comprehensive nature of the Energy Star® program makes it difficult to identify any measures "outside" the program. Therefore, no market effects are attributed to this type of indirect influence.
    - **Estimated Effect**: 0%

- **Outside Project Market Effects**: The program has an effect in influencing participants to carry over Energy Star® measures and practices to other non-participant projects.

[69] Draft estimate. To be revised / refined for final report. The range for the estimate will also be computed for the final report.

[70] The topics were addressed in three pieces: 1) whether the factor exists, 2) the share of savings from this effect as a multiple of the direct program savings, and 3) the share of these savings that were influenced by / due to the program.

- A total of about 28% of the participating builders indicated that the program had influenced their practices at buildings that had not gone through the program. The influence was felt on about 23.5% additional buildings, beyond those asked about in the survey. The respondents stated that the average building size and resulting savings beyond energy code was very similar to the savings realized in the participating buildings. This implies that for every multifamily building (or unit) participating through the program, the influence from the program carried over to about another 23.5% of that many buildings.

- **Non-participant market effects**: The program can indirectly influence non-participant builders to upgrade their energy practices because of the influence of the program on the market.
  - The surveys collected data from participants asking about potential non-participant market effects, and asked about this influence from the non-participant surveys as well. This influence is considerably harder to estimate, and is often considered more indicative than quantitative. Participants were asked whether multifamily builders that had not participated were influenced to build more efficient buildings because of the influence of the program. Nearly half indicated they believed this influence existed; when asked about the number of buildings and square footage affected, the resulting computation indicated a market effect value of perhaps 0.6, or 60%. The non-participants were also asked whether their building practices (or those of their non-participating colleagues) were influenced by the program, even if they had not participated. Approximately 56% stated the program had influenced them to increase energy efficiency.

The results of these computations are provided in the table below.

Net to Gross Results: The estimated Net to Gross Ratio[71] is developed in the following table.

Table 68: Summary of NTG Elements and Computation of NTG Ratio

		Indirect Market Effects			(1-Col A)	(1+Col B+C+D)	(E*F)
Source of Estimate	**A.** Free Rider	**B.** Inside	**C.** Outside	**D.** Non-Partic.	**E.** Net factor	**F.** Market Factor	**G.** NTG Ratio
Household - Participant, non-participant, and control groups	0.50	0.00	0.12- 0.23	0 - 0.14	0.50	1.12- 1.37	0.56-0.69

Comparison of Estimated NTG Values to Other Programs: The results can be compared to results from a review of net-to-gross results from programs at other

[71] Draft results

utilities.[72] While not available as readily for multifamily buildings, the information gathered shows that Energy Star® new homes and retrofit programs (in NY and elsewhere) tend to derive:

- Free ridership of about 0.8, with values a little lower for new homes than retrofit;
- Market Effects of 0.4 to 0.5, with values a little lower for retrofit programs, and
- Net to gross ratios about 1.1-1.2.

The results[73] from the Energy Star® Multifamily program (2002-2003) indicate:

- Free ridership of 0.50, a value that is quite a bit lower than found for programs elsewhere;
- Market effects of 0.12-0.37, which is a little lower than the range provided elsewhere; and
- NTG ratio of 0.56-0.69, about half the range found elsewhere.

The basis of the discrepancy of results rests with the low free ridership figure. We would expect the program influence factors or the NTG to be lower for this program, especially in this time period (2002-2003). Until "gaps" in the code and related modeling were addressed in the more recent standards, multifamily dwellings could readily meet the code with little to no change from baseline practices, so the influence of the program would be expected to be much lower than results for programs elsewhere. The code and modeling problems have been addressed, and we expect to see significantly different program influence levels in the evaluations of later years of the program.

Baseline Building Practices and Program Influence

Several questions were asked about net-to-gross issues in order to ensure the most accurate calculations. Two of the most basic of these were the percentage the program project exceeded code and how much the project would have exceeded code without the program. The results are shown in the table below, with 8.1% higher efficiency in program projects.

[72] Skumatz, Lisa A. 2004. "Leveraging and Review of Indicators and NTG Results from US Programs", Skumatz Economic Research Associates, Inc. Report 2004-04, Superior, CO. and also summarized in Skumatz, Lisa A., Ph.D., John Gardner, and Charles Bicknell (SERA), "Techniques for Getting the Most from an Evaluation: Review of Methods and Results for Attributing Progress, Non-Energy Benefits, Net to Gross, And Cost-Benefit, Proceedings of the EEDAL conference, Turin Italy, May 2005

[73] Draft results.

Table 69: Baseline and Program Related Energy Savings Estimates

	Average Percentage
Average Percentage Program Project Exceeded Code	15.6%
Average Percentage Program Would Have Exceeded Code without Program	7.5%

When this question was asked in more qualitative and broad terms, the responses were more varied. These results are shown in the following two tables.

Table 70: Program-induced Energy Savings Estimates

Estimated Efficiency of Building without Program	Percent of Respondents
Much More Efficient	20%
Somewhat More Efficient	13%
Slightly More Efficient	20%
About the Same Efficiency as Title 24	33%
Slightly Less Efficient than Title 24	0%
Somewhat less efficient than Title 24	0%
Much Less Efficient than Title 24	13%

Table 71: Comparison of Standard Practice to Code

How Standard Practice Compares to Code	Percent of Respondents
Less than Code	0.0%
Just to Code	42.9%
Above Code	57.1%

These results were impacted by the finding that 63% of participants had a need to exceed Title 24 by 15% for a reason not related to the Energy Star Homes program. This finding is corroborated by 53% indicating that energy efficient design changes would have been made without the program. These results are also shown in the table below.

Table 72: Program and Other Influences in Exceeding Code

	Percent of Respondents
Percentage with Need to Exceed Code by 15% Apart from Program	63.2%
Percentage that Would Have Made Energy Efficient Design Changes without Program	52.9%

These results indicate that, likely for a number of reasons related to the program design and the operation of the codes and standards, many of the program participants would have exceeded code without the influence of the program. However, the results imply that the actions and savings from about half the respondent participants were influenced by the program. Further, the responses indicate that the program has also had some influence on the market, moving participants to achieve higher savings in non-participating buildings, and non-participants to achieve greater efficiency and energy savings in non-participating buildings than they would have without the program.

Summary of Program Attributable Savings Results

RLW computed the gross program savings. These figures are presented in the following table.

Table 73: Program-induced Energy Savings Estimates (Source: RLW Analytics)

Year	Cooling Savings (Source Kbtu/year)	Gas Heating Savings (Kbtu/year)	Electric Heating Savings (Source Kbtu/year)	Water Heating Savings (Kbtu/year)	Total Energy Savings (KBtu/year)	Electric Savings (Site kWh/year)	Gas Savings (therms/ year)	Dwel-ling Units	Struc-tures
Total	11,487,257	7,754,467	685,743	29,566,694	49,494,161	1,189,932	373,212	7,281	758
2002	2,199,013	702,346	164,521	2,629,545	5,695,425	231,039	33,319	740	131
2003	9,288,244	7,052,121	521,222	26,937,149	43,798,736	958,892	339,893	6,541	627

The total kWh and Therm savings, computed in terms of total KBtu per year were also computed by RLW Analytics. These figures are presented in the following table.

Table 74: Program-induced Energy Savings Estimates (Source: RLW Analytics)

Utility	Structures	Tracking Savings (KBtu/year)
PG&E	113	6,649,016
SCE	28	2,900,669
SCG	367	27,209,307
SDG&E	250	12,735,169
Total	758	49,494,161

Using the findings from the self-report net to gross computations derived earlier in this chapter, the estimated net savings attributable to the program are presented in the following table.[74]

Table 75: Estimated Net Program Attributable Savings

Program	Gross savings (Source: RLW Analytics)	Estimated NTG Ratio (Source: SERA)	Estimated Net Savings for Program
Total 2002-2003 combined kWh (site kWh/year)	1,189,932 site kWh/yr	0.56-0.69	666,362-821,053 kWh/yr
Total 2002-2003 combined Therms	373,212 therms/yr	0.56-0.69	209,000-257,516 therms/yr
Total 2002-2003 KBtu/year	49,494,161 KBtu/year	0.56-0.69	27,716,730-34,150,971 KBtu/yr

[74] Draft results. Note that, due to relatively small numbers of participants and respondents in these early years of the program, we only apply the NTG for total savings. No information to support differences in NTG for different climate zones, program year, fuels, or utility territories are derived.

19. Multifamily Non-Energy Effects – Skumatz Economic Research Associates (SERA)

Introduction

Although California's Statewide Energy Star® Multifamily program is designed to save energy, the reality is that participation in energy efficiency (EE) programs or adoption of energy efficiency measures occurs for a host of reasons in addition to the specific goals of any program. When asked, participants routinely cite non-energy impacts and considerations either as a component of decision-making or as benefits they recognized after installing energy efficient equipment. In studies of commercial programs, participants routinely mention non-energy benefits (NEBs) as reasons for their satisfaction with various Programs.

Importance of Indirect / Market Effects for Market Transformation Programs

The Multifamily component of the California Statewide Energy Star® Homes Program incorporated a wide variety of direct and indirect goals and outcomes. As a market-transformation-type program, indirect effects and hard-to-measure outcomes on the market and market actors are very important components of identifying "success" for the Program. In addition to success factors due to the number of Energy Star® Homes and equipment, there were also a number that were related to non-energy benefits. These factors are described in the following sections.

Background on Non-Energy Benefits

While the focus of traditional program evaluations – energy savings, awareness, market share and other metrics – provide direct indicators of program effects, a significant body of work has developed around recognizing and measuring net non-energy benefits (NEBs). NEBs include a variety of program impacts — positive and negative — that result from the program.[75] Strictly speaking, NEBs are "omitted program effects" – impacts attributable to the program, but often ignored in program evaluation work. After nearly a decade of research, more and more utilities and regulators are considering these effects.

In order to assess the NEBs associated with the California Statewide Energy Star® Multifamily program, Skumatz Economic Research Associates (SERA) developed a questionnaire directed at identifying NEBs accruing to Program participants. The sampling source consisted of (a) a list of program participants supplied by PG&E and (b) the California Residential Builders Database. Potential respondents were called in random order a maximum of five times. The final sample consists of 25 completed surveys.

[75] Note that the literature has used the designation "non-energy benefits" although we examine both positive and negative impacts from energy efficiency measures. Although the conventional term NEB is used in this project, the name refers to "net" non-energy benefits.

While the primary purpose of most energy efficiency programs is to save energy or reduce peak demand, these programs, by their nature, lead to a host of effects beyond these outcomes. These other effects are commonly called Non-Energy Benefits (NEBs) – even though not all the effects are positive.[76] There are three main types of net non-energy benefits based on who is the beneficiary:[77]

- **Utility/agency benefits.** These are positive or negative impacts that affect ratepayers and utilities and reduce revenue requirements – for example lower bad debt because of lower arrearages, lower line losses, power quality issues, and reduced labor cost from fewer bill-collection-related calls. These effects are generally valued at utility (marginal) costs.

- **Participant (or "user") benefits.** These consist of non-energy factors that benefit or affect the participant users of the energy efficient equipment beyond energy savings – for example, comfort, improved ability to pay bills, and a wide variety of factors included in the tables below. These effects are valued in terms relevant to the participant.

- **Societal benefits.** Non-energy impacts that (positively or negatively) affect the greater society or that can't be attributed directly to utility/ratepayers or participants. These include emissions/environmental benefits/health benefits, direct and indirect economic multipliers, water system benefits (if they need fewer treatment plants, etc.), or similar items. These effects are valued as appropriate to the benefit category.

Typical categories of benefits based on a decade of past work follow in Table 76 below. This list is not comprehensive, and obviously some benefits can cross categories.[78] Whether specific benefits are included or excluded from the analysis tends to depend on which measures are included in the program, and the use intended for the NEB analysis. The list of benefits to be included in the program attribution analysis is usually refined in collaboration with the program staff.

[76] We most commonly call them "net non-energy benefits" to account for the negative benefits as well. We have also called them non-energy impacts, non-energy effects, non-utility benefits, and others, but the commonly accepted term in the literature is NEBs, so we use that convention.

[77] The literature has adopted the convention of categorizing NEBs into three groups based on beneficiary; this is developed from Skumatz, Lisa A., "Recognizing All Program Benefits: Estimating the Non-Energy Benefits of PG&E's Venture Partners Pilot Program (VPP)", 1997 Energy Evaluation Conference, Chicago, IEPEC, August 1997.

[78] We tend not to include tertiary type benefits like tax –related impacts, as we prefer to be more conservative.

Table 76: Net Non-Energy Benefits (NEBs) Categories included in "NEB-It"© Model[79]

NEB Categories	
Utility Benefits	
• Reduced carrying cost on arrearages (interest) • Bad debt written off • Shutoffs • Reconnects • Notices • Customer calls / bill or emergency-related • Other bill collection costs	• Emergency gas service calls (for gas flex connector and other programs) • Insurance savings • Transmission and distribution savings (usually distribution only) • Fewer substations, etc. • Power quality / reliability • Reduced subsidy payments (low income) • Other
Societal Benefits	
• Economic benefits – direct and indirect multipliers • Emissions / environmental (trading values and/or health / hazard benefits) • Health and safety equipment • Water and waste water treatment or supply plants • Other	
Multifamily Participant Benefits[80]	
• Water / wastewater bill savings • Operating costs (non-energy)[81] • Equipment maintenance • Equipment performance (push air better, etc.) • Equipment lifetime • Tenant satisfaction / fewer tenant complaints • Comfort • Aesthetics / appearance • Lighting / quality of light • Noise • Safety, insurance	• Health issues • Ease of selling / leasing • Labor requirements (separate from equipment O&M) • Indoor air quality • Doing good for environment • Reliability of service / power quality • Savings in other fuels or services (as relevant) • Feeling of greater control over bill / understanding of energy use (residents if relevant) • NEGATIVES (usually incorporated into above) some may have worse maintenance, parts may be harder to get, greater training needs for maintenance staff, etc.

Note that several benefits arise in multiple categories. For example, having fewer bill-related calls to the utility benefits both the utility / ratepayers AND the households making or receiving those calls. This is not double-counting benefits – rather, it recognizes that some effects have multiple beneficiaries and each is valued at the appropriate tailored valuation method. For example, this saved time from calls may be valued at the marginal labor cost for customer service staff for the utility's benefit, and at the minimum wage rate for low income households. Benefits are recognized and realized by both groups; whether they are included in specific computations depends on their appropriateness to the application.

Estimation of the various categories of NEBs can be conducted using several key steps:

- Attribution of utility and societal NEBs can be measured using a combination of primary and secondary data. There is an extensive literature measuring the arrearage impacts of programs (particularly low income programs), as well as many others of these impacts. Detailed examination of the program impacts – or the literature– may

[79] Skumatz, Lisa A., Evaluating Attribution, Causality, NEBs, and Cost Effectiveness in Multifamily Programs: Enhanced Techniques", EEDAL Conference Proceedings, London, England, 2006.

[80] Positive and negative impacts, estimated using participant surveys for many of the NEBs.

[81] Sometimes omit if likely to double count with the next two categories

be needed to estimate the impacts on reconnections and other factors that may be affected by the program.[82]

- Societal impacts also have a significant literature and indeed, the two key components, environmental and economic impacts – have a very high degree of volatility depending on the data sources and valuation methods used. Impacts on greenhouse gases (GHG) are increasing in importance and have been estimated in the literature.[83] There also exists a growing literature estimating the *net* economic impacts from energy efficiency programs, assuming a transfer of expenditures from electricity generation to economic sectors affected by the weatherization or other program.[84]
- Estimation of participant benefits rely mostly on responses to surveys, combined with a limited amount of programmatic and secondary data.

Given that the 2002-2003 Program Year included only 25 participants, estimate of the societal and utility benefits are not included in this report, but will be addressed in the report for later program years in which there are larger numbers of participants.[85] This report on the 2002-2003 program year focuses benefits that accrue to program participants.

Estimating Participant NEBs

The most challenging portion of non-energy benefits work is assessing the participant portion of the benefits. SERA has spent considerable time on this issue, and has pioneered, tested, and compared several credible methods of estimating these "hard to measure" (HTM) impacts based on the results of NEB analyses for several thousand program participants over 10 years. The research includes an evaluation of measurement options with respect to: ease of response by respondent / comprehension of the question by respondents; reliability of the results / volatility; conservative / consistent results; and

[82] See for example, Hall, Skumatz, and Megdal, "Low Income Public Purpose Test: Non-Energy Benefits for Low Income Weatherization Programs", prepared for PG&E, 2000 for an extensive discussion of these estimation methods.

[83] These impacts are a "slippery slope" – they can be estimated in a simplistic way, or if health impacts are to be measured in detail, then issues related to specific microclimates and time of day and zones are important. For some programs, average generation mix should be used to assess emissions; for others (e.g. a peak load reduction program, residential air conditioning programs, etc.) emissions from marginal peak load plants should be used to estimate changes in emissions from the energy savings. Valuations are the source of considerable debate in the literature as wellFor some clients, there are values that have been agreed upon by the regulators. For others, we used specific values included in the literature, or averages of valuations from many sources. Which valuations are most appropriate depends on not only the location, but also the use to which the work will be applied.

[84] Some of the literature is flawed in that they estimate the job creation and economic multipliers of a *gross* expenditure toward conservation on the economy when instead they should be measuring the *net* impact of a transfer of funds. For an extensive discussion of the environmental and economic impacts, see Gardner and Skumatz, "Do Economic NEB Multipliers Vary with Program Design and State?", forthcoming, proceedings for the ACEEE Summer Study, Asilomar, CA, 2006, and Imbierowicz and Skumatz, " The Most Volatile Non-Energy Benefits (NEBs) – New Research Results "Homing In" On Environmental And Economic Impacts", American Council for an Energy Efficient Economy Summer Study, held in Asilomar, CA, ACEEE, Washington, DC, August 2004.

[85] Given the small number of participants, the total value of the societal and utility NEBs would be fairly small.

computation clarity, among other criteria. The state-of-the-art measurement approaches that have been tested include: [86]

- Contingent valuation (CV) including Willingness to pay (WTP) / willingness to accept (WTA)
- Alternative methods of comparative, scaling, or relative valuations
- Direct computations of value to owner,
- Discrete choices or ordered logit, and
- Other revealed and stated preference, statistical methods, and other approaches.

Each is described in the following sections.

Contingent Valuation (CV) Techniques[87]

The contingent valuation approach to measuring NEBs involves some manner of asking program participants to place a dollar value on the benefits that they experienced. Contingent valuation is one of the standard methods of measuring the value of environmental damage in litigation and has long been debated in the environmental economics literature.

There are two basic variations of the contingent valuation method. The first, Willingness to Pay (WTP), asks participants to estimate how much (usually in dollars annually) they would be willing to pay for the NEBs that they claim to have experienced. As the name implies, Willingness to Accept (WTA) asks them to estimate how much they would accept in compensation if they were divested of those same benefits. Empirically, WTP and WTA values tend to fall near one another, although there is considerable theory and evidence that WTA values average higher than their counterparts.[88]

In addition, WTP and WTA questions can be phrased as either discrete referendum-style questions in which respondents are asked whether they would pay (or accept) a predetermined amount (this value is usually determined through either open-ended pre-testing or values obtained in similar studies) or as open-ended questions in which respondents are simply asked to estimate the dollar value with no prompt. Such questions are easier for respondents to answer than open-ended questions because most consumers have little experience placing an exact dollar value on commodities that they have never purchased directly. In addition, responses to yes/no WTP and WTA questions

[86] See descriptions in Skumatz and Gardner, "Differences in the Valuation of Non-Energy Benefits According

to Measurement Methodology: Causes and Consequences", Proceedings of the AESP Conference, San Diego, 2006, and

Skumatz, Lisa A., "Comparing Participant Valuation Results Using Three Advanced Survey Measurement Techniques: New Non-Energy Benefits (NEB) Computations of Participant Value", Proceedings of the 2002 ACEEE Summer Study on Energy Efficiency in Buildings held in Asilomar, CA, ACEEE, Washington, DC, August 2002.

[87] This description derived from Skumatz and Gardner, "Differences in the Valuation of Non-Energy Benefits According

to Measurement Methodology: Causes and Consequences", Proceedings of the AESP Conference, San Diego, 2006.

[88] Horowitz, John and K.E. McConnell. 2002. "Willingness to Accept, Willingness to Pay and the Income Effect." October, 2002.

can be transformed into median values by applying a logistic regression method. This technique, though, is sensitive to the values that are chosen to be asked of respondents. Careful pre-testing must be conducted to ensure that the price prompts given are in a reasonable range. Moreover, when budgets are small or when sample universes are limited, adequate pre-testing may not be possible.

In such cases, open-ended contingent valuation questions may be posed. Evidence from surveys clearly shows that NEBs valuation responses given in the open-ended format tend to vary widely and exceed values obtained through any other technique. In addition, many respondents find it too difficult to even estimate a value, particularly when the benefit that they are considering is at the level of whole-building savings or larger.

All types of contingent valuation approaches to measuring NEBs are subject to some degree of bias. Economists believe that WTP and WTA questions may either (a) lead respondents to believe that they have entered a bargaining situation in which they have an incentive to misrepresent the true value of the good in question or (b) appear so hypothetical that respondents do not seriously consider the true value to them of the benefit that is under consideration, leading to highly variable replies.

Scaling Techniques[89]

At their core, scaling techniques for measuring NEBs are straightforward. They all involve asking program participants to express the value of the NEBs that they experience relative to a numeraire with which they are familiar. Given that this work is most often undertaken in the context of the evaluation of programs that aim to provide program participants with savings on their energy bills, an obvious choice for this numeraire is the energy savings itself.[90] One advantage to using energy savings as the reference point for measuring NEBs is that, in the context of a survey regarding the measures installed as part of the relevant program, participants have already been asked to discuss their energy savings, as well as other issues regarding the program's effect on energy use, and they are more likely to be mentally familiar with the issue than they might be otherwise.

Direct scaling asks participants to express the benefits that they experience as a percentage of their energy savings. This approach is advantageous in that it easily produces participant-level energy savings multipliers that should, at least in theory, more

[89] This description derived from Skumatz and Gardner, "Differences in the Valuation of Non-Energy Benefits According to Measurement Methodology: Causes and Consequences", Proceedings of the AESP Conference, San Diego, 2006.

[90] This approach was pioneered in 1996 by SERA and discussed in Skumatz and Bordner, "Evaluation of PG&E's Venture Partners Pilot Program", prepared for PG&E, 1996, and in Skumatz and Dickerson, "Recognizing All Program Benefits: Estimating the Non-Energy Benefits of PG&E's Venture Partners Pilot Program (VPP)", Proceedings of the IEPEC Conference, Chicago, IL, August 1997, among other sources. The approach derived from the concern that participants repeatedly found it difficult to report dollar values; SERA tests asking "relative" valuations was discovered to be far more successful at obtaining responses – and consistent responses – from surveyed participants. Considerable literature was identified recommending this type of approach.

accurately reflect the value of the NEBs that each participant received. It also produces answers to a higher degree of standardization. Although energy savings may differ among participants, there can be no disagreement regarding what is meant when a respondent reports that they experienced non-energy benefits on the order of ten percent of their energy savings.

Direct scaling does, however, present some drawbacks. Though having benefits expressed as a percentage of energy savings is desirable for many reasons, survey respondents may find it difficult to estimate that percentage at all, let alone with any reassuring degree of accuracy. Very often respondents (especially residential respondents) are not terribly comfortable with percentages. The issue of accuracy may be dealt with statistically by assuming a normal distribution error in respondent replies.[91] The issue of missing data, however, can seriously disrupt program analysis – it is extremely important to present participants with survey questions that they can actually answer.

Relative scaling attempts to resolve that problem. Relative scaling questions once again ask respondents to value the non-energy benefits that they experience relative to their energy savings. However, they do not require interviewees to choose exact percentages. Rather, they ask them to express the benefits qualitatively relative to their energy savings. The relative answers are then translated into average percentages or ratios using empirical research. The tradeoff between relative and direct scaling questions is obvious. One presents a harder-to-answer question to respondents, but potentially offers more accuracy; the other presents an easier-to-answer question (and thus, generally includes less missing data), but is less directly translated into a dollar value.

Regardless of the specific type of scaling question used, the technique is very successful in producing meaningful and interpretable responses. One potential drawback of both question formats is the assumption that respondents actually experienced energy savings. In cases where program participants claim that there were no noticeable changes in their energy bills, scaling-based NEBs valuation needs to use a different comparator.[92] Nevertheless, empirical research indicates scaled NEBs values are, in general, much more stable than those obtained through the techniques primary competitor: contingent valuation.[93]

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[91] Monte Carlo simulations or statistically-appropriate hot deck imputations can help address this issue of missing data. See, for example, Holt, Barnes, Skumatz, “Non-Response in Energy Surveys: Systematic Patterns and Implications for End-Use Models”, The Energy Journal, 1988.

[92] A variation of this effect is the variable savings scenario. When efficiency programs are homogenous in the measures that they install and the locations in which they install them, average deemed energy savings generally suffice when multiplying scaling answers to obtain dollar-valued savings. However, when either factor differs significantly from participant to participant, average savings may drastically distort the value of NEBs, particularly when extreme scaling responses coincide with extreme savings estimates. Unfortunately, individual-level energy savings data may be difficult or impossible to obtain, potentially diluting the accuracy of NEBs valuation using the scaling technique.

[93] For additional corroboration, see Skumatz, 2002, *op. cit.*

Other Measurement Approaches

In addition to contingent valuation and scaling options, several other main types of options are available; however, each family of methods has drawbacks.

- Direct computations of value have the advantage of accuracy; however, they are rarely computed (especially in the case of residential programs). Therefore, two significant problems arise from this approach: missing data and bias. Few participants perform direct computations of benefits, leading to significant missing data. Also, those computing the effects are unlikely to represent a random sample of beneficiaries, but would more likely include those with high benefits; hence, generating a biased set of data. Direct estimation of benefits using statistical approaches can also be computed. However, data are likely available for only a subset of benefits[94] categories or from a small sample of participants.

- Discrete choice or ordered logit approaches have proven to be robust methods for estimating NEBs.[95] Unfortunately, they are relatively difficult to administer via telephone and are a better fit for mail, web, email or similar applications.[96] Discrete choice and ordered approaches can also be more difficult for residential participants to answer.

In addition, other revealed and stated preference, statistical methods, and other approaches are being developed, but are still undergoing study.

Selected Measurement Approach

These measurement methods can be complex to implement, and a great deal of work has been conducted to refine the techniques. Based on research over 10 years on more than 50 programs, we have found that generally, comparative or relative valuations[97] perform substantially better than other methods. Willingness to pay (WTP) can often provide very volatile numbers and respondents have an extremely difficult time understanding the concept of stating a dollar amount they would be willing to pay for these benefits. We have incorporated multiple measurement methods into the same studies, and have found

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[94] For example, see Lisa Heschong's (Heschong Mahone Group) work on daylighting in a retail chain and in schools in Proceedings of the ACEEE Summer Study on Buildings, Asilomar, CA, 2002 and 2004.

[95] See Gardner and Skumatz, "NEBs in the Commercial and Industrial Sector", forthcoming, Proceedings from the ACEEE Summer Study on Buildings, Asilomar, CA 2006.

[96] Web approaches have been demonstrated starting in 2002 in work in New Zealand. See write-up in Stoecklein and Skumatz, "Using NEBs to Market Zero and Low Energy Homes in New Zealand", Proceedings of the ACEEE Summer Study, Asilomar, CA, 2004.

[97] Methods pioneered and adapted by the authors, based on the academic literature; see descriptions in Skumatz, Lisa A., "Comparing Participant Valuation Results Using Three Advanced Survey Measurement Techniques: New Non-Energy Benefits (NEB) Computations of Participant Value", Proceedings of the 2002 ACEEE Summer Study on Energy Efficiency in Buildings held in Asilomar, CA, ACEEE, Washington, DC, August 2002.

that on average, WTP is volatile (and less conservative), and that scaling, discrete choice, and other measurement methods we have adapted perform more reliably; our research incorporates these approaches.[98]

The relative and direct scaling approaches represent the primary estimation approaches in this project; however, some information was also gathered using contingent valuation methods.

Valuing the NEBs

A key objective of the NEB portion of the evaluation was to "value" previously unvalued or undervalued benefits to participation in the program. Extensive field experience and a wide body of literature suggest that, for programs such as the California Statewide Energy Star® Multifamily program, the value of the NEBs experienced by participants can be as much as, or more than, the energy savings that occur due to program effects.[99]

NEBs Valuation Methodology

To estimate the value to participants of the home energy-efficiency improvements implemented through the program, we employed the relative comparison value method of NEBs valuation.

We asked respondents about NEBs in terms of their relative value on a verbal scale. These responses were translated into numeric values. Respondents were asked about the value of the benefits relative to energy savings using a five-point scale (much less valuable, somewhat less valuable, same value, somewhat more valuable, and much more valuable). The relative values were then scaled to percentage-of-energy-savings values obtained from other empirical research, SERA research, and academic scaling literature. Because these questions are more quickly answered than percentage responses - and because time on the surveys was limited - this was the approach used for valuing individual NEB categories as well as the overall totals.

One potential problem associated with each approach is the issue of "adding up." Generally, when asked the value of individual benefits, the total is greater than the figure that respondents provide when answering a question about the total of all the benefits. That is, the sum of the parts is greater than their estimated totals. The issue is addressed by normalizing the individual benefits - reducing their values proportionally to add to the estimated total benefits as valued by the respondents. Both individual and total benefits

[98] For an analysis of comparative, willingness to pay, and labeled magnitude scaling methods, see Skumatz, Lisa A., Ph.D., “Comparing Participant Valuation Results Using Three Advanced Survey Measurement Techniques: New Non-Energy Benefits (NEB) Computations of Participant Value”, Proceedings of the 2002 ACEEE Summer Study on Energy Efficiency in Buildings, held in Asilomar, CA, American Council for an Energy Efficient Economy, Washington, DC, August 2002.

[99] Bicknell and Skumatz, “Non-Energy Benefits (NEBs) in the Commercial Sector: Results from Hundreds of Buildings”, Proceedings from the ACEEE Summer Study, Asilomar, CA, 2004 and sources mentioned therein.

were asked in association with estimating the NEBs for the Program to allow for this normalization.

A final methodological issue relates to the issue of "net" non-energy benefits.[100] The appropriate approach for attributing NEBs to the program is to provide estimates that are "net" in three ways.[101]

- **Net Positive and Negative**: First, despite the historical name for these impacts (non-energy benefits), both positive and negative impacts must be incorporated.[102] Both positive and negative impacts are explicitly requested - for each individual NEB and for the total of all NEBs - there is no presumption of a positive effect. The results are the combination of positive and negative valuations.

- **Net above New Standard Equipment**: Second, to attribute the impact due to the program, the respondents need to be asked about the NEBs for the new efficient equipment relative to the base non-efficient equipment that would otherwise have been purchased. The appropriate comparison is generally not the new efficient equipment but the baseline equipment and features. The respondents are asked to specify the net non-energy benefits from the energy efficient equipment installed through the program - above and beyond the effects they would have realized from installation of a standard efficiency model. While it is true that this may be somewhat difficult for respondents to answer, it is the appropriate comparison for the program to make. It is important to note, however, that it is also a conservative approach. Some percentage of the participants would not have replaced the equipment at all without the program; in those cases, it might be argued that all the non-energy benefits realized compared to the old equipment could be attributed.

- **Net of Free Ridership / NTG Considerations**: A third adjustment is also appropriate. If there are free riders that would have purchased the same equipment without the program, then the NEBs associated with that equipment should not be attributed to the program. Only those benefits from installations that would not have happened without the program's influence should be attributed to the program, so the NEBs associated with free riders should be omitted, and net to gross ratios could appropriately be applied.

The survey asked program participants to estimate the extent to which the energy efficient measures that were installed in multifamily units were due to the program, and the extent to which energy efficient measures might have been installed in non-participating housing developments as an indirect result of the program. These questions are hypothetical and

[100] These nuances are important components of the proper evaluation approach and have been incorporated into this NEB research.

[101] Skumatz, Lisa A., "Methods and Results for Measuring Non-Energy Benefits in the Commercial and Industrial Sectors", Proceedings of the ACEEE Industrial Conference, West Point, NY, July 2005.

[102] The term we use is "net non-energy benefits" (NNEBs) but we will refer to them as "NEBs" in this paper. Over a 10 year period, we have developed effective (proprietary) methods of asking these questions and valuing the responses. In addition, a model "NEB-It"© is used to compute values.

require respondents to perform a great deal of extrapolation based on both their experiences with the participating housing development in question and other housing facilities with which they have had experience. In order to account for potential inaccuracies that might arise from this free-ridership and market effects valuation methodology, NEBs value ranges are presented using both the program-specific data collected through the survey as well as other empirical data gathered by SERA on a variety of similar projects.

In this study, care was taken to assure that the non-energy benefits that were attributed to the program were not intentionally overstated or biased.

Overview of NEBs Impacts

Three elements of valuation of the NEBs are explored, including:

- Percent reporting positive vs. negative effects in NEBs, by category,
- Share of the value represented by each NEB category, and
- Total value of the NEBs.

Results from each analysis are discussed below, as well as implications of the results.

Percent Reporting Positive and Negative NEBs

Both participants and non-participants were asked whether they associated negative, positive, or no non-energy impacts with the Energy Star® equipment and measures. The directions (negative, no or positive impact) of the non-energy effects reported by program participants and non-participants are presented in Table 77. Participants were asked whether they experienced any differential effects from using high-efficiency equipment instead of standard equipment; responses from non-participants were based on their perceptions of differences between Energy Star® energy efficient compared to standard new equipment.

Table 77: Direction of NEBs Impacts

	Participants			Non-Participants		
Category	Negative	No Effect	Positive	Negative	No Effect	Positive
Operating cost (other than energy)	0%	31%	69%	0%	70%	30%
Equip maintenance	0%	47%	53%	0%	86%	14%
Equip Performance	0%	53%	47%	14%	57%	29%
Equip Lifetime	0%	38%	62%	0%	86%	14%
Occupant satisfaction	0%	44%	56%	0%	67%	33%
Occupant Comfort	0%	56%	44%	0%	67%	33%
Aesthetics / Appearance	0%	69%	31%	10%	50%	40%
Lighting / Quality of Light	13%	56%	31%	10%	30%	60%
Noise	6%	50%	44%	0%	50%	50%
Building Safety	0%	88%	12%	0%	90%	10%
Ease of leasing/selling	0%	53%	47%	0%	40%	60%
Doing good for environment	0%	19%	81%	0%	17%	83%
Power quality / reliability	0%	67%	33%	0%	100%	0%

Participants: Participants noted environmental benefits, operating cost, equipment lifetime, occupant satisfaction and equipment maintenance as among the most commonly positive categories associated with the program. In each of these categories, more than half of those surveyed reported a positive effect. The effect of "doing good for the environment" was rated as positive by an overwhelming 81% of respondents, punctuating the idea that some of the most important consequences of the program are distinct from the goals of increased energy efficiency and cost savings, at least in the eyes of program participants.

Few reported experiencing any effects, positive or negative, in building safety, aesthetics or power quality. For every other category, nearly half of those surveyed reported experiencing some effect. The only categories for which negative effects were reported were noise (6%) and light quality (13%) – for each of these categories, however, a greater percentage of respondents reported experiencing positive effects than did negative effects.

Non-Participants: Non-participants were most likely to associate positive benefits in the form of doing good for the environment, improved light, reduced noise, and ease of selling / leasing the dwelling. For each of these categories, half or more thought the energy efficient Energy Star® equipment delivered positive NEBs compared to standard efficiency equipment. Few thought there were positive effects from maintenance, lifetime, safety, or power reliability effects.

About one-seventh of the non-participants feared the energy efficient equipment would perform less well than standard equipment, and one-tenth expressed concerns about aesthetics / appearance and quality / quantity of light (matching the concerns expressed by participants).

Relative Values of the NEBs by Category

Table 78 shows the proportion of the total NEBs reported by program participants attributable to the various NEB effects categories. Results for non-participants were not computed.[103] After the participants were asked – category by category – whether they associated negative, positive, or no non-energy effects with the energy efficient Energy Star® equipment, those reporting non-zero impacts were asked a follow-up question. If their response was positive, they were asked whether the NEB was more or less valuable than the incremental energy savings associated with the Energy Star® equipment, and how much more or less valuable, using a relative scale (much more, much less valuable, etc.). If their response was negative, they were followed up with requests for information about whether the NEBs were more (or less) costly than the energy savings, and how much more or less costly. The relative answers are then translated into average percentages or ratios using SERA's empirical research on more than 50 programs, and the results are incorporated into SERA's "***NEB-It***"© model. The percentage of total value associated with each NEB category is presented in Table 78.

The results show that the total NEBs value is distributed fairly evenly across categories, with no one category garnering an especially high or low share. Operating costs, equipment maintenance, equipment lifetime, occupant satisfaction and environmental benefits were the most valuable categories, each taking close to at least 10% of the total NEBs value associated with the program. The least valuable category was building safety, which accounted for only 2% of total NEBs.

Table 78: NEBs Shares

Category	Share
Operating Cost	14%
Maintenance	10%
Equipment Performance	9%
Equipment Lifetime	10%
Occupant Satisfaction	9%
Occupant Comfort	8%
Aesthetics	5%
Light Quality	5%
Noise	6%

[103] This is because there were relatively few respondents and because the results are relatively more "hypothetical" in nature.

Category	Share
Building Safety	2%
Ease of Selling/Leasing	6%
Helping the Environment	12%
Power Quality/Reliability	4%
Total	100%

Overall NEBs Value Estimates

The data were used to estimate the value of the total NEBs perceived by participants. Responses to several questions were used:

- Verbal scaling responses to whether the total NEBs are more or less valuable than the energy savings; and
- Percentage responses to whether the total NEBs are more or less valuable than the energy savings.

For the percentage responses, the average percent (including both positive and negative responses) was computed to derive the overall NEB energy savings multiplier. The verbal responses were analyzed as described above. The results provide the value of total NEBs as a multiple of energy savings attributable to the program.[104]

Table 79 presents a summary of the estimates of the total value of the program-attributable NEBs in terms of the energy savings due to the program. Using the comparison technique described in the methodology section, respondents were asked to describe the NEBs that they experienced in terms of the energy savings arising due to the energy efficiency improvements implemented in their housing project.

- The total value of the NEBs experienced by participants was 69% of the energy savings that occurred as a result of building energy efficiency improvements, based on the verbal scaling results.
- Using the percentage responses, the estimated value of the NEBs was 86% of the value of the energy savings.[105]

Adjustments for Net Attributable Effects: Earlier in this report the net-to-gross (NTG) ratio was computed. The results showed that free ridership was 50% (half the savings associated with the program would likely have occurred without the program). In addition, the results showed induced market effects of about 12-37% from the program. The

[104] In addition, responses to willingness to pay questions were examined. The results showed contingent valuation results were in the range of about $540 - $1,200; however, there were few responses to these questions.

[105]In most previous work, the results from the percentage and verbal scaling methods are more similar. The results in this report likely suffer from small sample size issues.

resulting NTG ratio is 56%-69%, a ratio that represents the share of program monitored energy savings that could be attributed to the impacts of the program.

Combining the NEBs estimates and the NTG results, an adjusted figure for NEBs is computed and is presented in the Table 79.

Table 79: NEBs Value Estimates

Category	Value
A. Computed value of NEBs	69-86% of program energy savings
B. Free ridership (from Table 3.1)	50% of total energy efficiency improvements
C. Market Effects (from Table 3.1)	12%-37% market effects
D. NTG (from Table 3.1; B*C)	56%-69%
E. Attributable Total NEBs value multiplier (A*D)	39% to 59% of program energy savings

The survey also asked whether these NEBs were used to try to convince the builder to install energy efficiency measures as part of the Energy Star® program. Almost two-thirds (64%) of respondents indicated NEBs were used in helping make the case for the Energy Star® measures. Of those reporting NEBs were used to influence the decision, the respondents stated the NEB were fairly influential in the decision on the measures (3.8 on a 5 point scale, where 5-very important, and 1=not important).

Summary and Implications

These results imply that the program's benefits go beyond providing efficiency and energy savings to occupants. On a per-household basis, the program's measures and practices lead to benefits that are worth another 69-86% of the value of the energy savings. Additional computations can estimate the NEBs that are "attributable" to the program – taking account of free ridership and potentially indirect market effects impacts. These computations derive an estimate of an additional 39% to 59% in added value from the program's array of non-energy impacts that accrue to residents. The NEBs add to the benefits side of benefit-cost analyses, suggesting that participants recognize significant additional benefits from the program beyond simply energy savings.

The NEB results indicate that the most valuable of the non-energy impacts in homes include lower operating costs, positive benefits from "doing good" for the environment, improvements in equipment (lower maintenance, longer equipment lifetimes, and better performance), improved satisfaction with the dwelling, and better comfort in the home. These impacts – particularly the comfort benefits – may be important to include in program materials to help encourage participation.

Table 76 and Table 77suggest several points about the NEBs arising from the Energy Star ® Program:

- **In general, satisfaction with the non-energy effects of the program is high**. Negative effects were reported for only two of the categories discussed, and in each instance of a negative report, a much greater percentage of those answering the question reported a positive effect for the same category.

- **Equipment effects are important to participants**. A substantial proportion of the participants surveyed reported positive effects relating to the operating costs, maintenance costs, performance and lifetime of the equipment that was installed under the program. Cumulatively, these equipment effects comprised over 40% of the total NEBs associated with the program.

- **The environmental effects of the program are also important to participants**. An overwhelming 81% of respondents claimed positive effects from “doing good for the environment” as a result of participating in the program. Furthermore, the same environmental benefit category accounted for 12% of the total program-attributable NEBs.

- **There are differences in NEB perceptions between participants and non-participants:** The results show that there are several areas in which participants and non-participants have different perceptions about energy efficient equipment.
    - Non-participants are considerably less positive about operating costs, equipment maintenance, performance, and lifetimes than participants;
    - Participants are less positive about lighting / quality of light than non-participants;
    - Participants and non-participants had fairly similar perceptions about the effect of energy efficient Energy Star® equipment on helping the environment, building safety, noise, aesthetics / appearance, and comfort.

These results imply that concerns about the equipment and its features (including operating costs, maintenance, performance, and lifetimes) may represent “barriers” to adoption of energy efficient equipment for non-participants. If energy efficient Energy Star® equipment does not perform worse in these areas, then education or outreach may be needed to change these perceptions among non-participants. If, however, there are performance issues associated with energy efficient Energy Star® equipment, then the program information (and potentially incentives) may be needed to address the barriers.

These results can be used in several ways.

- Benefit-cost analysis (and associated payback) shows a significantly higher return to program participants than an analysis of energy savings alone.
- Program marketing materials should emphasize the strong NEBs including: operating costs, doing good for the environment, improved maintenance and equipment lifetimes.
- Program outreach or design should incorporate methods to address perceived barriers reported by non-participants (equipment performance, maintenance, lifetime, and costs). The issues may be addressed by education; however, if the barriers represent real problems, program incentives may be needed.

- A majority of respondents indicated that NEBs were important in influencing their decisions to invest in the Energy Star® measures under the program.

The NEB analysis associated with the 2004-2005 program will be expanded because the later program year represents significantly more participants.

20. Researchable Program Questions Informed by NTG and NEB Analyses – Skumatz Economic Research Associates (SERA)

The planning efforts for this evaluation included a review of the program theory and logic, and the researchable questions that could be supported by the research.[106] A summary of those researchable questions is presented in the following table. Those researchable questions that were expected to be informed by the NTG or NEB research are then listed in the second table, along with a summary of the relevant results addressing the issue.

Researchable Questions, Data Sources, and Priorities

The consultants examined the program documents to review the program logic, identify key program actors, and establish the outcomes and program indicators that could track progress in the market. These items were tabulated, and we identified likely sources for information on the indicator. In addition, program staff and evaluation consultants examined the priorities of the various indicators.

Clearly, although a number of direct indicators are important success factors, the success of the California Statewide Energy Star® Homes (ESH) program also relies on a variety of indirect and induced – longer-term market effects – as well. Some of these indicators are addressed by the NTG and NEB analyses presented in this chapter. These results are presented in the next section.

Table 80: Outcomes, Indicators, and Measurements for CA-Energy Star® Homes Program[107]

Outcomes	Indicators	Potential / Proposed Measurement Method(s) and Source[108]	Priority (1=low, 3=high) [109]?
Short Term Outcomes			
A. Increased builder awareness	Percent aware participants and non-participants; track over time	PNP Builder surveys	H (3.0)
B. Educated market actors	1) Understanding of program elements by builders 2) Understanding of program elements by	1) Builder interviews (process) 2) N/A – process interviews of owners	H (3.0)

[106] Sebold, et.al., "A Framework for Planning and Assesssing Publicly Funded Energy Efficiency", Study ID PG&E-SW040, March, 2001, referred to as "California Framework Study.

[107] Skumatz, Lisa A., Skumatz Economic Research Associates, Memo to Matt Brost, RLW Analytics: "Comments on CA-ESH Theory and Logic", September 7, 2005.

[108] Note, differences between regions will be interesting in the short run; tracking over time important in longer run.

[109] Priority assigned based on feedback from consultant and utility program manager votes, using 1-3 scale.

Outcomes	Indicators	Potential / Proposed Measurement Method(s) and Source[108]	Priority (1=low, 3=high) [109]?
	owners 3) Understanding of ESH benefits by builders 4) Understanding of ESH benefits by owners	3) NEB interviews of builders 4) NEB interviews of owners	
C. Number of ESH built / savings attributable to the program	1) Number built; number of homes participating in program 2) Elapsed time to build?	1) Program records combined with NTG results from builder interviews on extra built to standards but not participating 2) N/A	L (1.5)
D. Increased public awareness of ESH	1) Advertising "hits" 2) Percent of public aware of ESH	1) N/A 2) N/A. Best from public surveys; not doing, so second source may be perceptions by builders	M (2.13)
E. Consumer demand for ESH / upgraded homes increases	1)Number of homes participating in program 2) Builder reports on percent of homeowners requesting ESH (weak – few interactions) 3) Realtor reports on percent of homeowners asking about ESH (stronger)	1) Program records 2) PNP builder interviews 3) N/A – realtor interviews at some point	M (2.13)
F. Homebuyer purchases ESH	1) Number sold 2) Percent ESH of market for new homes 3) Percent ESH dollars of total new homes $	1) program records 2) program records plus Dodge or other 3) program records plus Dodge $	L (1.25)
Intermediate Outcomes			
G. Increased builder acceptance of ESH	6) Number of ESH participating builders 7) Number of ESH homes relative to non-ESH 8) Increasing share of homes by participating builders built to ESH 9) Increasing share of Non-participating builders that build ESH / increasing share of their homes built to ESH 10) Perception of ESH homes, advantages by PNP builders	1) Program records / vs. database 2) Program records plus Dodge 3) Particip. builder interviews (later) 4) NP builder interviews (later) 5) PNP builder interviews (later)	H (2.75)
H. Increased need for C-Hers raters	1) Backlog – time to get rater on-site 2) Costs for raters (higher cost)	1) builder process interviews Or Program records 2) program records Interviews with raters	H (2.5)
I. Rating industry matures	1) Number of raters certified 2) Class sizes 3) Number of rating schools / outlets? 4) Hits on rating websites? 5) Reduced(?) cost for ratings	1, 2, 3, 4) Rating school interviews Program records 5) program records	M (2.38)

Outcomes	Indicators	Potential / Proposed Measurement Method(s) and Source[108]	Priority (1=low, 3=high) [109]?
J. Advanced home designs	ESH program encourages more innovation in energy efficient homes and features	Builder interviews	L (0.75)
K. Increased public acceptance / demand for Energy Star Products	4) reported ES sales / appliances holdings by consumers increases 5) Perceptions of quality and other features for ES models 6) Percent of sales of ES models increases	1) consumer interviews / surveys (future) 2) consumer interviews / surveys (future) 3) D&R, Itron, or other tracking data for state	M (2.13)
L. Increased demand for EE goods / products / services	1) Percent of models on sales floors (or available) that are ES models 2) Market price differential decreases for ES products 3) Percent of sales of ES models increases	1) on-site inspections / tallies; also web search for larger “box” stores (see SERA report) 2) special analysis of prices (see SERA report) 3) D&R, Itron, or other tracking data for state	M (2.0)
M. Increase availability of EE goods / products / services	1) Percent of models on sales floors that are ES models 2) Percent of sales of ES models increases	1) on-site inspections; also web search for larger “box” stores (see SERA report) 3) D&R, Itron, or other tracking data for state	M (2.0)
N. Homebuyer enjoys lower energy bills	4) bill comparisons to other homes 5) reports from owner about bills vs. expectations 6) kWh usage compared to other comparable homes	1) Impact evaluation – future 2) Owner interviews 3) Impact evaluation – future	M (2.25)
O. Builders promote and advertise ESH	4) number of builders actively promoting program 5) advertisements mentioning ESH; builders saying they include in advertisements 6) listings mentioning ESH	1) builder interviews Program records 2) TBD; builder interviews 3) MLS run / work with realtors	H (3.0)
P. More non-participating homes built to ESH standards	Percent of NP homes built to ESH	PNP builder interviews, (Potentially, also inspections), interviews with building inspectors	M (2.38)
Q. Direct and indirect program savings and environmental benefits provided	Value of non-kWh impacts – omitted program effects	SERA NEB analysis from interviews with PNP and detailed analysis of environmental and other impacts by NEB category (societal, utility, and participant effects)	H (2.50)
R. Market recognizes value of ESH	4) ESH sell for higher prices 5) Builder reports of premiums 6) Realtor reports of premiums	1) regression analysis of selling prices using program and MLS data 2) Builder interviews 3) Realtor interviews	M (2.25)
S. Purchasers recognize benefits and spread word of ESH / word of mouth (awareness / value)	3) Value of NEBs / omitted effects (combined with housing prices) 4) Reports of “spreading the word”	1) SERA NEB analysis 2) Homeowner interviews	M (2.25)
T. Availability of eligible builders / knowledgeable builders (and raters?)	6) Share / number of builders building to ESH standards – inside or outside program 7) Number enrolled in some program? 8) Number of different builders requesting	1) Program records Interviews with builders. Interviews with RLW database of builders (or mailing); some info from NTG analysis / builder interviews 2) Records	M (2.0)

Outcomes	Indicators	Potential / Proposed Measurement Method(s) and Source[108]	Priority (1=low, 3=high) [109]?
	services of raters 9) Number of raters in business 10) Backlog for raters	3) Data from raters / agencies 4) Rater interviews 5) Rater interviews	
Longer Term Outcomes			
U. Quality home construction / enhanced home design	1) Percent of market built to enhanced standards	1) N/A – inspections in future	H (3.0)
V. Good builder reputation	1) Percent of realtors saying builder has strong reputation (by ESH participants / non partic) 2) Complaints / suits against ESH participating builders compared to others	1) realtor interviews in future 2) BBB, D&B, court records, other	n/a
W. Product differentiation	Builders differentiate their ESH homes in the marketplace as a superior product	1) builder, realtor, rater interviews 2) Homeowner interviews	M (2.0)
X. Increased (builder) profitability	3) Profit ratios for builders to ESH vs. non-ESH designs? 4) Percent of builders building to ESH that say profit margins are higher for ESH homes?	1) N/A; builder questionnaires in future 2) N/A. Future questionnaires for builders	M (1.75)
Y. Lower energy consumption and demand	1) energy consumption compared to other homes	1) N/A. Impact evaluation in future	H (2.75)

Summary of Input to Researchable Questions from NEB and NTG Analyses

The results from the NTG and NEB analyses provide feedback on a number of program and market progress indicators. The information is summarized in Table 81.

Table 81: Input to Researchable Questions for Multifamily Component of the California Statewide Energy Star® Homes Program

Program Indicator	Information from NTG and NEB Analysis
B - Educates market actors - Understanding of ESH benefits by builders and owners:	Results indicate significant NEBs recognized and associated with the program – equaling about half to two-thirds the value of energy savings. In addition, almost two thirds indicate that developers and builders used NEBs to help influence the decision to adopt the Energy Star® measures.
C - Number of ESH homes built / savings attributable to the Program:	The NTG research indicates between 56%-69% of the participant energy savings associated with the program can be attributed to program effects. There were significant free riders (50%) associated with the program because: 1) Builders indicated[110] that many projects need to exceed Title 24 by 15% for tax incentives

[110] From the Strategy Assessment surveys conducted by RLW Analytics.

	/ financing reasons (particularly for low income housing), and 2) The energy modeling programs included several baselines and assumptions that had the effect of allowing multifamily units to meet 15% for program purposes with few to no changes in standard practices.
N - Homebuyer enjoys lower energy bills:	Only about half to two-thirds of the Program's 15% energy savings can be attributed to the 2002-2003 program; most builders found they could participate in the program without changing the building measures because of the tax incentives program or energy modeling issues described above.
O - Builders promoting and advertising ESH:	Almost 2/3 of respondents noted that developers or builders used NEBs to help convince the building to install energy efficiency measures as part of the project. A significant share stated this was important to decision-making on program measures.
P - More non-participating homes built to ESH standards:	The program attribution analysis showed that for the 2002-2003 program year non-participants may be upgrading the efficiency of their projects and incorporating Energy Star® into non-participating buildings. These efforts are equal to about 0-14% of the energy savings associated with the program's direct savings. [111]
Q – Direct and indirect program savings and environmental benefits provided:	Indirect benefits to participants are on the order of 69% - 86% of the direct associated program savings. After a NTG adjustment, these net NEBs are equal to about 39-59% of the program's measured energy savings. Societal / environmental and utility benefits will not be estimated until the 2004-2005 evaluation, when additional sample will be available. One of the popular NEBs is the feeling of "doing good" for the environment by participating in the program.
S – Purchasers recognize benefits and spread word of ESH and value:	Participants recognized the energy savings associate significant NEBs with the program equal to about half to two-thirds of the value of the energy savings. Responses for the NTG analysis showed that approximately half the participants reported they have recommended measures to other programs.
T – Availability of eligible / knowledgeable builders:	TBD
U – Quality home construction / enhanced home design:	TBD
Y – Lower energy consumption and demand:	See Item N.

[111] In addition, about half the non-participants stated that they felt the influence of the program in the marketplace. This figure appears high for the early years of the program, and will be confirmed in the 2004-2005 evaluation work.

21. Appendix A – Ratio Estimation

Stratified Ratio Estimation

Stratified ratio estimation combines a stratified sample design with a ratio estimator.[112] Both stratification and ratio estimation take advantage of supporting information available for each project in the population. As an example, suppose that an impact evaluation study is being undertaken to assess the annual energy savings of the projects undertaken in a given program. Suppose that the program tracking system provides an estimate of the annual energy savings of each project in the population. Suppose, furthermore, that a substantial fraction of the projects have comparatively small tracking savings but a relatively small number of projects have very large tracking savings. In this case, the coefficient of variation of the tracking savings will often be quite large, e.g., three or larger, and it can be expected that the population coefficient of variation of the actual savings is also large. In this case, the simple random sampling methods described in the preceding section would not be practical.

This problem can be partly mitigated by using the tracking estimate of savings as a stratification variable. Stratifying by the tracking savings generally reduces the coefficient of variation of actual savings in each stratum thereby improving the statistical precision.[113] Moreover, the sampling fraction can be varied from stratum to stratum to further improve the statistical precision. In particular, a relatively small sample can be selected from the projects with small tracking savings, but the sample can be forced to include a higher proportion of the projects with larger tracking savings. In particular, the largest projects can, if desirable, be included in the sample with certainty.

The tracking estimates of savings can also be used in ratio estimation. In impact evaluation, one ratio of interest is the realization rate, i.e., the ratio between the total gross annual savings of all projects in the population and the total tracking savings.[114] To understand the potential advantage of ratio estimation, suppose hypothetically that the actual savings of each project in the population is directly proportional to the savings recorded in the tracking system as illustrated in Figure 41.

In the extreme example illustrated in Figure 41, the actual savings of each project is 0.8 times the tracking estimate of savings. In other words, the tracking system systematically overstates the saving of each project by 20%. The realization rate, 0.8, is the slope of the

[112] Statisticians have developed many other approaches to sample design and estimation, including sequential sampling, cluster sampling, multi-stage sampling, stratified sampling with mean per unit estimation, stratified sampling with regression estimation, etc. See, for example, *Sampling Techniques* (* Cochran 1977). Any of these methods may be appropriate in a particular application. The authors have found that stratified ratio estimation is generally effective in both impact and process evaluation studies, especially when (a) there is substantial variation in the size of projects in the Program, and (b) the tracking system provides fairly accurate estimates of the savings of each project. These conditions are frequently true for energy conservation Programs.

[113] In this case, however, the coefficient of variation of tracking savings within each stratum usually does not provide a meaningful estimate of the coefficient of variation of actual savings within each stratum. Therefore added information is needed to estimate the expected statistical precision and to choose the sample size, e.g., from a prior sample or from a model characterizing the relationship between tracking and actual savings.

[114] The net-to-gross ratio is another ratio of interest. Our experience has been that ratio estimation can be used to estimate essentially all parameters of interest in evaluation.

line relating the actual savings to the tracking for every project. If the realization rate is known, then the true savings of all projects can be accurately estimated by multiplying the total tracking savings by the realization rate. Moreover, in this extreme case, the realization rate can be assessed perfectly by measuring the actual savings of any one project in the population.

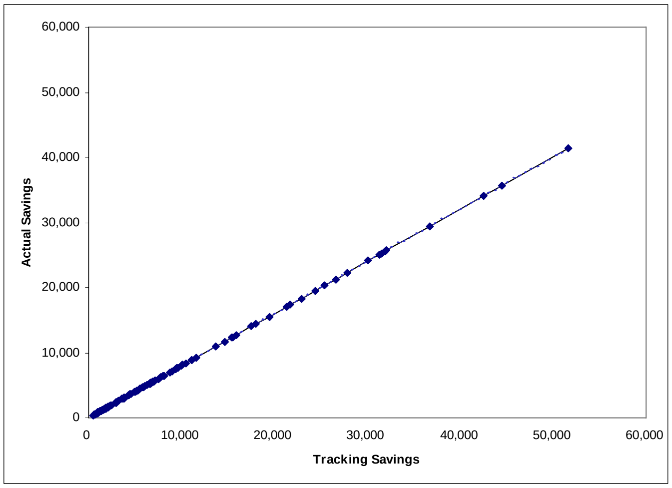

Figure 41: Ideal Case for Ratio Estimation

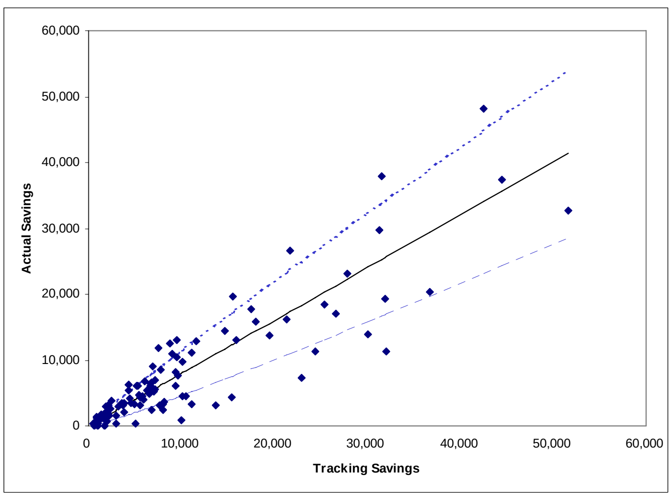

Figure 42: More Typical Relationship between the Actual and Tracking Savings

In practice, of course, there is always some random error in the association between the actual and tracking savings. Figure 42 illustrates a more typical situation. In this case the tracking estimate of savings is a good but not perfect predictor of the actual savings of each project. Nevertheless, the statistical precision can be greatly improved by using stratified ratio estimation to estimate the realization rate rather than by using simple random sampling to assess the average actual savings as discussed in the prior section.

Goals of the Section and Basic Definitions

This section will provide the tools needed to use stratified ratio estimation effectively in evaluation. The goal is to explain the underlying concepts in enough detail for users to be comfortable with the methodology. Specifically, this section will explain:

- How to estimate the population parameters of interest and to calculate the associated confidence intervals,
- How to characterize the population variation when efficiently stratified ratio estimation is to be used,
- How the expected statistical precision is related to the population variation and to the planned sample size assuming that efficient stratification is used,
- How to estimate the required sample size to achieve a desired relative precision,
- How to construct an efficiently stratified sample design, and
- How to estimate the relevant population variation from the sample for use in planning future studies.

Much of the notation needed to discuss the methodology of stratified ratio estimation is retained from the earlier discussion of simple random sampling. Let N denote the number of projects in the population and assume that the projects are labeled $i = 1, \ldots, N$. Let y denote any measurable variable of interest, such as gross or net savings and let y_i denote the value of y for project i. Y denotes the true total of y for all N projects in the population, i.e., $Y = \sum_{i=1}^{N} y_i$, and μ_y denotes the population mean of y, $\mu_y = \frac{Y}{N} = \frac{1}{N}\sum_{i=1}^{N} y_i$.

Stratified ratio estimation focuses on the relationship between y and a second variable, denoted x. The value of x is assumed to be known for each project in the population,[115] and to avoid minor notational inconveniences, x is assumed to be greater than zero for each project in the population. In the impact evaluation context, x is usually the tracking estimate of the savings of each project. X denotes the total of x for all N projects in the population, i.e., $X = \sum_{i=1}^{N} x_i$ and μ_x denotes the population mean of x, $\mu_x = \frac{X}{N} = \frac{1}{N}\sum_{i=1}^{N} x_i$.

The key population parameter of interest is the ratio between the population total of y and the population total of x, which is denoted B and defined by the following equation:

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[115] Stratified ratio estimation can also be used when the denominator of the ratio is unknown. For example this methodology can be used to estimate the net-to-gross ratio. In this case, a different variable, usually the measure of size in the tracking system, is used for stratification.

$$B = \frac{Y}{X} = \frac{\sum_{i=1}^{N} y_i}{\sum_{i=1}^{N} x_i}.$$

Of course, B is also equal to the ratio between μ_y and μ_x, i.e., $B = \frac{\mu_y}{\mu_x}$.

Stratified sample design uses knowledge about the population to add efficiency to the sample design. A stratum is any subset of the projects in the population that is based on known information. A stratification of the population is a classification of all units in the population into mutually exclusive strata that span the population. Under a stratified sample design, simple random sampling is used to select a chosen number of projects from each of the pre-established strata.

Added notation is needed to discuss stratified sampling. Let L denote the number of strata and assume that the strata are labeled $h = 1, \ldots, L$. Let N_h be the total number of population projects in stratum h. Let n_h be the number of projects to be randomly selected from stratum h. Assume that n_h is greater than zero for each stratum h. Then $\sum_{h=1}^{L} N_h = N$, the total population size, and $\sum_{h=1}^{L} n_h = n$, the total sample size.

Using this notation, the stratified ratio estimator can be defined. For each project i in the sample, the case weight is defined according to the equation $w_i = N_h / n_h$ where h denotes the particular stratum that contains project i. Using the case weights, define the stratified ratio estimator of B, denoted b, as follows: [116]

116 An equivalent equation is $b = \frac{\hat{Y}}{\hat{X}} = \frac{\sum_{h=1}^{L} N_h \ \bar{y}_h}{\sum_{h=1}^{L} N_h \ \bar{x}_h}$. Technically, the stratified ratio estimator is a biased estimator of the true population ratio. However, Cochran shows that the bias is small if the relative precision of $\sum_{h=1}^{L} N_h \ \bar{x}_h$ is small, pp. 160-167 (* Cochran 1977). In impact evaluation, the bias should be negligible if the population has been appropriately stratified by size as discussed later in this chapter.

$$b = \frac{\sum_{i=1}^{n} w_i \ y_i}{\sum_{i=1}^{n} w_i \ x_i} \quad .$$

The statistical precision of b can be assessed by calculating the standard error using the following equation:

$$se(b) = \frac{1}{\hat{X}} \sqrt{\sum_{i=1}^{n} w_i \ (w_i - 1) \, e_i^2} \quad .$$

Here $\hat{X} = \sum_{i=1}^{n} w_i \ x_i$ and $e_i = y_i - b \ x_i$. Then, as usual, the error bound can be calculated as $eb(b) = 1.645 \ se(b)$ and the relative precision can be calculated as $rp = eb(b)/b$.

Stratified ratio estimation can also be used to estimate the population mean or population total of y from the known population mean or population total of x. The estimator of the mean is $\hat{\mu}_y = b \ \mu_x$ and the corresponding standard error is $se(\hat{\mu}) = \mu_x \ se(b)$. The estimator of the total is $\hat{Y} = b \ X$ and the corresponding standard error is $se(\hat{Y}) = X \ se(b)$.

The Ratio Model

To develop a suitable sample design, it is necessary to characterize the relation between x and y in the population. This is done by assuming a statistical model called the ratio model. The primary equation of the ratio model is $y_i = \beta \ x_i + \varepsilon_i$. Here x_i and y_i denote the value of x and y for each project i in the population, β is an unknown but fixed parameter of the model that is similar to a regression coefficient, and ε_i is similar to the random error in a regression model. As in a regression model, the expected value of ε_i is assumed to be zero for each project i in the population. It is also assumed that $\varepsilon_1, \ldots, \varepsilon_N$ are mutually independent. Then μ_i is defined to be the expected value of y_i given x_i. Under the ratio model $\mu_i = \beta \ x_i$.

Instead of assuming that the standard deviation of ε_i is constant, the standard deviation of ε_i is allowed to vary from project to project. For any project i in the population, the standard deviation of ε_i is denoted as σ_i. This is called the residual standard deviation of project i. The population error ratio of x and y, denoted er, is defined to be

$$er = \frac{\sum_{i=1}^{N} \sigma_i}{\sum_{i=1}^{N} \mu_i}.$$

The error ratio is the key measure of the population variability in the relationship between x and y for stratified ratio estimation. The role of the error ratio in stratified ratio estimation is virtually the same as the role of the coefficient of variation in simple random sampling. Figure 43 shows several examples of error ratios ranging from 0.4 (a relatively strong relationship) to 1.0 (a weak relationship).

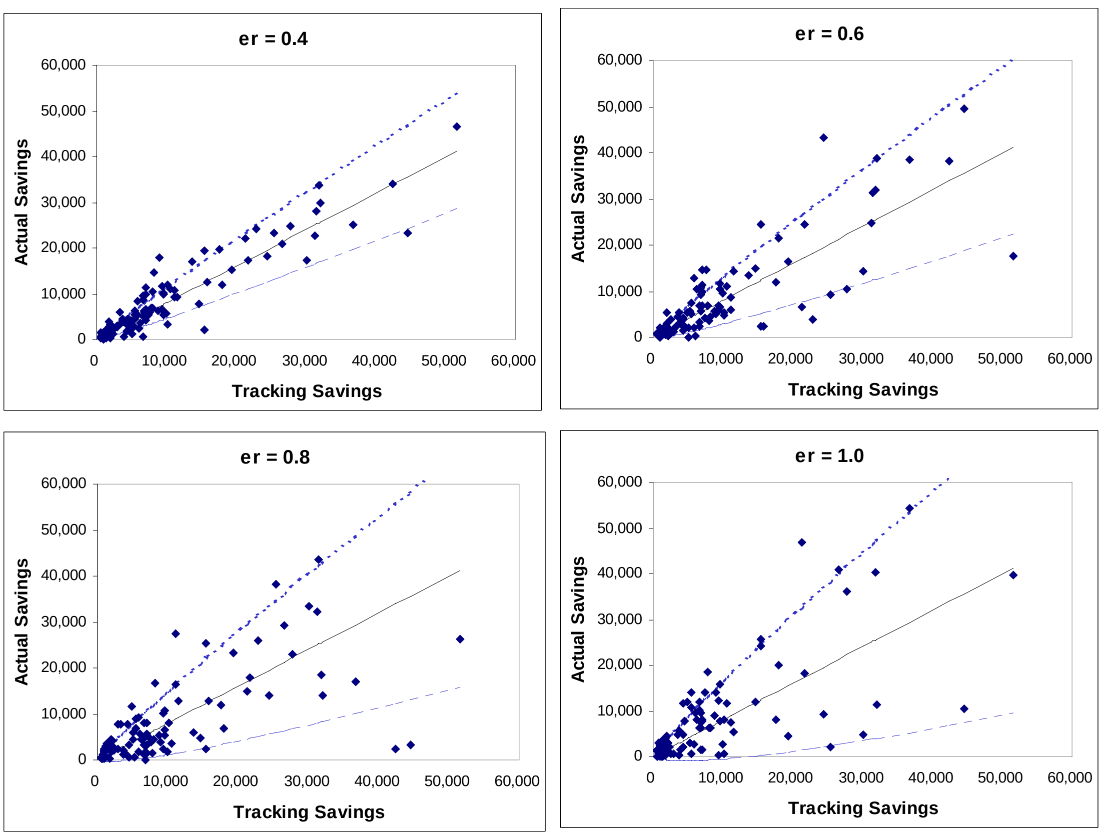

Figure 43: Examples of Different Error Ratios

The following specific functional form for σ_i is often assumed: $\sigma_i = \sigma_0\, x_i^{\gamma}$. This is called the secondary equation of the model.[117] The secondary equation specifies that the residual standard deviation of each project i in the population is proportional to the value

[117] Sarndal writes the secondary equation as $\sigma_i^2 = c\, x_i^{\gamma}$ (Sarndal et al. 1992), pp. 449.

of x_i raised to the power γ, pronounced gamma. A common assumption is that $\gamma = 0.8$. This specification is used in constructing efficiently stratified sample designs and to assist in the estimation of the error ratio from a prior sample.

The secondary equation includes a parameter denoted σ_0. This parameter is determined by the error ratio as follows:

$$\sigma_0 = er \; \frac{\sum_{i=1}^{N} \mu_i}{\sum_{i=1}^{N} x_i^{\gamma}}.$$

Sampling Distributions

The simple random sampling section discussed the concept of repeatedly selecting a random sample of a fixed size from a fixed population, observing the value of a particular variable y for each sample project, and calculating appropriate statistics. This concept was used to define the sampling distribution of a statistic such as the sample mean. This same concept of repeated sampling is used in the present discussion with one extension. Instead of regarding y_i as fixed for each project i, y_i is assumed to vary randomly from sample to sample, generated by independent realizations of the ratio model. In other words, the sample is regarded to be randomly determined following the prescribed sample design, and the true values of y_i are considered to be randomly determined for all N units in the population following the ratio model. A more in-depth discussion of this concept can be found in Sarndal.[118]

Expected Statistical Precision and Choice of Sample Size

A key result for stratified ratio estimation is the following: Assuming that the ratio model is accurate, that the sample design is efficiently stratified for the model as described later in this section, that the population size N is large and that the 90% level of confidence is used, then the expected relative precision of the stratified ratio estimator is approximately equal to

$$rp = 1.645 \frac{er}{\sqrt{n}}.$$

This result can be used to guide the choice of the sample size. Suppose that the desired relative precision is denoted D. Under the preceding assumptions, the sample size needed to provide an expected relative precision of D at the 90% level of confidence is approximately

[118] (Sarndal et al. 1992), pages 448-471.

$$n = \left(\frac{1.645\, er}{D} \right)^2 .$$

These are the same equations given in the discussion of simple random sampling, but with the coefficient of variation replaced by the error ratio. If N is moderate or small, the finite population correction factor can be used as a first approximation as in simple random sampling. A somewhat more complex but more accurate way of adjusting the large population results for the size of the population will be presented later in this chapter.

For example, if $D = 0.10$ and $er = 0.5$, then the preceding equation gives

$$n = \left(\frac{1.645 \times 0.5}{0.10} \right)^2 = 68 .$$

Table 82 shows the results of this type of calculation for various values of er and D. Table 11.3 is similar to Table 13.1 except that in Table 13.3 the error ratio is used since efficiently stratified ratio estimation is being discussed. The sample sizes shown in Table 13.3 are generally much smaller than in 1 because the error ratio is generally much smaller than the coefficient of variation for a given population.

		Error Ratio er						
		0.4	***0.5***	***0.6***	***0.7***	***0.8***	***0.9***	***1.0***
Desired Relative Precision D	***0.25***	7	11	16	21	28	35	43
	0.20	11	17	24	33	43	55	68
	0.15	19	30	43	59	77	97	120
	0.10	43	68	97	133	173	219	271

Table 82: Required Sample Size Assuming a Large Population

Assessing the Error Ratio without a Prior Sample

Table 82, above, illustrated four examples of relationships between x and y. These are typical examples of the type of association expected under the ratio model, assuming various error ratios. In each graph, the solid line represents the expected value of y given x, $\mu_i = \beta\, x_i$, and the broken lines represent the one standard deviation intervals around the mean: $y_i = \beta\, x_i \pm \sigma_i$. In preparing these graphs, the secondary equation $\sigma_i = \sigma_0\, x_i^{\gamma}$ has been assumed with $\gamma = 0.8$.

In most impact evaluation studies, the error ratio can be expected to be in the range 0.4 to 1.0, as illustrated in Table 13.3. If the tracking system is expected to provide quite accurate estimates of the actual savings of most sample projects in the evaluation study, then the error ratio is likely to be relatively small, e.g., near 0.4. This might be the case, for example, if the program provides energy efficiency retrofits to large commercial buildings, and the tracking estimates of savings are based on a fairly detailed analysis of each project that is undertaken in the program. If the tracking system is expected to provide rather poor estimates of the actual savings of most sample projects in the evaluation study, then the error ratio is likely to be larger, e.g., near 1.0. This might be the case, for example, if the program is an express-style program that requires only a simple application and does not provide any site-specific analysis as part of the program delivery.

Estimating the Error Ratio from a Sample

When stratified ratio estimation is being used to analyze a sample, the sample can also be used to estimate the underlying error ratio for use in future sample designs. Assuming the secondary equation $\sigma_i = \sigma_0 \; x_i^{\gamma}$ with $\gamma = 0.8$, then the error ratio can be estimated as

$$\hat{er} = \frac{\sqrt{\left(\sum_{i=1}^{n} w_i \; e_i^2 / x_i^{\gamma}\right)\left(\sum_{i=1}^{n} w_i \; x_i^{\gamma}\right)}}{\sum_{i=1}^{n} w_i \; y_i} \quad .$$

Here, as usual, $e_i = y_i - b \; x_i$.[119]

Model-Based Stratification

The preceding results assume that stratified ratio estimation is used with an efficiently stratified sampling plan. This section will describe how to construct an efficiently stratified sampling plan. The goal is to group the projects into several strata based on the value of x, usually the tracking estimate of savings, and then specify the number of sample projects to be selected from each stratum. The following method is called model-based stratification by size.[120]

The following steps are required:

1. Create a spreadsheet or database listing each project in the population and providing the value of x_i for each project, $i = 1, \ldots, N$.

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[119] If it is also necessary to estimate gamma from the sample, a method is available. See "Estimating regression models with multiplicative heteroscedasticity" (Harvey 1976).

[120] Another method of constructing strata is called Dalenius-Hodges stratification by size. The authors have chosen to emphasize model-based stratification because it is known to provide nearly optimal sample designs for stratified ratio estimation. See *Model Assisted Survey Sampling*, (Sarndal et al. 1992).

2. Use the assumed secondary equation of the ratio model to calculate σ_i for each project, $i = 1, \ldots, N$. Typically, $\sigma_i = \sigma_0 \, x_i^{\gamma}$ where γ is a set value, often 0.8. The value of σ_0 can be calculated from the assumed value of the error ratio using the equation given previously. Sort the list by increasing σ_i. For each $i = 1, \ldots, N$ calculate the cumulative sum of the σ_i, $c_i = \sum_{j=1}^{i} \sigma_i$.

3. Choose the desired number of strata L, (usually three to five) and divide the projects in the sorted list so that the sum of the σ_i is approximately equal in each of the L strata. This can be done by calculating $h_i = INT(L \frac{c_i}{c_N} + 0.99999999)$.

   Here the *INT* function rounds the value down to the nearest integer and 0.99999999 has been added to the equation to keep the last project from being assigned to a new stratum.

Once the strata have been constructed as just described, the sample should be allocated equally to each stratum. If the sample size in a particular stratum exceeds the population size in that stratum, the projects in that stratum should be selected with certainty. If desired, the sample may be increased in the remaining strata so that the sample size is closer to the planned value.

In some applications, it may be desirable to stratify the population by a categorical characteristic of the projects as well as by size. For example, the projects might be stratified by building type, technology, contractor, or region. The underlying principle is that the sample size allocated to each categorical stratum should be proportional to the sum of the σ_i within each stratum. Given the definition of the error ratio, a convenient way to determine the sum of the σ_i within each stratum is to multiply the expected actual savings in each stratum by the error ratio assumed in the stratum. This gives the rule: the sample size allocated to each categorical stratum should be proportional to the product of the expected actual savings in each stratum and the error ratio assumed in the stratum.[121]

Once the sample size has been determined within each categorical stratum, the projects within each stratum should be further stratified by size as described above.

[121] This result can be used to allocate evaluation resources among a portfolio of Programs, especially if the marginal evaluation cost per sample project is approximately the same for all projects in the portfolio. See the chapter on Uncertainty.

The Expected Statistical Precision for Any Sample Design

This section discusses how to assess the expected statistical precision of the stratified ratio estimator when stratified ratio estimation is used with an arbitrary sample design. These results assume that the ratio model is accurate and that the sample design is truly followed without non-response or other similar problems.

To develop the result of interest, a new concept is needed. For any given sample design, define the inclusion probability π_i to be the probability that project i is included in the sample, for all $i = 1, \ldots, N$ in the population. Assume that the inclusion probability is greater than zero for every project in the population, and that sample size n is fixed. There are two useful facts about inclusion probabilities. First, the population sum of the inclusion probabilities is equal to n. Second, for any stratified sample design, the inclusion probability is equal to the sampling fraction in each stratum.

Now the result: Let b be the stratified ratio estimator. Under the ratio model, the expected value of the standard deviation of b in repeated sampling is approximately

$$sd(b) = \frac{1}{X}\sqrt{\sum_{i=1}^{N}\left(\pi_i^{-1} - c\right)\sigma_i^2} \ .$$

Here c is 1 if the finite population correction is desired, or 0 if not.[122] Under the ratio model, the expected relative precision can be defined to be $rp = sd(b)/\beta$.

The preceding equation can be used to assess the expected relative precision for any stratified sample design under the ratio model. This methodology can be used, for example, to explore the effect of increasing the number of strata. This type of analysis indicates that three to five model-based strata are adequate in most impact evaluation applications. This equation has also been used to explore the effect of using model-based stratification with a set value of gamma that is smaller than the value assumed in the ratio model. In several evaluation applications, it has been shown that there is very little loss in expected statistical precision if the strata are constructed using a gamma of 0.5 when the value in the secondary equation is 0.8. This tends to decrease the sampling fractions in the strata containing larger projects. This can sometimes facilitate recruiting and data collection.

Using the preceding equation, a sample design is said to be optimal under the assumed ratio model if the inclusion probabilities minimize $sd(b)$ for a given sample size n. It can

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[122] For example, the finite population correction might not be suitable if random measurement error is a large contributor to the residual standard deviation of each project.

be shown that a sample design is optimal if and only if $\pi_i = n\,\sigma_i \Big/ \sum_{i=1}^{N} \sigma_i$ provided this is not greater than 1. If $n\,\sigma_i \Big/ \sum_{i=1}^{N} \sigma_i > 1$, then project i should be selected with certainty.[123]

Applicability to Impact Evaluation

Stratified ratio estimate also relies on the assumptions that the sample design is followed and that the true savings are measured for the sample projects with little or no bias, as discussed in the section on simple random sampling. Since the sample can generally be smaller with stratified ratio estimation than with simple random sampling, it should be possible to give even more attention to minimizing bias from self-selection, non-response, deliberate substitution of sample projects, or systematic measurement error.

Stratified ratio estimation is generally especially effective when simple random sampling is inappropriate. Whenever the coefficient of variation of savings is greater than one, stratified ratio estimation should be considered. Stratified ratio estimation will almost always be more effective than simple random sampling if the program provides good tracking estimates of savings.

Stratified ratio estimation often focuses on the relationship between the tracking estimates of savings and the actual savings. The two key parameters are the realization rate and error ratio. The realization rate is the slope of the trend line. It is the ratio between the average or total value of the actual savings and the average or total value of the tracking estimates. Thus, the realization rate reflects the amount of systematic bias in the tracking estimates of savings.

The error ratio, on the other hand, describes the strength of the association between the tracking estimates of savings and the actual savings, i.e., the variation of actual savings around the trend line associated with the realization rate. The error ratio measures whether the tracking savings are accurate from project to project across the population of projects.

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[123] Under the ratio model, $\sum_{i=1}^{N} \mu_i = \beta\, X$. This result can be used to show that if $\pi_i = n\,\sigma_i \Big/ \sum_{i=1}^{N} \sigma_i$ for all projects in the population and $c = 0$, then $rp = 1.645\,\frac{sd(b)}{\beta} = 1.645\,\frac{er}{\sqrt{n}}$. This justifies our use of the error ratio to calculate the estimated relative precision assuming that a ratio estimator is used with an efficiently stratified sample design and a large population.

The error ratio is a useful indicator of the quality of the program delivery system. Well-designed and managed programs will tend to have smaller error ratios than programs with poorer control and less attention to detail. Indeed, if the error ratio is found to be higher than expected, it generally indicates that there is a problem with program delivery. Conversely, stratified ratio estimation tends to reward strong programs, i.e., those with relatively small error ratios, by making it possible to carry out an effective impact evaluation using a relatively small sample.

With stratified ratio estimation, the ratio model has been used to assist in the development of a suitable sample design. It is important to understand, however, that the model is only used to develop the sample design. The model is not used to support the statistical analysis of the sample data, except the estimation of the error ratio. If the model is accurate, the achieved statistical precision will be close to the expected statistical precision predicted by the model. If the model is inaccurate, the expected statistical precision may be inaccurate also. But even if the model is inaccurate, the stratified ratio estimator is still free of any material bias and the standard error is still a good guide to the achieved statistical precision.[124]

[124] Sarndal has referred to these methods as model-assisted since, although the analysis does not depend on the accuracy of the model, the model does guide the analysis. (Sarndal et al. 1992), pp. 227 and 239. Sarndal provides a much more general model called the generalized regression model which may, in some circumstances, suggest other estimators such as the difference or regression estimators, but the authors have found that the ratio estimator generally is suitable in evaluation.

22. Appendix B - Net Savings: Difference-of-differences Calculation Methodology

Equations

The essence of the "difference-of-differences" analysis is to compare ENERGY STAR® Homes to non-participant homes' standard construction practices. While Gross savings is defined as the difference between Standard (package D) and Proposed modeled energy consumption, Net Savings is defined as the gross savings less naturally occurring savings (due to industry standard practice). If for one home,

S_p[125] = Participant CF-1R standard energy use (kBTU/sf-yr)

P_p = Participant CF-1R proposed energy use (kBTU/sf-yr)

S_{np} = Non-participant CF-1R standard energy use (kBTU/sf-yr)

P_{np} = Non-participant CF-1R proposed energy use (kBTU/sf-yr)

SF = Conditioned floor area of the home

Then, the

Net Savings = (Gross savings) – (Natural savings) = $(S_p\text{-}P_p)$*SF – $(S_{np}\text{-}P_{np})$*SF,

And the equation can be seen to motivate the name, as the Net savings is indeed a difference-of-differences.

$(S_{np}–P_{np})$*SF represents "the naturally occurring non-participant energy savings due to current standard building practice." Unfortunately, S_{np} and P_{np} do not exist, since non-participant homes of the exact same size, location and other building characteristics were not constructed. To estimate them, a baseline study of residential new construction, conducted by Itron, was utilized.

The Net savings of the population of ENERGY STAR® homes was calculated as follows:

(1) Net savings = [savings of ENERGY STAR® Homes above standard] – [naturally occurring savings due to current practice]

(2) Savings of ENERGY STAR® Homes above standard = $[N_p * \overline{SF}_p * \overline{S}_p * \overline{CM}_p]$, and

(3) Estimated naturally occurring savings = $[N_p * \overline{SF}_p * \overline{S}_p * \overline{CM}_{np}]$

(4) So, Net Savings $= [N_p * \overline{SF}_p * \overline{S}_p * \overline{CM}_p] - [N_p * \overline{SF}_p * \overline{S}_p * \overline{CM}_{np}]$

(5) $= N_p * \overline{SF}_p * \overline{S}_p * [\overline{CM}_p - \overline{CM}_{np}]$

Where:

N_p = Number of ENERGY STAR® Homes participant homes

125 The subscript p is used to denote Participants, and np is used for Non-Participants.

$\overline{SF}_p$ = Participant homes' average conditioned floor area = $\dfrac{\sum_{i=1}^{N_p} SF_{p_i}}{N_p}$

$\overline{S}_p$ = Participant homes' weighted average Standard energy consumption = $\dfrac{\sum_{i=1}^{N_p} S_{p_i} SF_{p_i}}{\sum_{i=1}^{N_p} SF_{p_i}}$

$\overline{CM}_p$[126] = Participant homes' weighted average Compliance Margin = $\dfrac{\sum_{i=1}^{N_p} (S_{p_i} - P_{p_i}) SF_{p_i}}{\sum_{i=1}^{N_p} S_{p_i} * SF_{p_i}}$

$\overline{CM}_{np}$[127] = Non-participant weighted average Compliance Margin =
$\dfrac{\sum_{i=1}^{N_{np}} (S_{np_i} - P_{np_i}) SF_{np_i} * w_i}{\sum_{i=1}^{N_{np}} S_{np_i} * SF_{np_i} * w_i}$, where w_i s are the weights of the non-participant homes sampled in the baseline study. These non-participant case weights were used to extrapolate the true non-participant sample data to a population similar in composition to the population of ENERGY STAR® Homes Program participants.

What is the justification for equation (2)?

The Total Savings of the ENERGY STAR® Homes above standard must equal the sum of the savings of each individual home, or

Savings of the ENERGY STAR® Homes above standard = $\sum_{i=1}^{N_p} (S_{p_i} - P_{p_i}) SF_{p_i}$

Is this equal to equation (2)? Is,

$$N_p * \overline{SF}_p * \overline{S}_p * \overline{CM}_p = \sum_{i=1}^{N_p} (S_{p_i} - P_{p_i}) SF_{p_i} \ ?$$

By substitution into (2),

[126] Participant weighted average Compliance Margin is weighted by conditioned floor area of each home.

[127] The non-participant weighted average Compliance Margin is weighted by both the conditioned floor area of each home, and its associated sample weight from the baseline study.

Savings of ENERGY STAR® Homes above Standard =

$$N_p \frac{\sum_{i=1}^{N_p} SF_{p_i}}{N_p} * \frac{\sum_{i=1}^{N_p} S_{p_i} * SF_{p_i}}{\sum_{i=1}^{N_p} SF_{p_i}} * \frac{\sum_{i=1}^{N_p} (S_{p_i} - P_{p_i}) SF_{p_i}}{\sum_{i=1}^{N_p} S_{p_i} * SF_{p_i}} = \sum_{i=1}^{N_p} (S_{p_i} - P_{p_i}) SF_{p_i}$$, so yes.

Similarly equation (3) is derived, and the difference between the two sums in (4) is justified as the Net Savings.

Single Family Participant and Non-Participant Comparison Grouping

This analysis was conducted at the individual CEC climate zone, and end-use level. We had data on 575 non-participant homes from the baseline study. This small non-participant sample, when distributed across the 16 CEC climate zones, led to very small sample sizes in some individual climate zones. Whenever we had too few non-participant sample homes within a particular CEC climate zone, all sample homes within the same RMST (that contains the CEC) were used as a proxy. Table 83 shows the frequency of participant and non-participant homes in each CEC climate zone.

RMST Zone	CEC Zone	Number Non-Participants	Number Participants
RMST 1	CEC 2	10	28
	CEC 3	7	85
	CEC 4	4	116
	CEC 5	19	0
RMST 2	CEC 6	81	36
	CEC 7	8	888
RMST 3	CEC 8	99	262
	CEC 9	1	455
	CEC 10	27	1,708
RMST 4	CEC 11	18	610
	CEC 12	235	2,052
	CEC 13	26	64
RMST 5	CEC 14	36	150
	CEC 15	1	396
	CEC 16	3	0
Total		575	6,850

Table 83: Frequency of Participant and Non-participant Homes in each Climate Zone

Table 84 shows how participants were compared. Whenever sample sizes permitted, comparisons were done CEC-to-CEC climate zone. As can be seen from the tables, the participants from CEC climate zone 2 were compared to non-participants from RMST 1, where RMST 1 consists of CEC climate zones 1, 2, 3, 4, and 5.[128] On the other hand, participants from CEC climate zone 8 were strictly compared to all non-participants from CEC climate zone 8.

[128] No data (on participants or non-participants) was available for CEC climate zone 1

In particular, CEC climate zones 2, 3, 4, 5, 7, 9, and 15 had very few non-participant baseline sample homes. As can be seen from the table below, participant homes from CEC climate zones 2, 3, 4, and 5 were each compared to non-participant sample homes in RMST climate zone 1. Similarly, participants from CEC climate zones 7, 9, and 15 were compared to non-participants from RMSTs 2 (CEC climate zones 6, and 7), 3 (CEC climate zones 8, and 9), and 5 (CEC climate zones 14, and 15) respectively.[129]

Non Parts Reference Group	Participant Group	Number Non-Participants	Number Participants
RMST 1	CEC 2	40	28
RMST 1	CEC 3	40	85
RMST 1	CEC 4	40	116
CEC 6	CEC 6	81	36
RMST 2	CEC 7	89	888
CEC 8	CEC 8	99	262
RMST 3	CEC 9	127	455
CEC 10	CEC 10	27	1,708
CEC 11	CEC 11	18	610
CEC 12	CEC 12	235	2,052
CEC 13	CEC 13	26	64
CEC 14	CEC 14	36	150
RMST 5	CEC 15	40	396
Total		na	6,850

Table 84: Frequency of Homes in the Two Comparison Groups

Table 85 below presents some summary statistics on the two comparison groups. The average compliance margins of the participants and the non-participants are also reported in the same table for each end-use, and CEC climate zone. The difference in the compliance margins between the participant and the non-participant homes acts as an indicator of expected savings in a particular CEC. As can be seen from the following table, this difference is always positive for heating – which indicates positive savings from heating in all CEC climate zones. The absolute magnitude of savings in kwh or kbtu depends on the number of participant homes and their total square feet in each CEC. The difference in the compliance margins between the participant and the non-participant homes is positive for cooling in all climate zones except 7. This difference is very high in some climate zones, like 12, 13, and 15. The same difference for water heating can be positive or negative

[129] No comparisons were made in CEC climate zones 5 and 16 as we did not have any participant data for any of these climate zones.

Comparison Groups			Heating		Cooling		Water Heating	
Participant CECs	Non-Participant CECs	Average Square Ft	Participants	Non-participants	Participants	Non-participants	Participants	Non-participants
02	02, 03, 04, 05	2,690	29.93%	21.79%	40.47%	-2.34%	12.25%	15.02%
03	02, 03, 04, 05	1,991	30.37%	21.79%	68.82%	-2.34%	41.60%	15.02%
04	02, 03, 04, 05	1,940	26.29%	21.79%	36.07%	-2.34%	15.90%	15.02%
05	02, 03, 04, 05	N/A	N/A	N/A	N/A	N/A	N/A	N/A
06	06	2,026	1.51%	-4.98%	55.00%	48.24%	16.56%	14.49%
07	06, 07	2,737	31.80%	13.68%	30.31%	34.23%	14.12%	8.58%
08	08	2,223	34.55%	29.79%	17.74%	16.07%	16.60%	-2.47%
09	08, 09, 10	2,910	35.39%	25.94%	33.19%	4.57%	10.21%	11.23%
10	10	2,443	29.52%	23.70%	26.03%	2.76%	14.68%	13.29%
11	11	1,961	24.93%	15.51%	25.95%	10.87%	15.66%	12.41%
12	12	2,266	23.96%	2.60%	25.05%	-41.24%	16.32%	13.12%
13	13	1,771	22.67%	3.64%	24.20%	-14.35%	13.16%	14.82%
14	14	2,031	17.14%	-2.93%	18.58%	-10.06%	15.76%	13.59%
15	14, 15	1,703	30.13%	-2.52%	30.37%	-13.63%	13.00%	13.67%
16	16	N/A	N/A	N/A	N/A	N/A	N/A	N/A

Table 85: Comparison of Participants and Non-Participants By CEC Climate Zone

23. Appendix C – Gross High Rise Energy Savings

Title 24 reports and compliance margin calculations for high-rise buildings are conducted somewhat differently than for single or multifamily housing projects. High rise buildings are modeled by zone with different occupancy types for each zone of the building. The ENERGY STAR® Homes Program has decided to include high-rise buildings with compliance margins greater than 15% excluding Process, Receptacle, and Lighting end-uses. The Title 24 compliance margin calculations for the three high-rise buildings are below.

Project:	**Northgate Apartments, Oakland, CA (PGE)**				
Energy Component	**Standard Design**	**Proposed Design**	**Compliance Margin**	**GAS Sav**	**Elec Sav**
Space Heating	10.26	8.73	1.53	1.53	0
Space Cooling	1.55	1.5	0.05	0	0.05
Indoor Fans	15.42	17.89	-2.47	0	-2.47
Heat Rejection	0.44	0	0.44	0	0.44
Pumps & Misc.	0.36	0.32	0.04	0	0.04
Domestic Hot Water	20.39	11.73	8.66	8.66	0
Lighting	17.64	17.64	0	0	0
Receptacle	16.93	16.93	0	0	0
Process	0	0	0	0	0
Totals	82.99	74.74	8.25	10.19	-1.94
Percent Better than Standard:	9.94%				
Excluding Process:	9.94%				
Excluding Process & Receptacle:	12.49%				
Energy Star Percentage:	**17.04%**	Excludes Process, Receptacle, and Lighting			
	Standard Des	**Proposed Design**			
	48.42	40.17	8.25	10.19	-1.94
Conditioned Floor Area (sf)			44,514	44,514	44,514
Annual Energy Saving (kBTU)			367,241	453,598	(86,357)
Annual Energy Saving (kBTU/unit)			8,744		
Annual Energy Saving (Therms)				4,536	
Annual Energy Saving (Therms/unit)				108	
Annual Energy Saving (Site kWH)					(8,442)
Annual Energy Saving (Site kWH/unit)					(201)
Number of Dwelling Units			42		

Project:	**Housing Alliance, Castro Valley, CA (PGE)**				
Energy Component	**Standard Design**	**Proposed Design**	**Compliance Margin**	**GAS Sav**	**Elec Sav**
Space Heating	13.32	8.06	5.26	5.26	0
Space Cooling	3.36	3.69	-0.33	0	-0.33
Indoor Fans	8.01	13.07	-5.06	0	-5.06
Heat Rejection	4.36	1.52	2.84	0	2.84
Pumps & Misc.	4.13	2.38	1.75	0	1.75
Domestic Hot Water	22.71	17.75	4.96	4.96	0
Lighting	19.13	19.13	0	0	0
Receptacle	16.68	16.68	0	0	0
Process	0	0	0	0	0
Totals	91.7	82.28	9.42	10.22	-0.8

Percent Better than Standard:	10.27%				
Excluding Process:	10.27%				
Excluding Process & Receptacle:	12.56%				
Energy Star Percentage:	**16.85%**	Excludes Process, Receptacle, and Lighting			
	Standard Des	**Proposed Design**			
	55.89	46.47	9.42	10.22	-0.8
Conditioned Floor Area (sf)			27,108	27,108	27,108
Annual Energy Saving (kBTU)			255,357	277,044	(21,686)
Annual Energy Saving (kBTU/unit)			9,120		
Annual Energy Saving (Therms)				2,770	
Annual Energy Saving (Therms/unit)				99	
Annual Energy Saving (Site kWH)					(2,120)
Annual Energy Saving (Site kWH/unit)					(76)
Number of Dwelling Units			28		

Project:	Villa Havey Mandel, San Diego, CA (SDGE)				
Energy Component	**Standard Design**	**Proposed Design**	**Compliance Margin**	**GAS Sav**	**Elec Sav**
Space Heating	4.35	5.23	-0.88	0	-0.88
Space Cooling	6.66	13.4	-6.74	0	-6.74
Indoor Fans	23.31	21.75	1.56	0	1.56
Heat Rejection	7.25	0	7.25	0	7.25
Pumps & Misc.	6.28	7.22	-0.94	0	-0.94
Domestic Hot Water	43.05	23.55	19.5	19.5	0
Lighting	20.51	20.51	0	0	0
Receptacle	17.98	17.98	0	0	0
Process	0	0	0	0	0
Totals	129.39	109.64	19.75	19.5	0.25

Percent Better than Standard:	15.26%				
Excluding Process:	15.26%				
Excluding Process & Receptacle:	17.73%				
Energy Star Percentage:	**21.73%**	Excludes Process, Receptacle, and Lighting			
	Standard Des	**Proposed Design**			
	90.9	71.15	19.75	19.5	0.25
Conditioned Floor Area (sf)			42,453	42,453	42,453
Annual Energy Saving (kBTU)			838,447	827,834	10,613
Annual Energy Saving (kBTU/unit)			8,384		
Annual Energy Saving (Therms)				8,278	
Annual Energy Saving (Therms/unit)				83	
Annual Energy Saving (Site kWH)					1,037
Annual Energy Saving (Site kWH/unit)					10
Number of Dwelling Units			100		

24. Appendix D – Single Family Weights for Difference-of-differences and Spillover

This section summarizes the calculation of weights in the single family difference-of-differences analysis, and the single family spillover analysis.

A. Difference-of-differences: In the difference-of-differences analysis, our main purpose was the comparison of savings between the following two groups -

1. Group 1- Population of ENERGY STAR® Homes (6,850 Homes)
2. Group 2- Sample of Non Participants (575 Homes)

When comparing the ENERGY STAR® Homes participants to the program non-participants in the difference-of-differences analysis, it was important to ensure that the homes in the two comparison groups have similar distribution across different strata. Otherwise, the comparison of the two groups could potentially be misleading. The population of non-participant homes greatly outnumbers the ENERGY STAR® Home participant population. Using our in-house SAS modules (Analyze-IT), we appropriately grouped the data (participant ENERGY STAR® Homes, and the non-participant sample) into several strata and calculated case weights for the non-participants in order to extrapolate the non-participant sample data to a population similar in composition to the population of ENERGY STAR® Home Program participants. Specifically, the classifications of homes into several strata were made on the basis of square feet of the homes and the CEC climate zones where the homes were located.

These weights were applied to our sample of non-participant homes in order to make the distribution of homes the same in the two comparison groups (of participants and non-participants).

B. Calculation of Spillover Savings: In the calculation of spillover analysis, our main purpose is the comparison of savings between the following two groups -

1. Group 1- Sample of Partial Participants (100 or 235)
2. Group 2 – Sample of True Non Participants (297)

The non-participant case weights are based on weights provided by Itron along with the baseline study data. The Itron provided case weights were calculated by utility service territory and RMST CZ 1-5 (RMST Climate zones). These weights were used by Itron to extrapolate the non-participant sample data to the non-participant population.

In order to make the distribution of homes the same across different strata for the above two comparison groups, weights that were applied to the sample of partial participant non-participant homes are reported in Table 88 below. These weights are calculated as the ratio of the numbers reported in Table 86 and Table 87.

This set of weights was used so that a population similar to the population of Partial Participants can be created.

Climate Zone	PGE	SCE/SCG	SDGE
1	13,412	6	
2		3,584	6,807
3		32,555	2,852
4	50,869	1,977	
5	1,199	16,921	858

Table 86: Population of Non-Participant Homes by Climate Zone

Climate Zone	PGE	SCE/SCG	SDGE
1	40		
2		24	65
3		113	14
4	256	23	
5	3	36	1

Table 87: Sample of Non-Participant Homes by Climate Zone

Climate Zone	PGE	SCE/SCG	SDGE
1	335.30		
2		149.58	104.72
3		288.10	203.71
4	198.71	85.96	
5	399.67	470.03	858.00

Table 88: Weights Used for Partial Participants

The numbers reported in the Table 86 represent the population of non-participants in all groups. The next table, Table 87 represents the Itron samples in each category. Table 88 reports the weights used by the partial participants. For each sub-group, the weight is = Population/Sample.

The next set of weights are applied to the group of true non-participants so that a population of true non-participants can be created that is similar in composition to the population of partial participant non-participants.

Climate Zone	PGE	SCE/SCG	SDGE
1			
2		3	18
3		29	1
4	26	16	
5		7	

Table 89: Sample of Partial Non-Participants by Climate Zone

Climate Zone	PGE	SCE/SCG	SDGE
1	38		
2		20	7
3		44	7
4	146	5	
5	3	26	1

Table 90: Sample of True Non-Participants by Climate Zone

Climate Zone	PGE	SCE/SCG	SDGE
1	335.30		
2		149.58	104.72
3		288.10	203.71
4	198.71	85.96	
5	399.67	470.03	858.00

Table 91: Itron Case Weights by Climate Zone

Climate Zone	PGE	SCE/SCG	SDGE
1	0.00		
2		22.44	269.29
3		189.88	29.10
4	35.39	275.06	
5	0.00	126.55	0.00

Table 92: Weights Used for True Non-Participants

Table 89 and Table 90 report the sample sizes in each sub group of climate zone and utility. Table 91 reports the Itron case-weights. Table 92 contains the weights that were used for the true non-participants. The numbers are calculated by using the following formula: (Case_Weights*Partial)/True in each sub group.

25. Appendix E – Sample Designs (Single family and Multifamily)

Single Family Sample Design

Before conducting the sample design, RLW requested data on the population of ENERGY STAR® Homes from CHEERS.

CHEERS® (California Home Energy Efficiency Rating Services) is a California statewide 501 (C) (3) non-profit organization dedicated to promoting energy efficiency. CHEERS® was approved in 1999 by the California Energy Commission as the first home energy rating provider under the Home Energy Rating System Regulations. Once a home is inspected and certified that it meets state energy standards, information about each home is entered into a CHEERS computer program that calculates an energy rating for the home. The data from all of the CHEERS homes are aggregated into the CHEERS database. The California IOUs use the CHEERS database as a repository for the building plans of the participating ENERGY STAR® Homes.

A participating builder's project may have several plans and structures. In the case of the single family listings, a 'structure' represents a single residence. A plan refers to the specific model of the home, a number of which are available in each project. A project refers to each unique development. CHEERS provided us with information on structures, locations, plans, and projects of single and multifamily new homes for the four utilities PG&E, SCE, SDG&E, and SCG.

We first aggregated information from these tables into one single dataset. Each row of this aggregated data contained information on a unique structure id. Structures were excluded from the population if:

- they were not inspected in the year 2002, 2003, or 2004
- they did not pass all inspections (Structure status was not marked as 'Approved')
- the program year for the project was not 2002, 2003, or 2004

Only structures with "Approved" status qualified for ENERGY STAR®.

The most recent inspection date (or the "Test Date", as named in the CHEERS database) for a structure was used to populate the "Inspected Year" data field. For some structures, errors (dates that are several years in the future) were found in the data stored in this field. In these cases we used the most recent "Upload Date" as a replacement value for the "Test Date" field as the "Upload Date" was computer-generated and thus not prone to human data-entry errors. Additionally, we verified from the data that these two dates were not far apart for almost all records that seemed to have no errors.

The climate zones reported in the CHEERS data ranged between CZ1 and CZ16. Following the Itron RNC Baseline study, we grouped these 16 zones into 5 broader (RMST[130]) climate zones. These 5 groups were used as the 5 different strata in our sample.

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[130] There are 16 CEC climate zones in California. These climate zones can be collapsed into 5 RMST (Residential Efficiency Market Share Tracking Study) climate zones. RMST climate zone 1 encompasses CEC climate zones 1, 2, 3, 4, and 5. RMST climate zone 2 includes CEC climate zones 6, and 7. CEC climate zones 8, 9, and 10 are grouped into RMST 3. Finally, RMST 4

Our filtered population contained 18,296 single family structures, and 1,570 multifamily structures. Once the sample size was determined based on the project budget, we developed the participant sample design. In the sample design task, we determined the appropriate number of units that should be included in the participant sample in each stratum, and implemented the actual selection. Based on our budget, we determined that a sample size of 100 single family sites would be metered and inspected for this project. Our goal was to ensure that the participant sample provided statistically reliable results near the 10% level of precision at the 90% level of confidence. A sample size of 100 was determined to produce an overall relative precision of 10% or less, an estimate that the California Public Utilities Commission was agreeable to. Additionally, 10 units for the single family would receive only inspected.

There were several strategies that we considered when we decided on the sample design. As the single family homes were not expected to vary much in size, we decided to use proportional sampling for single family instead of model based statistical sampling. This meant that we used a sampling fraction of each stratum that is proportional to that of the total population.

We proportionally allocated the 110 single family sample sites by RMST climate zone in order to determine the number of sample sites in each stratum. For each climate zone, we calculated the percentage of the total sites within the particular climate zone. We multiplied these percentages by 110, the desired sample size for the study, to yield the sample size for each stratum. After the sample design was approved, we requested customer contact data from the utilities. To insure that we would have enough structures as backups, we pulled 3 backups for every sample point.

Multifamily

For the multifamily sample design, we decided to sample at the project level (complex). This is due to the fact that the multifamily structures were modeled differently for each project. Sometimes a single dwelling unit was assigned a unique structure id. Other times, portions of a building consisting of multiple dwelling units, or the entire apartment complex with many dwelling units, was assigned a unique structure id.

Based on our budget, we determined that a sample size of 23 low-rise multifamily sites would be metered and inspected for this project. Our goal was to ensure that the participant sample provided statistically reliable results near the 20% level of precision at the 90% level of confidence. A sample size of 23 was determined to produce an overall relative precision of approximately 21%, an estimate that the California Public Utilities Commission was agreeable to.

Our population of multifamily projects, after applying the same exclusion criteria described in the previous section on single family, contained 1,570 unique structure ids. These structures belonged to 97 unique projects. Information on square footage was available for every structure. We aggregated the square footage of all structures for each project and calculated the combined square footage for every project. We used two stratification variables – RMST climate zone and project square footage - to divide the population into strata. Each climate zone was divided into three sub-strata based on square footage.

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encompasses CEC climate zones 11, 12, and 13 and RMST 5 includes CEC climate zones 14, 15, and 16.

We used model based statistical sampling techniques to determine the square footage cutpoints for the multifamily sample design. Table 93 shows the cutpoints of each stratum, along with the population size, and the sample size in each stratum.

RMST Climate Zone	**Stratum**	**Square Footage**	**Square Footage**	**Population**	**Sample**
		Min	Max		
1	1	17,127	70,540	8	1
	2	82,397	115,828	4	1
	3	128,597	148,753	3	1
2	4	10,527	97,584	18	2
	5	109,678	239,076	7	2
	6	250,817	738,553	3	2
3	7	7,013	109,437	23	3
	8	110,688	243,768	10	3
	9	263,658	598,869	6	2
4	10	60,328	86,254	4	1
	11	142,248	147,192	3	1
	12	190,576	246,807	2	1
5	13	56,550	76,992	3	1
	14	98,452	172,704	2	1
	15	201,600	201,600	1	1
Total				97	23

Table 93: Multifamily Stratification

The tables below document our sample design. Table 94 shows the total number of single family and multifamily homes in each of the 5 RMST climate zones, while Table 95 shows the sample sizes drawn from each stratum.

RMST Climate Zone	**Single Family Population**	**Multifamily Population**
1	839	245
2	1,863	615
3	5,830	532
4	7,831	116
5	1,933	62
Total	18,296	1,570

Table 94: Population – Number of Structure IDs

RMST Climate Zone	Single Family Sample (Structure Ids)	Multifamily Sample (Project Ids)
1	5	3
2	10	6
3	39	8
4	45	3
5	11	3
Total	110	23

Table 95: Sample

In addition to the low rise multifamily projects, our dataset contained 3 high rise buildings. All three of the high rises were inspected.

Theoretical Foundation – Model Based Statistical Sampling

MBSS™ methodology was used to develop an efficient MF sample design and to assess the likely statistical precision. The target variable of analysis, denoted *y*, is the energy use of the project. The primary stratification variable, the estimated energy savings of the project, will be denoted *x*. A ratio model was formulated to describe the relationship between *y* and *x* for all projects in the population, e.g., all participating low-rise multifamily projects.

The MBSS™ ratio model consists of two equations called the primary and secondary equations:

$$
\begin{aligned}
y_k &= \beta x_k + \varepsilon_k \\
\sigma_k &= sd\left(y_k\right) = \sigma_0 x_k^{\gamma}
\end{aligned}
$$

Here $x_k > 0$ is known throughout the population. *k* denotes the sampling unit, i.e., the project. $\{\varepsilon_1, \ldots, \varepsilon_N\}$ are independent random variables with zero expected value, and β, σ_0, and γ (gamma) are parameters of the model. The primary equation can also be written as

$$\mu_k = \beta x_k$$

Under the MBSS ratio model, it is assumed that the expected value of *y* is a simple ratio or multiple of *x.*

Here, y_k is a random variable with expected value μ_k and standard deviation σ_k. Both the expected value and standard deviation generally vary from one unit to another depending on x_k, following the primary and secondary equations of the model. In statistical jargon, the ratio model is a (usually) heteroscedastic regression model with zero intercept.

One of the key parameters of the ratio model is the error ratio, denoted *er*. The error ratio is a measure of the strength of the association between *y* and *x*. The error ratio is suitable for measuring the strength of a heteroscedastic relationship and for choosing sample sizes. It is *not* equal to the correlation coefficient. It *is* somewhat analogous to a coefficient of variation except that it describes the association between two or more variables rather than the variation in a single variable.

Using the model discussed above, the error ratio, *er*, is defined to be:

$$er = \frac{\sum_{k=1}^{N} \sigma_k}{\sum_{k=1}^{N} \mu_k} = \frac{\frac{1}{N}\sum_{k=1}^{N} \sigma_k}{\frac{1}{N}\sum_{k=1}^{N} \mu_k}$$

Figure 1 gives some typical examples of ratio models with different error ratios. An error ratio of 0.2 represents a very strong association between *y* and *x*, whereas an error ratio of 0.8 represents a weak association.

As Figure 1 indicates, the error ratio is the principle determinant of the sample size required to satisfy the 90/10 criteria for estimating *y*. If the error ratio is small, then the required sample is correspondingly small.

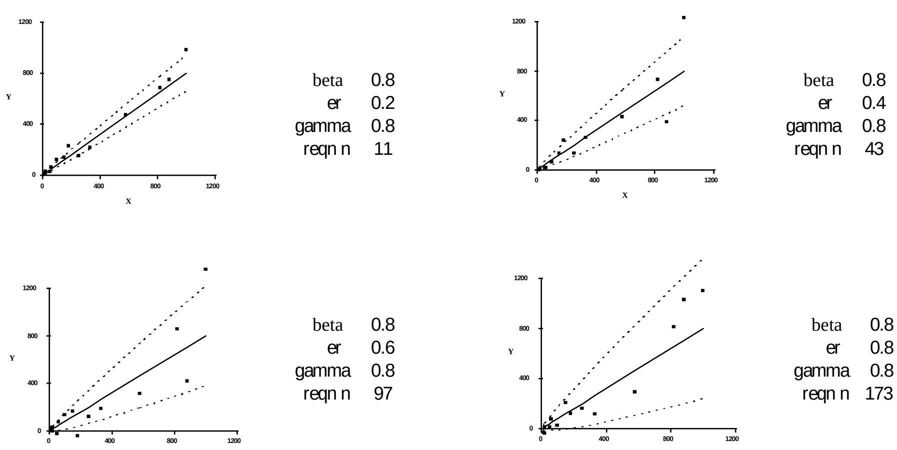

Figure 44: Examples of MBSS Ratio Models

The model parameters -- β, γ, and the error ratio -- were estimated from our experience on similar residential studies. The model parameters are shown in Table 96.

Parameter	Value
β	1.0
γ	0.8
Error ratio	0.5

Table 96: Study Model Parameters

26. Appendix F – Billing Analysis Data, Methodology, and Weather Normalization

Data and Limitations

Data for the billing analysis came from a variety of sources. Table 97 outlines the relevant data that was obtained for the analysis.

Data	Part. Status	Obtained Form	Data Obtained	Dates
Housing Characteristics	Non-Participants	Itron baseline residential new construction study	zipcode, CEC zone, CFA	na
	Participants	CHEERS database	zipcode, CEC zone, CFA	na
Billing Data	Both	Provided by the IOUs	kWh, therms usage	Aug03 - Sep05
Weather Data	N/A	Western Regional Climate Center, 94 weather stations	average daily temperature	Jan95 - Dec05

Table 97: Data and Sources for the Billing Analysis

Much of the data from CHEERS had errors or were missing key elements. For some of the errors in zipcode and climate zone, we were able to correct the values and include the errant houses. For several hundred homes, however, missing housing characteristic information in the CHEERS registry led to us dropping them from the analysis. Of the remaining homes, we were able to obtain electricity billing information for 3,918 participants and 457 non-participants, and gas billing data for 3,890 participant homes and 389 non-participant homes.

Table 98 shows the distribution of this data across the CEC Title 24 Climate Zones. Unlike the DoD calculations, which compared participants in a CEC zone to the non-participants pooled from the wider RMST zone, the billing analysis was limited to comparisons in CEC zones where there was enough data to legitimize a CEC-participants to CEC-non-participants comparison. Billing analysis focuses on absolute energy usage. Thus, such cross-zone comparisons are more problematic than in DoD analysis, which uses compliance margin percentages, a relative value. Table 98 highlights those climate zones where such comparisons could reasonably be conducted with the available sample sizes: CECs 6, 8, 10, 12, and 14 for both gas and electricity, and CEC 13 for electricity.[131]

[131] Weighting was deemed an unreasonable alternative due to the fact that it would have required weighting samples of 0-4 non-participant homes to represent hundreds of participant homes.

CEC Zone	Part	Electricity	Gas
2	**NP**	9	9
	P	4	4
3	**NP**	5	5
	P	4	56
4	**NP**	4	2
	P	97	96
5	**NP**	16	0
6	**NP**	76	20
	P	34	34
7	**NP**	8	8
	P	171	166
8	**NP**	95	82
	P	124	118
9	**NP**	1	0
	P	446	158

CEC Zone	Part?	Electricity	Gas
10	**NP**	24	20
	P	1557	1257
11	**NP**	14	6
	P	118	218
12	**NP**	141	185
	P	1180	1344
13	**NP**	25	22
	P	45	45
14	**NP**	36	0
	P	138	0
15	**NP**	0	0
	P	0	0
16	**NP**	3	0

Table 98: Distribution of Data in Gas and Electricity Billing Datasets by CEC Title 24 Climate Zone

House Characteristics Data

We received information on home characteristics of the participants from the CHEERS database, and information on home characteristics of non-participants from the Itron Residential New Construction Baseline Study database. For each house, we extracted the zip code (for use in weather normalization), the CEC Title 24 climate zone, the number of stories, and the conditioned floor area of the house. In the case of the CHEERS database, 400 homes had climate zone designations that did not match their reported zip codes. Of these, 376 had the wrong climate zone specified, and 24 had the wrong zip code specified. These errors were corrected in the data. Over 1,000 homes had no zip code reported or did not report the number of stories. These homes were dropped from the billing analysis.

The CHEERS and ITRON databases are databases of physical housing characteristics, and thus lack many of the variables that would be obvious parameters in an analysis of energy usage. We were not able to obtain data on the number of occupants of the homes, nor the income level of those occupants; both of which play as large a role in determining final energy consumption as the physical characteristics of the building.

Billing Data

We received the customer billing information from the four utilities: PG&E, SCG, SCE, and SDG&E. The beginning and ending dates of the billing period, the billing period length, the fuel type, utility, and amount of energy consumed (kWh for electricity or therms for gas) were reported for each monthly bill sent to each house for which the utilities had data available.

Out of the 6,850 homes in the ENERGY STAR® Homes Program, we were able to obtain billing data for 5,366 of them. Of the 575 non-participant baseline homes from the ITRON study, we were able to obtain billing data for 543.

We used the billing dates and billing periods to compute average daily usages for gas and electricity for every day contained in the billing cycles in the data. These were then recombined by calendar months so that we had usage information for full calendar months for all houses in the data. These values were divided by the number of days in the month for which there was billing data to compute the average electricity and gas usage per day.

Quality assurance checks on the billing data brought to light a number of problems that had to be corrected to complete the billing analysis. First, for 377 billing records, the reported billing period length was in discrepancy with the billing period beginning and end dates reported for the record. For these bills, we found that the billing period length recalculated from the reported dates matched the data better than the reported period length, and was used to replace the billing period length for those records.

Second, six addresses had multiple premise IDs reported. These homes were dropped, as we could not determine which premise was tied to the newly constructed home in question.

Finally, around 1.5% of the initial billing data for the participants contained monthly electricity usages that were unreasonably high for a single-family home. We computed the mean electricity usage per square foot for the houses, and dropped all months of billing data with a reported usage above 1.05 kWh/sf/month. To make sure that the billing data contained only data after the homes were occupied, we dropped all months with a billed amount less than 20% of the average monthly bill. In our tests of the data, this served as a reliable cutoff between occupied-house energy use and the low-level of energy used when a house has been connected to the utility, but not yet occupied.

These data were tied to the appropriate housing information using the address of the home. The new data set dropped all homes that had less than one year's worth of billing data, as these homes could not be properly weather normalized. The resulting data sets had 3,918 participant homes and 457 non-participant homes worth of electricity billing data, and 3,890 participant homes and 389 non-participant homes worth of gas billing data.

CEC Zone	Part?	Electricity	Gas
2	**NP**	9	9
	P	4	4
3	**NP**	5	5
	P	4	56
4	**NP**	4	2
	P	97	96
5	**NP**	16	0
RMST 1	**NP**	34	16
	P	105	156
6	**NP**	76	20
	P	34	34
7	**NP**	8	8
	P	171	166
RMST 2	**NP**	84	28
	P	205	200
8	**NP**	95	82
	P	124	118
9	**NP**	1	0
	P	446	158
10	**NP**	24	20
	P	1557	1257
RMST 3	**NP**	120	102
	P	2127	1533

CEC Zone	Part?	Electricity	Gas
11	**NP**	14	6
	P	118	218
12	**NP**	141	185
	P	1180	1344
13	**NP**	25	22
	P	45	45
RMST 4	**NP**	180	213
	P	1343	1607
14	**NP**	36	29
	P	138	64
15	**NP**	0	1
	P	0	375
16	**NP**	3	0
RMST 5	**NP**	39	30
	P	138	439

Table 99: Distribution of Participant and Non-Participant Homes Across Climate Zones in the Electricity and Gas Billing Datasets

Weather Data

Weather data was necessary to weather normalize the homes in our samples so that energy usage estimates were adjusted for the variation in temperatures within and between climate zones. We purchased the weather data from the Western Regional Climate Center which archives data from California weather stations. The data are mean daily temperatures (calculated as the average of the daily maximum and daily minimum temperature) for the 11-year period January 1995 – December 2005. We obtained data for some 94 weather stations across the state of California. Each zip code in our billing data set was linked to one of these weather stations based on proximity by using Microsoft's MapPoint software.

For each weather station, we calculated monthly values for cooling degree days per day based on reference temperatures in one degree increments from 60°F to 80°F. We calculated monthly heating degree days per day based on reference temperatures from 50°F to 75°F, also in one degree increments.[132]

The average weather in each CEC Title 24 climate zone was calculated by taking the average of the HDDs and CDDs observed at each zip code within that climate zone, weighted by the total amount of floor-area-square-footage in the ENERGY STAR® Homes

[132] A more thorough treatment of cooling and heating degree days and their calculation can be found in the discussion of the PRISM weather normalization methodology in Appendix XX.

in that zip code. The average weather in each RMST climate zone was similarly calculated by taking a square-footage-weighted average of the CDDs and HDDs of the zip codes within that RMST zone.

Summary Statistics

The following tables show the summary statistics of the key characteristics of the ENERGY STAR® Homes and the non-participants.

Conditioned Floor Area

This is a measure of the amount of floor area subject to climate control in each house. It includes all floors, including basements, intermediate floor tiers, and penthouses, measured from the exterior faces of exterior walls and the exterior face of walls separating conditioned and unconditioned spaces. Conditioned floor area does not include covered walkways, open roofed-over areas, porches, pipe trenches, exterior terraces or steps, chimneys, roof overhangs, parking garages, unheated basements, and closets for central gas forced air furnaces. The conditioned floor area per home in the electricity billing data sample and the gas billing data sample are shown below in Table 100 and Table 101.

ClimateZone	Participant	n	Mean CFA	STDEV	Min CFA	Max CFA
2	Non Part	9	2557.8	1437.3	1295	5184
	Part	4	2727.3	651.9	1924	3460
3	Non Part	5	2343.4	895.4	1504	3762
	Part	4	1758.0	396.0	1435	2244
4	Non Part	4	2426.3	574.0	1900	3200
	Part	97	1947.8	468.3	1489	4300
5	Non Part	16	2672.6	752.1	1496	4117
	Part	0				
RMST 1	Non Part	34	2564.8	948.9	1295	5184
	Part	105	1970.2	493.4	1435	4300
6	Non Part	76	2841.6	1031.0	702	5089
	Part	34	2024.2	221.2	1689	2282
7	Non Part	8	3145.3	774.2	2600	4671
	Part	171	2785.8	584.8	1788	6891
RMST 2	Non Part	84	2870.5	1009.5	702	5089
	Part	205	2659.5	611.2	1689	6891
8	Non Part	95	2791.5	1197.5	760	7498
	Part	124	2818.1	1392.1	1509	6323
9	Non Part	1	1706.0		1706	1706
	Part	446	2904.6	678.0	1406	4093
10	Non Part	24	2632.3	825.0	1200	5000
	Part	1557	2381.5	647.8	1287	4115
RMST 3	Non Part	120	2750.6	1130.3	760	7498
	Part	2127	2516.6	752.1	1287	6323
11	Non Part	14	1866.4	700.8	950	3600
	Part	118	1781.6	426.9	1278	3947
12	Non Part	141	2798.5	890.7	1269	5881
	Part	1180	2273.6	719.5	1252	5326
13	Non Part	25	1573.9	418.1	870	2363
	Part	45	1781.3	469.8	1422	3729
RMST 4	Non Part	180	2555.9	947.5	870	5881
	Part	1343	2213.9	709.8	1252	5326
14	Non Part	36	2471.8	745.2	1040	4100
	Part	138	2045.9	397.3	1351	2762
15	Non Part	0				
	Part	0				
16	Non Part	3	2435.3	503.9	1950	2956
	Part	0				
RMST 5	Non Part	39	2469.0	724.5	1040	4100
	Part	138	2045.9	397.3	1351	2762

Table 100: Electricity Billing Data, Conditioned Floor Area by Climate Zone (ft^2)

ClimateZone	Participant	n	Mean CFA	STDev	Min CFA	Max CFA
2	Non Part	9	2557.8	1437.3	1295	5184
	Part	4	2727.3	651.9	1924	3460
3	Non Part	5	2343.4	895.4	1504	3762
	Part	56	1950.3	428.3	1435	2517
4	Non Part	2	2852.5	491.4	2505	3200
	Part	96	1951.5	469.3	1489	4300
RMST 1	Non Part	16	2527.6	1165.1	1295	5184
	Part	156	1970.9	472.7	1435	4300
6	Non Part	20	2960.1	1199.7	702	5063
	Part	34	2024.2	221.2	1689	2282
7	Non Part	8	3145.3	774.2	2600	4671
	Part	166	2771.3	648.0	238	6891
RMST 2	Non Part	28	3013.0	1084.2	702	5063
	Part	200	2644.3	659.8	238	6891
8	Non Part	82	2775.0	1141.3	760	6531
	Part	118	2826.2	1427.5	833	6323
9	Non Part	0				
	Part	158	2663.6	888.8	1406	4008
10	Non Part	20	2621.7	627.9	1575	3620
	Part	1257	2396.8	671.6	1287	4115
RMST 3	Non Part	102	2745.0	1059.5	760	6531
	Part	1533	2457.3	790.1	833	6323
11	Non Part	6	1484.5	230.9	1139	1853
	Part	218	2099.2	569.7	1278	3947
12	Non Part	185	2614.1	894.4	1090	5881
	Part	1344	2261.4	691.5	1252	5326
13	Non Part	22	1531.3	403.4	870	2363
	Part	0				
RMST 4	Non Part	213	2470.4	921.2	870	5881
	Part	1562	2238.8	678.0	1252	5326
14	Non Part	29	2584.1	755.1	1040	4100
	Part	64	2072.4	456.9	1539	2762
15	Non Part	1	1810.0		1810	1810
	Part	375	1704.8	263.6	1458	2139
16	Non Part	0				
	Part	0				
RMST 5	Non Part	30	2558.3	755.3	1040	4100
	Part	439	1758.4	325.9	1458	2762

Table 101: Gas Billing Data, Conditioned Floor Area by Climate Zone (ft^2)

Number of Stories

The only other housing measure that we used in conducting the billing analysis was the number of stories each house had. Given the very small number of 3-story houses in our population, we chose to include all homes with more than one story as "multi-story" homes. As Table 102 shows, in both the gas and electricity billing data, there are enough homes of each type in the participant and non-participant groups in climate zones 8, 12, and 14 to allow for the single-to-multi-story comparison that we conducted. The number of non-participant homes in climate zone 10 (7 single-story homes for electricity and 5 for gas) is less than ideal, but was still enough to produce significant results.

		Electricity		Gas	
CEC Zone	**Part?**	**Single**	**Multi**	**Single**	**Multi**
2	**NP**	1	8	1	8
	P	1	3	1	3
3	**NP**	0	5	0	5
	P	0	4	0	56
4	**NP**	2	2	1	1
	P	0	97	0	96
5	**NP**	2	14		
6	**NP**	6	70	4	16
	P	0	34	0	34
7	**NP**	1	7	1	7
	P	2	169	4	162
8	**NP**	20	75	17	65
	P	11	113	13	105
9	**NP**	1	0		
	P	9	437	0	158
10	**NP**	7	17	5	15
	P	785	772	661	596
11	**NP**	11	3	6	0
	P	91	27	133	85
12	**NP**	40	101	68	117
	P	639	541	702	642
13	**NP**	24	1	21	1
	P	37	8	37	8
14	**NP**	16	20	12	17
	P	91	47	39	25
15	**NP**			0	1
	P			375	0
16	**NP**	2	1		

Table 102: Distribution of Single and Multi Story Homes by CEC Climate Zone in the Electricity and Gas Billing Datasets

Weather Normalization Methodology

One of the most important steps in the assessment of the effects of the ENERGY STAR® Homes Program is the comparison of the energy usage of program participants and non-participants. By controlling for other non-program influences, such as weather, the programs effects can be isolated and quantified. The following section presents the proposed methodology of the temperature normalization procedure that will be used in this billing analysis.

Heating and Cooling Degree Days

Heating and cooling degree days are a measure of the cumulative degrees below or above (respectively) a certain reference temperature. Heating degree days (HDD) are indicators of household energy consumption for space heating. Cooling degree days (CDD) are indicators of household energy consumption for space cooling.

For example, take a reference temperature of 70 degrees F. We first take the high and the low temperatures of the day, and average them. Is this value is greater than our reference temperature of 70 degrees F, then we have (avgtemp – 70) cooling degree days. If the average temperature is less than 70 degrees, then we have (70 – avgtemp) heating degree days. This value is calculated for every day in a month and totaled to produce the CDD and HDD for each month. For our methodology, these values were computed for every reference temperature between 60 and 80 degrees F for CDDs and every reference temperature between 50 and 75 degrees F for HDD.

Temperature Normalization Methodology

For the temperature normalization methodology, we looked at the dependence of each home's energy usage on local temperature and computed the energy consumption of each home for a value of the number of degree days expected in a given year at the climate zone level. Homes face different temperature-related energy demands depending on their location. The need for the temperature normalization arises from the fact that different homes are in different locations and thus face different weather. The normalized annual consumption of each home is an estimation of energy consumption that treats all homes within a climate zone as if they faced the same temperature conditions. This allows the comparison of the weather-normalized energy usage to reflect the impact of the actual building characteristics rather than any local differences in climate experienced.

The temperature normalization procedure finds its fundamental basis derived from the *Princeton Scorekeeping Model* (PRISM) algorithm. The PRISM algorithm develops a mathematical model that represents the temperature to energy consumption relationship.

This normalization analysis recognizes the fact that each home reacts differently to varying heating and cooling degree days, and each customer has unique space conditioning operating characteristics. Homes with more efficient heating or cooling appliances and equipments, radiant barrier insulation, magnetite windows and ceramic coating will consume less energy. A well designed house with good windows and better insulation will require much less heating or cooling.

This simplest model where the specification is such that energy consumption depends on either heating or cooling degree days only is shown in Equation 1.

$$U_i = \alpha + \beta * DD_i(\tau) + e_i$$

Where;

U_i = average daily consumption in interval i.
$DD_i(\tau)$ = average degree days in interval i, based on reference temperature τ
α,β = parameters to be estimated to minimize e.
e = a random error term.

Equation 1: The PRISM Heating Only Model

The PRISM model reflects that a customer's energy usage is equal to some base level α, and a linear function between a reference temperature τ, and the outside temperature. The constant proportionality, β, represents a customer's effective heat-loss or heat-gain rate.

As mentioned, PRISM recognizes that each customer has unique space conditioning operating characteristics. To capture these unique space conditioning characteristics, PRISM examines a range of heating and cooling reference temperatures. The model chosen to represent a customer's energy use is the model that best linearizes the relationship between usage and degree days. For each customer, an optimal model based on a unique temperature reference temperature (τ) is identified by the minimum MSE of the regression.

Once the optimal parameters have been established, normalized annual consumption is estimated using Equation 2.

$$NAC=365*\alpha+\beta*DD_o(\tau)$$

Where:

DD_o is the number of degree days expected in a typical year.

Equation 2: The Determination of Normalized Annual Consumption (NAC) [133]

When this model is applied to a home's heating characteristics, it is referred to as the *heating only model* (HOM). When this model is applied to a home's cooling characteristics, it is referred to as the *cooling only model* (COM).

We have three different end uses for the participant and non-participant new homes, heating, cooling, and water-heating. Heating and water-heating use mostly gas, and cooling always uses electric energy. The billing information contains separate data from electric and gas usages. As electric energy is only used for cooling, it is expected that consumption of electric energy is mostly affected by cooling degree days, and unaffected by heating degree days. Similarly, since gas energy is mostly used for heating, it is expected that consumption of gas energy is mostly affected by heating degree days.
We therefore ran the cooling only PRISM model for the temperature normalization procedure for electricity billing data. We similarly ran the heating only PRISM model with the gas data.

The standard PRISM approach uses usage and degree day data on a billing cycle basis. However, by doing that, the dependent variable has an inherent variability associated with the varying lengths of billing cycles. By bringing in the *average daily* usage as the dependent variable, the effects of the varying lengths of the billing cycle are mitigated for the

[133] For a more comprehensive technical discussion of PRISM, see Impact Evaluation Of Demand-Side Management Programs, Volume 1: A Guide to Current Practice, EPRI Report CU-7178,V1, page 5-6.

estimation of the heating and cooling slopes (β). This is a result of the number of degree days being directly correlated to the number of days in the cycle. However, the estimate of base load (β_o) reflects the average base load per cycle and does not account for the days in the cycle. In effect, this estimate infers the base load will be β_o, regardless of the length of the cycle. Since base load usage is a function of time, this result may introduce a slight bias into the calculation. To eliminate this bias, the augmented PRISM approach uses usage per day per square foot of floor area as the dependent variable, and expresses the degree days on a per day basis.

Weather Normalization: Results

The weather normalization process significantly changed our estimates of energy usage at the aggregated level. It tended to impact non-participant homes' energy consumption estimates more than participants'. This makes sense given that we would expect participant homes, with better insulation and conditioning equipment on average, to be less sensitive to temperature than non-participants. Table 103 and Table 104 present the pre-normalization and post-normalization energy consumption estimates for electricity and for gas.

Climate Zone	Participant	Pre Normal kWh/sf/yr	Post Normal kWh/sf/yr
2	Non Part	2.495	3.260
	Part	2.269	2.429
3	Non Part	2.951	2.993
	Part	1.842	2.414
4	Non Part	3.868	3.474
	Part	3.036	2.978
5	Non Part	2.068	2.503
6	Non Part	3.162	3.572
	Part	2.626	2.716
7	Non Part	2.518	3.241
	Part	3.051	2.839
8	Non Part	3.190	3.026
	Part	3.811	3.641
9	Non Part	3.534	4.422
	Part	4.234	4.004
10	Non Part	4.703	3.928
	Part	3.298	3.417
11	Non Part	4.813	4.929
	Part	3.608	4.088
12	Non Part	3.511	3.485
	Part	3.533	3.835
13	Non Part	6.510	4.812
	Part	3.620	4.813
14	Non Part	5.182	4.023
	Part	4.353	3.641
16	Part	5.329	6.689

Table 103: Average Electricity Usage by Climate Zone Before and After Weather Normalization

Climate Zone	Participant	Pre Normal therms/sf/yr	Post Normal therms/sf/yr
2	Non Part	0.098	0.248
	Part	0.084	0.179
3	Non Part	0.121	0.217
	Part	0.240	0.201
4	Non Part	0.154	0.239
	Part	0.279	0.266
6	Non Part	0.160	0.265
	Part	0.140	0.232
7	Non Part	0.096	0.148
	Part	0.141	0.184
8	Non Part	0.104	0.191
	Part	0.143	0.208
9	Part	0.134	0.248
10	Non Part	0.078	0.172
	Part	0.165	0.193
11	Non Part	0.219	0.331
	Part	0.212	0.263
12	Non Part	0.133	0.225
	Part	0.161	0.190
13	Non Part	0.103	0.251
14	Non Part	0.127	0.293
	Part	0.098	0.236
15	Non Part	0.085	0.190
	Part	0.086	0.204

Table 104: Average Gas Usage by Climate Zone Before and After Weather Normalization