CONSULTANT REPORT

IMPACT EVALUATION OF THE CALIFORNIA COMPREHENSIVE RESIDENTIAL RETROFIT PROGRAMS

Prepared for: California Energy Commission

Prepared by: DNV KEMA Energy & Sustainability

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ABSTRACT

This report documents findings and recommendations from an impact evaluation of the California Energy Commission's California Comprehensive Residential Retrofit program, a statewide energy upgrade program funded by the American Recovery and Reinvestment Act of 2009. The program funded local and regional subrecipients to develop and test initiatives aimed at transforming the residential energy upgrade market and building an infrastructure for whole-building energy upgrades. These local and regional governments collaborated with California's major utilities to jointly conduct the statewide Energy Upgrade California™ program. The Energy Upgrade California partners piloted whole-building upgrade programs for single-family and multifamily buildings, developing both the demand side (homeowner, building owner), and supply side (participating contractors and other professionals) of the marketplace.

The program recruited, educated, and supported building owners by providing an online Web portal, and through statewide marketing, education, and outreach. The Web portal provided county-specific information about available rebates and incentives, financing, and participating contractors and other professionals qualified to provide energy assessments and upgrade installations. The program prepared participating contractors and professionals to meet building owner demand through technical and business skills training and delivering quality assurance of the delivered services. A special effort was made to pilot Property Assessed Clean Energy financing for homes and businesses and other alternate innovative financing programs.

The Energy Commission allocated about $98 million in American Recovery and Reinvestment Act of 2009 funds to the following subrecipients to deliver the program: Association of Bay Area Governments, San Francisco Mayor's Office of Housing, Sacramento Municipal Utility District, Local Government Commission, CRHMFA (formerly California Rural Home Mortgage Finance Authority) Homebuyers Fund, County of Los Angeles, County of San Diego, and City of Fresno. These programs upgraded more than 8,100 single-family homes and 5,700 multifamily units, and installed 370 solar electric generation (photovoltaic) systems. These efforts delivered estimated annual energy savings of more than 21.2 gigawatt-hours and nearly 1.3 million therms, and produced nearly 3.2 gigawatt-hours of annual electricity generation impacts.

Keywords: Energy Upgrade California , local governments, whole-house, California Comprehensive Residential Retrofit programs, energy savings, electricity savings, natural gas savings, energy efficiency, partnerships, ARRA funding, evaluation, measurement and verification.

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EXECUTIVE SUMMARY

Introduction

The California Energy Commission designed the California Comprehensive Residential Retrofit program to enable market transformation and pilot a range of programs aimed at expanding whole-building energy upgrades in single-family and multifamily buildings in California. Program goals included spending the funds according to federal deadlines and requirements, creating jobs during the American Recovery and Reinvestment Act period, developing new business practices and saving energy across California's existing residential building sector. The California Comprehensive Residential Retrofit program worked in collaboration with regional and local governments, finance companies, the California Public Utilities Commission, and utility companies to deliver comprehensive energy efficiency assessments and upgrades to existing single-family and multifamily homes under the statewide Energy Upgrade California™ brand. The Energy Commission allocated about $98 million in American Recovery and Reinvestment Act of 2009 funds to multiple subrecipients under this program.

The U.S. Department of Energy used the structure of the long-standing State Energy Program to allocate American Recovery and Reinvestment Act funding to state energy offices to encourage energy efficiency and renewable energy. States were encouraged to pursue programs to achieve economic stimulus and recovery with emphasis on strengthening core state energy programs and initiatives that would lead to market transformation. The United States Department of Energy (DOE) defines market transformation as, *"strategic interventions that cause lasting changes in the structure or function of a market or the behavior of market participants, resulting in an increase in adoption of energy efficiency and renewable energy products, services, and practices."* The Department of Energy also encouraged states to achieve a high degree of leveraging of other resources and collaboration with state and local efforts, both public and private sector. The California Comprehensive Residential Retrofit program's enabling activities designed to transform markets and develop sustainable new business practices included developing the Energy Upgrade California™ brand, local and regional program development and delivery, contractor and rater training, energy assessment and rating incentives, and statewide education, outreach, and marketing.

An independent contractor team, led by DNV KEMA Energy & Sustainability, conducted an impact evaluation of the California Comprehensive Residential Retrofit program. From January 2012 to December 2012, evaluators visited a sample of 201 sites from six of the subrecipient programs and collected data. Additional residential upgrades funded under the Energy Upgrade California program reported energy savings but were not in the scope of the site visit evaluation. The programs or program elements not included in the site visit evaluations did not provide direct financial support for single-family energy efficiency upgrades but enabled the Energy Upgrade California collaboration. The site visit evaluations also did not include multifamily pilot energy efficiency upgrade programs and on-site photovoltaic system installations made in conjunction with single-family and multi-family energy efficiency upgrades.

Program Accomplishments

The following regional and local government administered programs were subrecipients that were allocated American Recovery and Reinvestment Act of 2009 funding by the Energy Commission under the California Comprehensive Residential Retrofit program, in collaboration with the Energy Upgrade California program.

The Retrofit Bay Area Program (primary administrator: Association of Bay Area Governments, a regional joint powers authority) pursued market transformation and piloted delivery of whole-house energy assessments and upgrades to single-family homes in eight San Francisco Bay Area counties, offering regional and local incentives to homeowners, in conjunction with utility rebates. The program also piloted multifamily whole-building energy assessments and upgrades in San Francisco and Alameda County. The program recruited and supported building owners by educating them about the whole house approach, connecting them to participating contractors and other professionals, informing them about financing and other resources available in their county, and streamlining the program participation process. The program also promoted workforce development through technical and business skills training for participating contractors and Home Energy Rating System raters, and provided incentive scholarships to trainees.

The Affordable Multifamily Retrofit Initiative (primary administrator: San Francisco Mayor's Office of Housing) provided partial funding and risk mitigation for a revolving loan fund that provided capital for energy efficiency and water conservation improvements for multifamily, affordable housing projects in San Francisco, Oakland, and Berkeley. The program collaborated with multiple programs that subsidize maintenance and upgrading of affordable housing to develop jointly funded projects to meet multiple objectives and drive down the participating building owners' cost share. The program pursued market transformation for these hard-to-reach buildings with outreach to candidate building owners in the region and workforce development to provide energy assessment protocols and training supported by participation scholarships. Projects were not completed in time for the site visits and, therefore, were not included in the scope of this evaluation.

The Moderate Income Sustainable Technology Program (primary administrator: CRHMFA [formerly California Rural Home Mortgage Finance Authority] Homebuyers Fund, a regional joint powers authority) delivered below-market interest rate revolving loan fund financing for deep whole-house energy efficiency measures. The program utilized 15-year loans with interest rates of 0 to 3 percent, and provided grants to single-family, moderate-income households to buy down the cost of whole-house upgrades, including on-site photovoltaic generation systems in some cases. This program was available in 31 counties throughout the state and required Home Energy Rating System ratings and documentation of upgrades for all loans. The energy efficiency upgrades completed through the program were included in the site visit evaluation.

The Home Performance Program (primary administrator: Sacramento Municipal Utility District) pursued market transformation and delivered whole-house/whole-building home performance upgrades to single-family and multifamily buildings in Sacramento County. The

program provided rebates for contractor and Home Energy Rating System rater performed energy assessments and for upgrades, in coordination with several county partners and Pacific Gas and Electric Company (PG&E). The program was open to all residential customers in the County, which included both low-income and higher-income owners. Low-income weatherization projects were not included in the site visit portion of this evaluation.

The Energy Upgrade California Program (primary administrator: the Local Government Commission, a statewide joint powers authority) administered statewide infrastructure support initiatives for the Energy Upgrade California collaboration, including development and implementation of the Web portal that provided homeowners with energy efficiency education; county-specific information and links to qualified, participating contractors and professionals that could provide energy assessments and upgrade services. The program also conducted extensive, on-the-ground local outreach and education efforts in 30 counties statewide, and provided statewide marketing, education, and outreach materials and tools for all Energy Upgrade California partners to use. The program also conducted workforce development training for participating contractors and raters, and provided incentives for home energy ratings. The contract also included pilot programs for Property Assessed Clean Energy financing for energy efficiency upgrades for single-family residential buildings in Sonoma County and commercial buildings in San Francisco City and County, City of Los Angeles, and Placer County. This program was not included in the site visit portion of the evaluation.

The Energy Independence Program (subprogram under the Local Government Commission contract, administrator: Sonoma County), under the Energy Upgrade California program, pursued market transformation and piloted delivery of Property Assessed Clean Energy financing for permanently installed energy efficiency and water conservation measures in single-family homes. The Sonoma County Energy Independence Program conducted marketing, provided education and outreach to recruit and support homeowner participants, provided workforce development and support, offered an innovative "contractor float" revolving loan program that covered contractor carrying costs between the time that upgrade projects were completed and the closure of Property Assessed Clean Energy financing for the projects, and initiated a participating contractor tool lending library. The program also provided incentives for energy assessments. This subprogram was not included in the site visit portion of the evaluation.

The Energy Upgrade California in San Diego Program (primary administrator: County of San Diego) delivered single-family and piloted multifamily comprehensive residential whole-building upgrade programs for the San Diego region. In addition to energy assessments and upgrades, this program trained home performance contractors and Home Energy Rating System raters. The multifamily program co-developed and piloted energy assessment tools in a substantial number of multifamily buildings. Single-family whole-house energy efficiency projects were included in the site visit portion of the evaluation. Multifamily projects and photovoltaic system installations were not included. The Energy Commission allocated discretionary Energy Efficiency and Conservation Block Grant funding to support these program efforts in the region.

The Regional Comprehensive Residential Retrofit Program (primary administrator: City of Fresno) was delivered in four counties of the South San Joaquin Valley. The program provided no-cost energy assessments and Home Energy Rating System ratings as well as training and support to develop a contractor workforce for whole-house upgrades. The intent of the program was to increase homeowner awareness and knowledge regarding the opportunity for energy efficiency upgrades, recognizing that homeowners in the San Joaquin Valley region were among the hardest-hit by the recession and would more likely make incremental upgrades over time, some through do-it-yourself projects. Even though this program approach was not expected to achieve extensive whole-house upgrades, this program was included in the site visit portion of the evaluation. The Energy Commission allocated a portion of its discretionary Energy Efficiency and Conservation Block Grant funding in combination with State Energy Program funds to support these program efforts.

The Retrofit Los Angeles Program (primary administrator: County of Los Angeles) was an extensive collaboration of initiatives that were jointly funded by discretionary Energy Efficiency and Conservation Block Grant funds from the Energy Commission, the United States Department of Energy (DOE) direct Better Buildings Program competitive grant, and the DOE large jurisdiction Energy Efficiency and Conservation Block Grant formula grant. The program pursued market transformation and pilot delivery of whole-building energy assessments and upgrade projects for single-family and multifamily buildings. The program recruited and supported building owner participants through marketing, education, and outreach, and supported workforce development through technical and business skills training for participating contractors. The program also pursued innovative financing options through loan loss reserve risk mitigation and interest rate buy downs. Single-family whole-house energy efficiency projects were included in the site visit portion of the evaluation. Multifamily projects and photovoltaic system installations were not included.

The Municipal Finance Program (primary administrators: the County of Santa Barbara and Alameda County) was awarded Energy Efficiency and Conservation Block Grant grant funding to develop residential Property Assessed Clean Energy financing programs. Before these programs were able to get started, the Federal Housing Finance Agency strongly discouraged federally funded lenders from cooperating with residential Property Assessed Clean Energy financing programs. As a result, the Energy Commission allowed these administrators to revise their programs. The County of Santa Barbara withdrew their efforts to start a Property Assessed Clean Energy financing program, using other American Recovery and Reinvestment Act of 2009 funds they received directly from DOE to pursue instead a loan loss reserve risk enhancement to encourage the start-up of a low interest, unsecured loan program through local credit unions. The emPowerSBC program coordinated with Energy Upgrade California, providing homeowner outreach and information and participating contractor training. Alameda County chose to cancel their program, returning most of the initial funding.

The primary goal of the evaluation was to assess the implementation effectiveness of the California Comprehensive Residential Retrofit subrecipient program and to verify the estimated energy savings of the programs. Overall, the programs successfully upgraded more than 8,100

single-family homes and more than 5,700 multifamily units, and installed more than 370 solar photovoltaic systems throughout California. These efforts delivered estimated annual energy savings of more than 21.2 gigawatt-hours and 1.3 million therms and produced more than 3.2 gigawatt-hours of annual electricity generation impacts. Overall impacts from the full scope of the Energy Commission's California Comprehensive Residential Retrofit program are shown in Table 1.

Table 1: Overall Impacts From all California Comprehensive Residential Retrofit Programs*

American Recovery and Reinvestment Act of 2009 Funding Source	Subrecipient Program	Primary Administrator	Number of Upgrade Projects	Estimated Annual Electricity Savings (kWh**)	Estimated Annual Natural Gas Savings (therms)	Estimated Annual Electricity Generation (kWh**)
State Energy Program	Retrofit Bay Area	Association of Bay Area Governments	919 single-family homes, 30 multifamily properties (1,057 units)	1,768,817	300,023	
	Affordable Multifamily Initiative	San Francisco Mayor's Office of Housing	6 multifamily properties (529 units)	100,892	49,353	
	Moderate Income Sustainable Technology	CRHMFA Homebuyers Fund	564 single-family homes, 121 photovoltaic system installations	1,356,461	73,406	829,449
	Home Performance	Sacramento Municipal Utility District	836 single-family homes, 2,000 single-family low-income households, 49 multifamily properties (2,513 units)	10,637,284	301,496	
	Energy Upgrade California, including Sonoma County Energy Independence Program	Local Government Commission	1,794 single-family homes, 239 photovoltaic installations	2,326,149	258,406	2,249,631

American Recovery and Reinvestment Act of 2009 Funding Source	Subrecipient Program	Primary Administrator	Number of Upgrade Projects	Estimated Annual Electricity Savings (kWh**)	Estimated Annual Natural Gas Savings (therms)	Estimated Annual Electricity Generation (kWh**)
Energy Efficiency and Conservation Block Grant	Energy Upgrade California in San Diego	San Diego County	19 single-family homes, 10 multifamily properties (884 units), 7 photovoltaic installations	606,492	36,487	49,201
	Regional Comprehensive Residential Retrofit	City of Fresno	22 single-family homes	70,296	3,283	
	Retrofit Los Angeles	Los Angeles County	1,961 single-family homes, 9 multifamily properties (720 units), 3 photovoltaic system installations	4,342,655	240,382	34,130
	Municipal Finance Program	Santa Barbara County /Alameda County (cancelled)	2 residential photovoltaic installations	NA***	NA***	13,574
Total				21,209,046	1,262,836	3,175,985

* Includes evaluator adjusted savings estimates for single-family whole-house programs, plus subrecipient savings estimates (ex ante, not evaluator-adjusted) for multi-family whole-building programs and single-family, single measure programs. Only the impacts from whole-house upgrades completed in single-family homes were included in the site visit portion of the evaluation.
** kWh = kilowatt-hours
*** NA = Not Available
Source: Energy Commission and DNV KEMA

Evaluation Results

The portion of California Comprehensive Residential Retrofit program impacts resulting from whole-house, single-family upgrade initiatives were the focus of site visit evaluations. To verify the impacts of the whole-house, single-family upgrade initiatives, evaluators completed the following steps:

1. Selected a random sample of single-family homes that participated in American Recovery and Reinvestment Act of 2009-funded whole-house upgrade initiatives. The homes were chosen for sampling in proportion to the number of energy assessments and upgrade projects completed by each program.
2. Visited the sampled single-family homes after the completion of upgrade projects to determine independently the pre-existing building characteristics and pre-existing energy efficiency measures that remained unchanged by the project, as well as to verify upgrade measure installations.

3. Collected the historical energy usage data from the utilities for the sampled single-family homes for a period of one to three years prior to the assessment and upgrade projects.
4. Collected the building simulation files that were prepared by the participating contractor (or Home Energy Rating System rater) at the time of the energy assessment, which included the assessment of preproject building characteristics (including pre-existing energy efficiency measures), project energy efficiency measure upgrades to be made, and building simulation based estimates of preproject energy use and estimated energy savings expected to result from the upgrades.
5. In some cases, asked homeowners questions about the installed measures and conditions of the home before the upgrade to better understand the building simulation file inputs that were made by the participating contractor (or Home Energy Rating System rater).
6. Revised the contractor building simulations for the preproject condition to reflect evaluator-observed building characteristics and pre-existing energy efficiency measures that remained unchanged by the project, and for the postproject condition to reflect evaluator-observed building characteristics and postproject energy efficiency upgrades.
7. Based on the revised building simulations, revised the estimated preproject energy use and estimated energy savings for the installed upgrade measures, and compared the energy savings of the revised building simulation models to the energy savings of the contractor's original building simulation models to determine a "verification factor" multiplier.
8. Compared the historical energy usage to the estimated preproject energy use from the evaluator's revised building simulations (from Step 3 above) to determine a "usage adjustment factor" multiplier.
9. Multiplied the estimated energy savings from the contractor's building simulations by the "verification factor" and the "usage adjustment factor" to determine the evaluator's estimated energy savings based on site visits and preproject historical energy usage.

The evaluation results indicate more than 9 gigawatt-hours of annual electricity savings and about 900,000 therms of natural gas savings from the whole-house, energy efficiency upgrade measures implemented in single-family homes. Table 2 and Table 3 present the expected energy savings estimates (ex ante), the verified savings estimates (ex post), and the usage-adjusted savings estimates for the single-family components of the subrecipient programs. The tables present the total annual electricity and natural gas savings estimates, as well as the verification factors from site visits and the usage adjustment factors from the comparison to preproject historical energy usage reported by utilities for the home. Verification factors are the same for electricity and gas since the program used a site energy conversion approach to convert electricity and gas to a single energy metric. Estimates of energy use from the contractor and evaluator models were compared using site converted British thermal units (Btus). Usage adjustment factors are determined for each specific subrecipient program since historical

electricity and natural gas energy usage for the home reported by the utilities were compared separately to the estimates from the evaluator building simulation models.

Data for the subrecipient programs for which the evaluators conducted site visit evaluations are shown at the top of these tables with a subtotal for those programs. Evaluators did not conduct site visits for Energy Upgrade California (Local Government Commission) or Energy Independence Program (Sonoma County), and the expected impacts from these two programs are listed after the subtotal in the table. The amount after the subtotal also includes Shared Projects that received funding from both Retrofit Bay Area and Moderate Income Sustainable Technology, both Home Performance Program and Moderate Income Sustainable Technology, or both Retrofit Bay Area and Sonoma County.

Table 2: Evaluation Results – Estimated Annual Program-Level Electricity Savings (Whole-House, Single-Family Only)

American Recovery and Reinvestment Act of 2009 Funding Source	Subrecipient Program	Estimated Annual Gross Ex Ante Electricity Savings (kWh*)	Verification Factor	Estimated Annual Gross Ex Post Electricity Savings (kWh*)	Electricity Usage Factor	Estimated Annual Gross Usage-Adjusted Electricity Savings (kWh*)
State Energy Program	Retrofit Bay Area	1,114,638	98%	1,092,345	76%	830,182
	Moderate Income Sustainable Technology	2,417,072	92%	2,223,706	61%	1,356,461
	Home Performance	3,430,696	86%	2,950,399	77%	2,271,807
Energy Efficiency and Conservation Block Grant	Energy Upgrade California in San Diego	31,069	85%	26,409	107%	28,258
	Regional Comprehensive Residential Retrofit	121,200	NA**	121,200	58%	70,296
	Retrofit Los Angeles	4,094,671	90%	3,685,204	66%	2,432,235
Subtotal		11,209,346	90%	10,099,263	69%	6,989,239
Energy Upgrade California, Energy Independence Program, and Shared Projects***		3,632,596	90%	3,269,336	69%	2,255,842
Total		14,841,942	90%	13,368,599	69%	9,245,081

* kWh = kilowatt-hours
** NA = not applicable, site visits for Regional Comprehensive Residential Retrofit were of homes that did energy assessments but not upgrades
*** Site visits were not conducted for the Energy Upgrade California and the Energy Independence Program. Shared Projects received services from more than one subrecipient program.
Since the Municipal Finance program didn't have electricity savings, the program is not shown in Table 2.
Source: Energy Commission and DNV KEMA

Table 3: Evaluation Results – Estimated Annual Program-Level Natural Gas Savings (Whole-House, Single-Family Only)

American Recovery and Reinvestment Act of 2009 Funding Source	Subrecipient Program	Estimated Annual Gross Ex Ante Natural Gas Savings (therms)	Verification Factor	Estimated Annual Gross Ex Post Natural Gas Savings (therms)	Natural Gas Usage Factor	Estimated Annual Gross Usage Adjusted Natural Gas Savings (therms)
State Energy Program	Retrofit Bay Area	358,262	98%	351,097	58%	203,636
	Moderate Income Sustainable Technology	126,649	92%	116,517	63%	73,406
	Home Performance	259,251	86%	222,956	69%	153,839
Energy Efficiency and Conservation Block Grant	Energy Upgrade California in San Diego	2,757	85%	2,343	50%	1,172
	Regional Comprehensive Residential Retrofit	4,690	NA*	4,690	70%	3,283
	Retrofit Los Angeles	258,644	90%	232,780	93%	216,485
Subtotal		1,010,253	91%	930,383	72%	651,821
Energy Upgrade California, Energy Independence Program, and Shared Projects**		379,760	91%	345,581	72%	248,819
Total		1,390,013	91%	1,275,964	72%	900,640

* NA = not applicable, site visits for Regional Comprehensive Residential Retrofit Program were of homes that did energy assessments but not upgrades
** Site visits were not conducted for the Energy Upgrade California and the Energy Independence Program. “Shared Projects” received services from more than one subrecipient program.
Since the Municipal Finance program did not have natural gas savings, the program is not shown in Table 3.
Source: Energy Commission and DNV KEMA

The life-cycle savings estimated for the whole-house, single-family portion of the California Comprehensive Residential Retrofit program totaled nearly 185 gigawatt-hours and more than 18 million therms, as shown in Table 4. Adding impacts from multifamily projects, non-whole-house single-family projects, and solar photovoltaic system installations to the single-family whole-house projects yields about 424 gigawatt-hours and 25 million therms of life-cycle energy savings, and about 63 gigawatt-hours of life-cycle electricity generation.

Table 4: Evaluation Results – Estimated Annual and Life-Cycle Program-Level Savings (Whole-House, Single-Family Only)

American Recovery and Reinvestment Act of 2009 Funding Source	Subrecipient Program	Estimated Annual Gross Usage-Adjusted Electricity Savings (kWh*)	Estimated Life-Cycle Gross Usage-Adjusted Electricity Savings (kWh*)	Estimated Annual Gross Usage Adjusted Natural Gas Savings (therms)	Estimated Life-Cycle Gross Usage-Adjusted Natural Gas Savings (therms)
State Energy Program	Retrofit Bay Area	830,182	16,603,640	203,636	4,072,720
	Moderate Income Sustainable Technology	1,356,461	27,129,220	73,406	1,468,120
	Home Performance	2,271,807	45,436,140	153,840	3,076,800
Energy Efficiency and Conservation Block Grant	Energy Upgrade California in San Diego	28,258	565,160	1,172	23,440
	Regional Comprehensive Residential Retrofit	70,296	1,405,920	3,283	65,660
	Retrofit Los Angeles	2,432,235	48,644,700	216,485	4,329,700
Subtotal		6,989,239	139,784,780	651,822	13,036,440
Energy Upgrade California, Energy Independence Program, and Shared Projects**		2,255,842	45,116,840	248,819	4,976,380
Total		9,245,081	184,901,620	900,641	18,012,820

* kWh = kilowatt-hours
**Site visits were not conducted for the Energy Upgrade California and the Energy Independence Program. Shared Projects received services from more than one subrecipient program.
Source: DNV KEMA

Annual and life-cycle greenhouse gas emissions reductions for the whole-house, single-family portion of the California Comprehensive Residential Retrofit program total 7,669 metric tons of carbon dioxide annually and 153,384 metric tons of carbon dioxide over the life of the energy efficiency upgrades, as shown in Table 5. Adding in impacts from multifamily projects, non-whole-house single-family projects, and solar electric generation (photovoltaic) system installations yields a total of roughly 14,530 metric tons of carbon dioxide annually and 290,599 metric tons of carbon dioxide over the life of all the measures.

Table 5: Evaluation Results – Estimated Program-Level Greenhouse Gas Reductions (Whole-House, Single-Family Only)

American Recovery and Reinvestment Act of 2009 Funding Source	Subrecipient Program	Estimated Annual Greenhouse Gas Reductions (metric tons CO_{2*})	Estimated Life-Cycle Greenhouse Gas Reductions (metric tons CO_{2*})
State Energy Program	Retrofit Bay Area	1,340	26,792
	Moderate Income Sustainable Technology	814	16,276
	Home Performance	1,527	30,536
Energy Efficiency and Conservation Block Grant	Energy Upgrade California in San Diego	15	301
	Regional Comprehensive Residential Retrofit	39	788
	Retrofit Los Angeles	1,909	38,183
Subtotal		5,644	112,876
Energy Upgrade California, Energy Independence Program, and Shared Projects**		2,025	40,508
Total		7,669	153,384

* CO_2 = carbon dioxide
** Site visits were not conducted for the Energy Upgrade California and the Energy Independence Program. Shared Projects received services from more than one subrecipient program.
Source: DNV KEMA

In addition to energy savings, the California Comprehensive Residential Retrofit program's goals were to create a sustainable market for home energy assessments and pilot the statutory expectations that were enacted in the California Assembly Bill 758 (Skinner, Chapter 470, Statutes of 2009) for the California Comprehensive Program for Energy Efficiency in Existing Buildings. The statute states:

> *"… a comprehensive efficiency program should include components necessary to ensure meaningful and reliable energy assessments, cost-effective energy efficiency improvements, public and private sector energy efficiency financing options, public outreach and education, and green workforce training."*

Consistent with DOE guidance "to strengthen core state energy programs to develop and adopt leading market transformation initiatives,[1]" the Energy Commission expressly designed the California Comprehensive Residential Retrofit program to use American Recovery and Reinvestment Act funding to pilot the implementation of these California Assembly Bill 758 statutory program elements. In each regional area, subrecipients pursued these same core components by seeking to increase building owner awareness and knowledge of whole-building energy efficiency and on-site renewable upgrades; increase contractors' and other professionals' technical knowledge, skills, and ability to deliver quality whole-building energy efficiency assessments and upgrades; and build from scratch both increased demand from willing building owners and increased supply of competent contractors and other professionals to meet that demand. The program supported the development of this nascent market through establishment of sustained local and regional government and utility collaboration, quality installations through effective quality control, and financing programs to help building owners meet the capital requirements for upgrades.

The program was successful in meeting the building owner information and workforce development goals, providing quality assurance, and establishing available financing mechanisms. The program trained more than 1,000 contractors and Home Energy Rating System raters. The programs also provided a Web portal to inform both homeowners and participating contractors, conducted targeted education and outreach, and provided contractor technical and business skills training.

Evaluators made the following recommendations to improve the program going forward:

- **Target inefficient homes with greatest consumption** by using preproject historical energy usage and savings as the basis for determining rebate amounts and move toward an incentive per unit of energy saved like nonresidential custom programs.
- **Improve energy savings realization** by continuing to improve the accuracy of building simulation software estimated energy consumption and savings. Continue the efforts of the California Public Utilities Commission and Energy Commission to improve the consistency of building simulation savings estimates with program participant's energy usage by developing and implementing rules for limiting preproject building characteristics assumptions consistent with national consensus Standards, and establishing a process to, on an ongoing basis, compare, and adjust building simulations to match energy usage.
- **Provide improved contractor training**, including initial and residual training for using building simulation software, using preproject building characteristics limitations, and

1 U.S. Department of Energy, State Energy Program Formula Grants, American Recovery and Reinvestment Act, Funding Opportunity Number: DE-FOA-0000052, February 3, 2009 http://www.energy.ca.gov/recovery/documents/SEP_Recovery_Act_Guidance_DE-FOA-00000521.pdf.

focusing on matching of estimated energy consumption with home energy usage, on an ongoing basis.

- **Develop a comprehensive database for projects**, including:
    - maintaining records on preproject conditions, limiting preproject conditions consistent with Building Performance Institute national standards, and allowing deviation only when building simulation energy consumption estimates are well-matched to energy usage or when verified by preproject quality control;
    - maintaining a record of all projects, including all funding sources and amounts or rebates and financing, and when energy upgrades are made in parallel to non-energy building improvements, a clearly separated estimate of the costs of the energy upgrades alone;
    - storing all building simulation files and project data are stored in a format that is easily accessible for quality control, evaluation and future program analysis;
    - actively enabling of the sharing of data with all program administrators that have a stake in the delivery of the program and with the participating contractors and other market actors, recognizing the need for data security through effective access protections, and safe data transfer and data storage. IOUs must fully cooperate with this data sharing for the database to be successful.

CHAPTER 1:
Introduction

This report provides the California Energy Commission (Energy Commission) with an independent evaluation of the California Comprehensive Residential Retrofit (CCRR) program funded by the American Recovery and Reinvestment Act of 2009 (ARRA). The site visit portion of the evaluation was conducted from January 2012 to December 2012.

Evaluators estimated energy savings and peak demand savings for the sample of 201 sites included in the evaluation. However, ex ante estimates of peak demand were unavailable for many of the nonsampled sites, which prevented extrapolating peak demand savings to the program population. Therefore, this report focuses on energy savings only and provides both annual and life-cycle estimates. The evaluation also made estimates of avoided greenhouse gas (GHG) emissions.

The report also explains the differences between estimated ex ante and ex post savings results, in terms of differences between evaluator site visit observed and contractor-reported building characteristics and energy efficiency measures, as well as differences between modeled energy consumption and weather-normalized historical energy usage from customer billing data. In the case of energy assessment-only participants, the estimated preproject energy consumption from contractor models was compared to weather-normalized historical energy usage.

The remaining sections of this report are organized as follows:

- **Chapter 2: Program Overview** describes the CCRR programs, the program objectives and goals, and the accomplished results.
- **Chapter 3: Evaluation Approach** provides an evaluation method overview, including primary data sources used, sample design, description of the final sample, data collection elements, and calculation method.
- **Chapter 4: Evaluation Issues** presents three key issues that the evaluation team observed regarding the analyses and the interpretation of results**.**
- **Chapter 5: Evaluation Findings** presents findings resulting from the postproject site visit evaluations of the sampled single-family homes, including differences between evaluator and participating contractor observations and testing of building characteristics and measure levels, and implications on building simulation estimates of pre- and postproject energy consumption and savings.
- **Chapter 6: Recommendations** provides proposals for program improvement.
- **Chapter 7: Glossary** provides a list and describes the meaning of acronyms and terms used in this report.

Appendices to this report include:

- **Appendix A: Verification Factors by CCRR Subrecipient Program** provides figures comparing evaluator and contractor results by subrecipient.
- **Appendix B: Incomplete Building Simulation Data** provides data on the sites with issues in the simulation model files.
- **Appendix C**: **Participant Site Data Collection Guide** provides data collection forms and test procedures for the whole-house, single-family sites included in the evaluation sample.
- **Appendix D: Evaluation Results for Sampled Sites** provides ex post evaluation results for the whole-house, single-family sites included in the evaluation sample.
- **Appendix E: Billing Data Disaggregation Memo** provides attempted methods and discussion of separating cooling and heating end-use estimates from historical usage.

CHAPTER 2:
Program Overview

The Energy Commission was authorized by the United States Department of Energy (DOE) to administer the ARRA funds for the State Energy Program (SEP) and the Energy Efficiency and Conservation Block Grant (EECBG) program.[2] In the wake of the worst recession since the Great Depression, the ARRA economic stimulus program was enacted to preserve and create jobs; to promote economic recovery; to assist those most affected by the recession; to provide investments needed to increase economic efficiency by spurring technological advances in science and health; to invest in transportation, environmental protection, and other infrastructure that will provide long-term economic benefits; and to stabilize state and local government budgets.[3]

The DOE established the following objectives for the ARRA SEP funds:

- Transform energy markets in partnership with states to accelerate near-term deployment of energy efficiency and renewable technologies.
- Promote an integrated portfolio of energy efficiency and renewable energy solutions to meet United States energy security, economic vitality, and environmental quality objectives.
- Strengthen core SEPs to develop and adopt leading market transformation initiatives.[4]

DOE also strongly encouraged states to achieve a high degree of leveraging of other resources and collaboration with state and local efforts, both public and private sector.

In response to this direction, the Energy Commission established an extensive portfolio of program initiatives to pursue the multiplicity of ARRA goals and objectives. The Energy

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2 The Energy Efficiency and Conservation Block grant was intended to provide ARRA funding primarily to local governments to conduct energy efficiency and renewable programs. DOE provided direct grants to large cities and counties. The Energy Commission administered additional Block grant funding for the state, at least 60 percent of which was to go to small cities and counties, primarily to make energy efficiency improvements to local government facilities. The Energy Commission allocated discretionary Block grant funds to support local government subrecipient delivery of California Comprehensive Residential Retrofit programs.

3 U.S. Department of Energy, State Energy Program Formula Grants, American Recovery and Reinvestment Act, Funding Opportunity Number: DE-FOA-0000052, February 3, 2009 http://www.energy.ca.gov/recovery/documents/SEP_Recovery_Act_Guidance_DE-FOA-00000521.pdf.

4 Market transformation is defined as "strategic interventions that cause lasting changes in the structure or function of a market or the behavior of market participants, resulting in an increase in adoption of energy efficiency and renewable energy products, services, and practices."

Commission's ARRA portfolio represented a continuum of program initiatives ranging from immediate investment in known opportunities for upgrade of buildings to investment in the development of market functions intended to result in ongoing market transformation and achievement of California energy efficiency and climate change goals. ARRA programs were designed to conduct initiatives at particular points along this continuum. In combination, the Energy Commission's program portfolio was intended to achieve a balanced emphasis on both immediate upgrade projects and on sustained market transformation.

The Energy Commission devoted $83.5 million of the SEP funds for programs that pursue innovative energy efficiency and renewable energy upgrades in existing residential buildings with extensive market development initiatives to establish sustained market transformation and advance the state's energy efficiency goals. These programs were designed to promote and achieve comprehensive upgrades in residential buildings (both single-family and multifamily). The programs relied on regional collaborations that take advantage of local insight, expertise, and initiative; promote and achieve specific targeted measures in nonresidential buildings through public-private partnerships; and develop and conduct sustainable, innovative municipal financing programs, including pilot Property Assessed Clean Energy (PACE) financing for upgrades in both residential and nonresidential buildings. The Commission subsequently decided to devote an additional $14.2 million of the EECBG state discretionary funds to pursue the comprehensive residential and municipal financing programs in additional regions within California.

Contemporaneously with the Energy Commission's development of the ARRA programs, California Assembly Bill 758 (AB 758) (Skinner, Chapter 470, Statutes 2009) was approved by the California Legislature. AB 758 directed the Energy Commission to develop and implement a comprehensive program to achieve energy efficiency in California's existing buildings. The legislation directed that the comprehensive program comprise a complementary portfolio of techniques, applications, and practices that will achieve greater energy efficiency in existing buildings. The legislation also identified the following set of program elements for potential inclusion in the comprehensive program: energy assessments, building benchmarking, energy rating, cost-effective energy efficiency improvements, public and private sector energy efficiency financing options, public outreach and education efforts, and green workforce training. Consistent with the DOE direction to "strengthen core State Energy Programs to develop and adopt leading market transformation initiatives," the Energy Commission's ARRA programs were specifically designed to pilot the "portfolio of techniques, applications and practices" and the explicit set of program elements statutorily specified in the AB 758 legislative language.

In parallel with the development of the Energy Commission's ARRA-funded comprehensive residential energy efficiency and municipal financing programs, California was moving toward a jump start of "home performance" programs. Since 2000, the Home Performance with ENERGY STAR® program and the Affordable Comfort Institute had been advancing efforts in other states to pursue whole-house or "house-as-a-system" approaches through a combination of integrated, interactive energy efficiency measures in homes to save energy, increase comfort,

and improve indoor air quality, health, and safety. Based on an extensive assessment of the current condition of the house, custom "house as a system" recommendations are made to homeowners for energy efficiency and on-site renewable upgrades that work together to improve the overall comfort, health and safety, and energy performance of the house. However, California's investor-owned utilities (IOUs) had never conducted such programs. In 2008, the California Long-Term Energy Efficiency Strategic Plan stated:

> *The IOUs currently offer a wide range of energy efficiency programs for existing homes, including audits, efficient appliance rebates, and consumer education. This Plan envisions a refocusing of these programs to move from a "widget" based approach to a "whole-house" approach to program delivery to offer comprehensive packages of audits, demand side management options and tools, rebates and financing options, and installation services.*

In 2009, the California Public Utilities Commission (CPUC) directed the IOUs (Decision 09-09-047) to "… transition from reliance on single measure incentive programs to implementation of an approach which incentivizes comprehensive savings and leverages creative financing." The CPUC worked over the next several months with the emerging building performance contracting industry and the IOUs to develop and launch the "Whole-House Performance Program" in response to CPUC direction. This program had a very similar set of objectives as the Energy Commission's ARRA comprehensive residential and municipal financing programs, and to be mutually successful the two programs needed to be highly coordinated, integrated, and leveraged.

In early 2010, the Energy Commission, the CPUC, and regional and local government ARRA subrecipients came together to form an unprecedented collaboration − the Energy Upgrade California program. These partners designed a unified statewide brand to reduce the residential customers' participation barriers and to generate demand for whole house assessments and retrofits. All partners agreed to adhere to consistent messaging and marketing through one logo. The centralized one-stop Web portal provided information to building owners about energy efficiency upgrades, local rebates and incentives and local financing. It also matched homeowners with local contractors and professionals that would provide energy assessment and upgrade installation services. The statewide program also prepared a ready workforce by helping local and regional government partners provide participating contractor and other training.

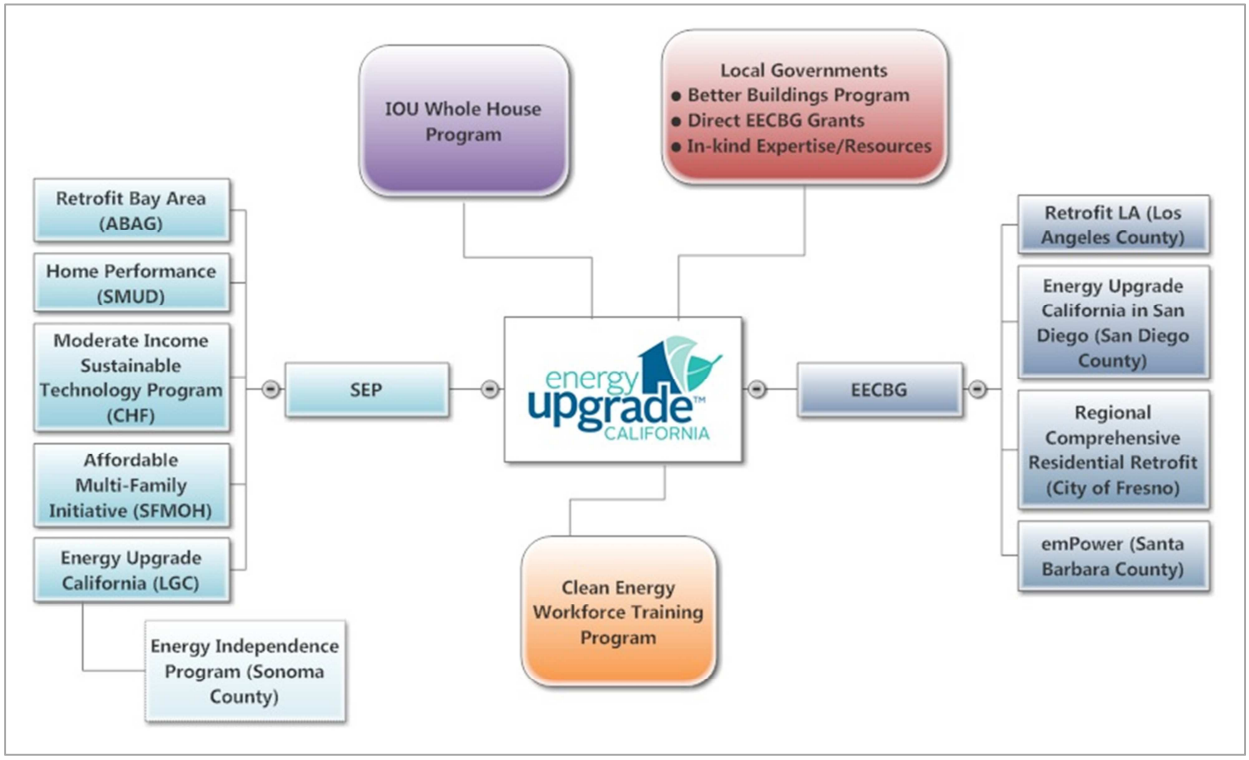
The CCRR subrecipients collaborated closely with IOU whole-house performance programs to deliver energy assessments and upgrade projects, including quality assurance review of the work delivered on the projects. Energy Upgrade California leveraged the resources of all funding partners to recruit, inform, and support homeowners; provide technical, business, and program training for contractors and other professionals; and deliver financing to homeowners and participating professionals.

Although not as extensive as the collaboration for single-family buildings, the CCRR subrecipients also collaborated on pilot programs to deliver energy assessments/ratings and upgrade projects for multifamily buildings in specific state regions by leveraging the Energy

Commission's ARRA funding, utility ratepayer funding, and local government direct DOE ARRA grants. The Energy Upgrade California partners collaborated on project completion and market transformation efforts, including development of project tracking, energy assessment protocols, and simulation software; contractor and assessment or/rater technical, business, and program training; building owner recruitment, information, and support; coordination with weatherization programs; cross-partner mentoring; and best practice coordination.

The CCRR subrecipients also coordinated and collaborated with the Clean Energy Workforce Training Program that conducted statewide workforce development efforts with the involvement of the California Workforce Investment Board (CWIB), local workforce investment boards (WIBs), and other workforce development providers. Figure 1 charts the relationships of the CCRR subrecipient programs and other funding partners and program initiatives that collaborated to accomplish Energy Upgrade California.

Figure 1: Relationship of CCRR Subrecipient Programs and Other Energy Upgrade California Partners



Source: California Energy Commission and DNV KEMA

This report focuses on the evaluation of the whole-house, single-family programs that were the primary emphasis of Energy Upgrade California, but also reports on the performance of the multifamily pilot programs, low-income weatherization energy efficiency installations, and

solar electric generation (photovoltaic [PV]) installations that also benefited from Energy Upgrade California collaboration. This report refers to all of these Energy Upgrade California initiatives that were accomplished by the Energy Commission through agreements with regional and local government and enabled by the ARRA SEP and the EECBG discretionary funds, as the CCRR program.

Subrecipient Program Descriptions

The subrecipient programs under the SEP-funded portion of the CCRR programs were:

- **Retrofit Bay Area** – administered by the Association of Bay Area Governments (ABAG), a regional joint powers authority.
- **Affordable Multifamily Initiative** – administered by the San Francisco Mayor's Office of Housing (SFMOH).
- **Moderate Income Sustainable Technology (MIST) Program** – administered by CRHMFA (formerly the California Rural Home Mortgage Finance Authority) Homebuyers Fund (CHF), a regional joint powers authority.
- **Home Performance Program** – administered by the Sacramento Municipal Utility District (SMUD).
- **Energy Upgrade California** – administered by the Local Government Commission (LGC), a statewide joint powers authority. LGC administered key support functions for the statewide Energy Upgrade California program.
- **Energy Independence Program** – a sub-subrecipient under the LCG contract, this program was implemented by Sonoma County

The subrecipient programs under the EECBG-funded portion of the CCRR programs were:

- **Energy Upgrade California in San Diego** – administered by the County of San Diego.
- **Comprehensive Residential Retrofit Program**[5] – administered by the City of Fresno (Fresno) in Fresno, Madera, Tulare, Kings, and Kern Counties. Fresno also received SEP funding.
- **Retrofit Los Angeles**– administered by the County of Los Angeles.
- **Municipal Finance Program**– administered by the County of Santa Barbara (called emPowerSBC) and the County of Alameda (canceled).

5 The Fresno Regional Comprehensive Residential Retrofit Program received funding from both SEP and EECBG. For this evaluation report, the results are included under the EECBG heading.

Key features for each of these CCRR subrecipient programs are described in Table 6. The table shows whether the target market for each program was single-family (SF), multifamily (MF), or both, and the circles represent activities funded by the specific CCRR programs.

Table 6: Summary of CCRR Subrecipient Funded Program Features

ARRA Funding Source	Subrecipient Program	Target Market	Low- or No-Cost Energy Assessments	Participant Marketing and Outreach	Contractor Training	Rebates for Upgrades*	Loans for Upgrades
SEP	Retrofit Bay Area (ABAG)	SF and MF	●	●	●	●	NA**
	Affordable Multifamily Initiative (SFMOH)	MF	●	●	●	NA	●
	Moderate Income Sustainable Technology Program (CHF)	SF	●	●	●	●	●
	Home Performance (SMUD)	SF and MF	●	●	●	●	NA
	Energy Upgrade California (LGC)	SF and MF	●	●	●	NA	●
	Energy Independence Program (Sonoma)	SF	●	●	●	NA	●
EECBG	Energy Upgrade California in San Diego (San Diego)	SF and MF	●	●	●	NA	NA
	Regional Comprehensive Residential Retrofit (Fresno)****	SF	●	●	●	NA	NA
	Retrofit LA (Los Angeles)	SF and MF	NA	●	●	NA	LF
	Municipal Finance Program (Santa Barbara, Alameda)*****	SF	NA	●	●	NA	LF

* All programs actively leveraged rebates from other sources
**NA = not applicable.
*** LF = provided by the program using other, leveraged funds
**** Fresno Regional Comprehensive Residential Retrofit Program also received some limited SEP funding but is included under EECBG in this table.
***** The Municipal Finance Program includes emPowerSBC, administered by the County of Santa Barbara, and a program administered by the County of Alameda that was cancelled.
Source: California Energy Commission

Retrofit Bay Area (ABAG)

The ABAG administered the Retrofit Bay Area Program, which provided energy efficiency assistance to residents in eight San Francisco Bay Area counties, including Alameda, Contra Costa, Marin, San Francisco, San Mateo, Santa Clara, Solano, and Sonoma. The program also sought to foster job growth and boost the regional economy by establishing a comprehensive program to perform energy-efficient upgrades in existing homes.

Through partnerships within the San Francisco Bay Area region, infrastructure was established to sustain a long-term, whole-house energy efficiency upgrade industry, including engagement of workforce development organizations to provide training to participating contractors and raters. Marketing and extensive outreach campaigns were conducted to promote homeowner participation and awareness of available rebates and whole-house energy efficiency offerings in accordance with the statewide Energy Upgrade California brand guidelines. ABAG and the individual counties provided rebates for both energy assessments and upgrades. The Retrofit Bay Area Program sought to streamline administration processes by dovetailing the qualification for regional and county rebates with existing utility (PG&E) whole-house rebate requirements. In addition to its single-family efforts, Retrofit Bay Area also conducted pilot multifamily programs in San Francisco and Alameda County, coordinating with other ARRA-funded multifamily pilots in other state regions.

Subsequent to the ARRA period, the Retrofit Bay Area is being sustained as the Bay Area Regional Energy Network (REN), receiving ongoing funding as directed by the CPUC to continue to promote residential energy upgrade projects in the region.

Affordable Multifamily Retrofit Initiative

The San Francisco's Mayor's Office of Housing, in collaboration with the City of Oakland and the City of Berkeley, established the Affordable Multifamily Retrofit Initiative to test the delivery of energy efficiency assessments and upgrades to the very hard-to-reach sector of large multifamily affordable housing. The program sought to coordinate with weatherization and other affordable housing subsidization programs to merge funding resources to promote energy efficiency upgrades in combination with other affordable housing maintenance and upgrade goals. The program provided, in combination with a private lender specializing in this market sector, low-risk financing of project costs net of subsidies. The program supported the completion of extensive energy assessments to identify cost effective energy efficiency upgrade opportunities in candidate buildings.

Subsequent to the ARRA period, the loan established in this program continues to be repaid, monitored, and tracked.

MIST Program

The CRHMFA Homebuyers Fund (CHF), a joint powers authority composed of cities and counties primarily from rural areas, administered the MIST program, which sought to connect moderate-income California homeowners to a source of funds previously denied by market barriers and achieve market transformation through program leveraging and the education of

program participants (including homeowners and participating contractors). CHF is an experienced administrator of low-income housing mortgage financing. The MIST program provided 0 and 3 percent interest rate, revolving loan account loans, as well as grants to lower the principal for upgrade projects in 33 counties throughout the state, providing easy qualification terms to moderate-income households. CHF piloted the delivery of home energy ratings for each participating home with public disclosure of the ratings on their website.[6]

Subsequent to the ARRA period, CHF continues to receive principal and interest repayments from "MIST I" loans that were funded and that continue to be available for future financing. ARRA funding that was under-spent from other programs was repurposed to establish the "MIST II" program. Under "MIST II" CHF is providing loan loss reserve funds that mitigate risk for energy upgrade loans. The CPUC has also directed the IOUs to continue funding for financing that was piloted under ARRA. As a result, PG&E is partnering with CHF to conduct "MIST II" financing using the loan loss reserve model.

Home Performance Program

SMUD collaborated with regional partners in Sacramento County to conduct a suite of pilot programs under the Home Performance Program, including whole-house, single-family programs; an expanded weatherization program that provided direct-install measures; and a major multifamily program, all with the goal of long-term sustainability and market transformation. SMUD conducted a regional education and marketing campaign to raise awareness in the region of building science approaches to energy efficiency and home performance.

Subsequent to the ARRA period, SMUD continued to provide Home Performance Program initiatives to its customers. In addition, since the end of the ARRA period, the City of Sacramento has launched the *Clean Energy Sacramento* PACE financing program for residential and commercial building energy efficiency and renewable generation upgrades.

Energy Upgrade California

The Local Government Commission (LGC) administered and implemented the program infrastructure for the statewide Energy Upgrade California collaboration. The LGC developed and managed the statewide Energy Upgrade California brand and Web portal that was used by all county partners to reach homeowners and contractors. The Web portal provided a one-stop online and interactive resource about the Energy Upgrade California program by county, identified for homeowners and contractors the array of incentives available through the local utility and local governments, helped homeowners access participating contractors and other professionals to provide energy assessments and upgrade installations, and helped homeowners avail themselves of local finance programs. The LGC subcontractors provided coordination of the multiple programs and efforts under the Energy Upgrade California brand

6 http://www.chfloan.org/programs/energy/hersinfo/hersinfo.aspx.

umbrella, including Energy Commission ARRA subrecipients, IOUs, local government partners, participating contractors, and Home Energy Rating System (HERS) raters.

The LGC subcontractors provided extensive marketing, education, and outreach throughout the state. This included cohesive branding, marketing, and messaging; extensive on-the-ground outreach support for regional/local governments and other stakeholders; and customer and contractor recruitment and support.

The LGC team also sponsored, in collaboration with local and regional partners, workforce development training. This training was targeted at energy upgrade contractors to gain competency for meeting program participation expectations, conducting technical procedures for the proper completion of energy assessments and upgrades, and establishing business skills to be able to succeed in providing quality services with business acumen. The LGC team also supported incentives to help home energy raters provide energy assessment and postinstallation ("test-out") quality assurance and ratings.

The LGC team was also responsible for data collection across all of the contributing Energy Upgrade California partners to track the progress of all projects in which individual households participated, and to assess program performance.

Under the general oversight of LGC, pilot programs were conducted to support and leverage the effectiveness of PACE financing through the Sonoma County residential PACE program and commercial PACE programs in San Francisco, Los Angeles, and Placer County.

A total of 96 contractors were trained, and more than 500 attendees attended workshops conducted as part of the LGC's statewide marketing and outreach efforts. Subsequent to the ARRA period, the LGC is continuing to provide oversight management for ongoing delivery of these PACE pilot programs.

Energy Independence Program

As a sub-subrecipient within the LGC contract, Sonoma County administered the Sonoma County Energy Independence Program (SCEIP) to deliver PACE financing to residential property owners to achieve energy efficiency, water conservation, and renewable generation property improvements through assessments that are repaid, over a 10- or 20-year term, "on-bill" in conjunction with the property taxes of the home. Sonoma County provided county bond funds to provide capital for financing the projects. The county used the ARRA funds for program development and delivery and market transformation, including contractor workforce development, and participant recruitment and information, in conjunction with the statewide Energy Upgrade California brand.

The ARRA funds were also used to:

- Provide incentives for energy assessments completed by either participating contractors or HERS raters.

- Conduct an innovative revolving loan fund to provide "contractor float" to cover contractor carrying costs between the time that upgrade projects were completed and the closure of PACE bond financing for the projects.
- Develop a contractor tool lending library.
- Develop a local information hub for tracking projects participating in the program.

Subsequent to the ARRA period, the SCEIP program continues to be one of the few operating residential PACE finance programs in the country.

Energy Upgrade California in San Diego

The Energy Upgrade California in San Diego Program delivered support initiatives for achieving comprehensive, whole-house, single-family upgrades throughout San Diego County. The program also developed and delivered the multifamily whole-building upgrade pilot program in the county. The county provided oversight to expert program managers who under subcontract delivered the programs in collaboration with the City of San Diego, City of Chula Vista, San Diego Gas & Electric Company (SDG&E), and the ARRA Better Buildings Program in the region.

The multifamily pilot developed detailed energy assessment protocols and energy analysis tools, trained home energy raters on these assessment methods, and funded delivery of energy assessments to a large number of dwelling units in the region. The program, with support from the Bay Area Retrofit multifamily program, developed an online navigation tool that helped multifamily building owners determine the availability of incentives from multifamily and affordable housing programs in the region, so as to decide the viability of upgrade projects in their facilities.

The single-family program provided incentives to participating contractors and HERS raters for energy assessments. In addition to energy assessments and upgrades, the programs provided training for home performance contractors and HERS raters. Interest in whole-house, single-family assessments and energy upgrades increased significantly in the last few months of the program, following marketing efforts and rebates for whole-house energy assessments.

The program also included a unique on-the-job training program for single-family building contractors, known as GETUP, which included two weeks of hands-on and internship training in performing whole-house upgrades, as well as classroom time developing "soft skills" such as resume building, finance literacy, and sales and administration skills.

Subsequent to the ARRA period the San Diego program has influenced the ongoing Energy Upgrade California program delivery and further market transformation efforts, including the statewide marketing design for the ongoing program and expansion of the Energy Upgrade California brand as a statewide umbrella brand for all energy efficiency programs conducted by the IOUs. The multifamily pilot in San Diego has greatly contributed to the strategies of ongoing multifamily whole building programs administered by Energy Upgrade California partners. The Los Angeles County post-ARRA financing program for residential heating,

ventilation, and air conditioning (HVAC) change-outs also has been extended to San Diego County.

Regional Comprehensive Residential Retrofit Program

The City of Fresno administered the Regional Comprehensive Residential Retrofit Program in four counties (Fresno, Tulare, Kings, and Kern) of the South San Joaquin Valley. Recognizing the different demographics of homeowners in the region, which was hit especially hard by the recession, the program was founded on a different strategy than other whole-house programs. Fresno pursued market transformation by increasing homeowner awareness of the opportunity for and benefits of making home energy upgrades.

Fresno anticipated that homeowners in the region likely would not be able to make point-in-time investments in deep whole-house upgrade projects, but instead would make more modest investments in incremental upgrades to their homes over time, including do-it-yourself improvements. Fresno focused on delivering no-cost, whole-house home energy assessments (with visualization of building envelope defects supported by infrared camera images) by home energy raters as a service so that homeowners, as they could afford to do so, could take incremental action to improve the energy efficiency of their homes. Homeowner confidence in the program was enhanced by the local government's sponsorship and endorsement.

The program also provided training and support to develop a workforce for whole-house energy assessments and upgrades.

The program was recognized by the U.S. Conference of Mayors as part of the national 2011 Mayors' Climate Protection Awards.

Subsequent to the ARRA period, the City of Fresno is working collaboratively with PG&E to build upon the energy assessments that were conducted by the program and to engage more homeowners in the region in whole-house projects

Retrofit Los Angeles

Los Angeles County administered Retrofit LA, an extensive collaboration of energy efficiency initiatives in the County that were funded through the Energy Commission's ARRA EECBG discretionary funding, the DOE direct competitive Better Buildings Program grant, and the DOE direct large jurisdiction EECBG grant to Los Angeles County. The Energy Commission ARRA funding supported the pursuit of whole-house energy efficiency energy assessments and upgrades, which were also promoted through financing and rebates that the county was able to provide through the other two funding sources. In addition, the county worked closely with Southern California Edison (SCE), Southern California Gas Company (SoCalGas), the City of Los Angeles, and assembled partners facilitated by the councils of government representing nearly all of the other 88 incorporated cities within the county.

The Energy Commission ARRA funding supported program design, implementation, and administration, including strong efforts for marketing and outreach of the combined program and workforce training for participating contractors and other professionals, including

incentives for participation in workforce training. These programs pursued not only whole-house energy assessments and upgrades for single-family buildings, but whole-building energy assessments and upgrades for multifamily buildings. In the aftermath of the Federal Housing Finance Authority (FHFA) guidance that strongly discouraged residential PACE financing, the county reprogrammed some of its direct EECBG funding to establish a loan loss reserve fund and interest rate buydown fund to promote alternate residential financing in the county.

The program also developed streamlined processes to more effectively pursue whole-house upgrades, including the "Flex Path" program, a points-based prescriptive incentive program that received wide response as an innovative approach to more effective delivery of whole-house upgrade projects.

Subsequent to the ARRA period, Los Angeles County has built on its efforts made with ARRA funds to promote the ongoing advancement of the Energy Upgrade California program. Retrofit LA is being sustained as the Southern California REN, covering Los Angeles County and the other Southern California counties that are served by SCE and SoCalGas, receiving ongoing funding directed by the CPUC to continue to promote residential upgrade projects and other building energy efficiency in other sectors in the region.

The "Flex Path" approach developed by the county has been used as a model for streamlining whole-house energy assessment and upgrade projects throughout the state, through initiatives pursued by the IOUs, the Bay Area REN, and the Southern California REN. The Southern California REN also has been funded by the CPUC to pursue financing programs, building on the experience that Los Angeles County gained during the ARRA period, including PACE pilot financing for commercial buildings and loan loss reserve and interest rate buydown funds to promote residential financing.

In addition, Los Angeles County continues to administer delivery of the pilot ARRA funded financing programs. These programs finance energy and on-site renewable upgrade projects, including a commercial PACE debt service reserve fund, a whole-house residential loan loss reserve fund, a revolving loan fund for Los Angeles County buildings, and interest rate buydown programs for residential HVAC change-out projects that fully comply with California building permit requirements.

Municipal Finance Program

The Municipal Finance Program was awarded EECBG grant funding to local programs to develop residential PACE financing programs. Before these programs were able to get started, the FHFA strongly discouraged federally funded lenders from cooperating with residential PACE programs. As a result, the Energy Commission allowed these administrators to revise their programs. The County of Santa Barbara withdrew their efforts to start a PACE program, using other ARRA funds they received directly from DOE to pursue instead a loan loss reserve risk enhancement to encourage the start-up of a low interest, unsecured loan program through local credit unions. The emPowerSBC program coordinated with Energy Upgrade California, providing homeowner outreach and information and participating contractor training. Alameda County chose to cancel their program, returning most of the initial funding.

Program Budgets, Expenditures, and Accomplishments

As shown in Table 7, $97 million was originally awarded to ten subrecipients, and, with modifications, the final CCRR program expenditures totaled $98 million. The total spending from whole-house IOU programs in the same period was $39.9 million.[7]

Table 7 summarizes the original budgets and final expenditures for each subrecipient program. Budgets were modified to ensure maximum use of ARRA funds, including allocation of EECBG discretionary funds. The MIST Program received the largest amount of additional funding to support more and larger loans for more comprehensive upgrades. The Affordable Multifamily Initiative, Home Performance, and Energy Upgrade in California program budgets were reduced due to lower-than-expected levels of participation.

7 Data from the California Public Utilities Commission website, now http://eestats.cpuc.ca.gov, formerly http://eega.cpuc.ca.gov.

Table 7: CCRR Programs – ARRA Budgets and Final Expenditures

ARRA Funding Source	Subrecipient Program	Original CCRR ARRA Budget	Final CCRR ARRA Program Expenditures
SEP	Retrofit Bay Area (ABAG)	$10,750,000	$10,817,219
	Affordable Multifamily Retrofit Initiative (SFMOH)	$2,993,029	$647,267
	Moderate Income Sustainable Technology Program (CHF)*	$16,500,000	$26,819,274
	Home Performance Program (SMUD)	$19,969,421	$17,969,421
	Energy Upgrade California (LGC)	$33,176,912	$26,230,591**
	Energy Independence Program (Sonoma)***	Part of LGC	Part of LGC
EECBG	Energy Upgrade California in San Diego (San Diego)	$3,000,000	$2,848,771
	Regional Comprehensive Residential Retrofit (Fresno)	$1,899,899	$2,398,797 (includes $500,000 from SEP)
	Retrofit LA (Los Angeles)****	$8,000,000	$8,932,227
	Municipal Finance Program (Santa Barbara, Alameda)	$1,257,031	$539,466
Total CCRR		$97,546,292	$97,704,493

* CHF final program expenditures include nearly $12 million in CHF loans and incentives provided to participants to support "shared projects" implemented in conjunction with the ABAG and SMUD programs.
** An additional $4.8 million in ARRA SEP funding was allocated to LGC for financing programs that would provide ongoing lending after the termination of these CCRR programs. These ongoing funds are not included in this total.
*** Sonoma was part of the LGC with a budget of more than $2 million.
**** The Energy Commission allocated an additional $11 million in ARRA SEP funding to Los Angeles for financing programs that would provide ongoing lending after the termination of these CCRR programs. These ongoing funds are not included in this total.
Source: California Energy Commission

Table 8 shows the single-family program accomplishments, including the number of completed energy assessments and upgrade projects, as well as the number of trained contractors, for each CCRR subrecipient program. Data for the subrecipient programs for which the evaluators conducted site visit evaluations are shown at the top of these tables with a subtotal for those programs. Evaluators did not conduct site visits for Energy Upgrade California (LGC) or Energy Independence Program (Sonoma County), and the expected impacts from these two programs are listed after the subtotal in the table. The amount after the subtotal also includes Shared Projects that received funding from both ABAG and CHF, both SMUD and CHF, or both ABAG and Sonoma County. The table also includes the expected impacts of non-whole-house upgrade programs conducted by SMUD and Sonoma County. In addition, the table includes expected impacts from solar PV system installations, where applicable.

The CCRR subrecipient programs targeting single-family homes, including Energy Upgrade California (LGC) and Energy Independence Program (Sonoma County), completed more than 8,100 upgrade projects, expected to achieve energy savings of more than 18.2 GWh and more than 1.4 million therms, and almost 3.2 GWh of PV electrical generation. This is the combination of savings for single family, whole-house programs, adjusted by evaluators as a result of the site visits conducted through this evaluation, plus the subrecipient estimated savings (ex ante without evaluator adjustment) for single family, single measure programs.

Table 8: Single-Family Energy Assessment and Upgrade Accomplishments (whole-house plus single measure upgrades)

ARRA Funding Source	Subrecipient Program	Number of Trained Contractors	Number of Single-Family Energy Assessments	Number of Single-Family Upgrades	Estimated Annual Ex Ante Electricity Savings (kWh)	Estimated Annual Ex Ante Natural Gas Savings (therms)	Estimated Annual Ex Ante Electricity Generation (kWh)
SEP	Retrofit Bay Area (ABAG)	780	2,300	919	1,114,638	358,262	NA
	Affordable Multifamily Initiative (SFMOH)	NA	NA	NA	NA	NA	NA
	Moderate Income Sustainable Technology Program (CHF)	100	1,043	564	2,417,072	126,649	829,449
	Home Performance (SMUD)*	200	5,513	2,836	6,820,022	300,851	NA
EECBG	Municipal Financing Program(Santa Barbara, Alameda)	NA	NA	NA	NA	NA	NA

ARRA Funding Source	Subrecipient Program	Number of Trained Contractors	Number of Single-Family	Number of Single-Family	Estimated Annual Ex Ante Electricity	Estimated Annual Ex Ante Natural	Estimated Annual Ex Ante Electricity
	Energy Upgrade California in San Diego (San Diego)	34	313	19	31,069	2,757	49,201
	Regional Comprehensive Residential Retrofit (Fresno)**	100	300	22	121,200	4,690	NA
	Retrofit LA (Los Angeles)	240	1,961	1,961	4,094,671	258,644	34,130
Subtotal		1,454	11,430	6,321	14,598,672	1,051,853	912,780
Energy Upgrade California (LGC), Energy Independence Program (Sonoma), and Shared Projects***		NA	439	1,794	3,702,903	389,347	2,249,631
Municipal Finance Program		NA	NA	NA	NA	NA	13,574
Total		1,454	11,869	8,115	18,301,575	1,441,200	3,175,985

* Included in the total for SMUD are low-income weatherization (single-family, single measure) upgrades completed at 2,000 single-family homes in SMUD's service territory. A total of 2,445 energy efficiency measures were installed, with expected impacts equal to 3,389,326 kWh and 41,600 therms per year in energy savings. The savings for these upgrades were estimated by the subrecipient (ex ante, unadjusted by evaluators), and were not included in the site visit portion of this evaluation but are included in this table of single-family accomplishments.
** Impacts for the Fresno Regional Comprehensive Residential Retrofit Program are shown here under the EECBG. However, Energy Commission ARRA funding for this program was split between the EECBG (83 percent) and the SEP (17 percent) funding sources.
*** Includes Shared Projects that were served by more than one ARRA subrecipient, plus projects that were served only by the Energy Upgrade California services administered by LCG and projects that were served by Sonoma. In addition to the 74 whole-house, single-family Energy Upgrade California upgrades completed by Sonoma, an additional 287 single-measure, energy efficiency upgrades were completed by Sonoma, resulting in energy savings of 70,307 kWh and 9,587 therms per year. The savings for these 287 upgrades were estimated by the subrecipient (ex ante, unadjusted by evaluators), and were not included in the site visit portion of this evaluation.
NA = not applicable
Source: California Energy Commission

The Energy Upgrade California collaboration emphasized homeowners taking advantage of all rebates and financing that were available from all CCRR programs and the IOUs. The geographic areas of several subrecipient programs overlapped, which enabled the programs to supplement the funding and support available to projects beyond what would have been possible through one program alone. The statewide LGC program supported all Energy Upgrade California efforts statewide. CHF provided financing to many projects that also received ABAG or SMUD rebates, and ABAG provided rebates to some of the Sonoma projects.

The CCRR programs with multifamily components completed more than 15,000 multifamily unit energy assessments, and about 5,700 multifamily units were upgraded. Some subrecipient programs required assessments prior to upgrades and for these subprograms the number of assessments and upgrades are the same. The multifamily program elements were not evaluated but reported a total savings of more than 8.5 gigawatt-hours and about 311,000 therms, shown in Table 9.

Table 9: Multifamily Ex Ante* Assessment and Upgrade Accomplishments

ARRA Funding Source	Subrecipient Program	Number of Multifamily Assessments	Number of Multifamily Retrofits	Estimated Annual Gross Ex Ante Electricity Savings (kWh)	Estimated Annual Gross Ex Ante Natural Gas Savings (therms)
SEP	Retrofit Bay Area (ABAG)	1,057	1,057	938,635	96,387
	Affordable Multifamily Initiative (SFMOH)	529	529	100,892	49,353
	Moderate Income Sustainable Technology Program (CHF)	0	0	0	0
	Home Performance (SMUD)	11,289	2,513	4,976,151	106,047
EECBG	Energy Upgrade California in San Diego (San Diego)	1,462	884	578,235	35,315
	Regional Comprehensive Residential Retrofit (Fresno)	0	0	0	0
	Retrofit LA (Los Angeles)	720	720	1,910,420	23,897
Total		15,057	5,703	8,504,333	310,999

* subrecipient estimated savings unadjusted by evaluators
Source: California Energy Commission

Table 10 summarizes project-level information for the CCRR program, including total program costs, loan amounts, and incentives (including those from ARRA and leveraged sources). The table also shows average funding amount per project, as well as the proportion of project costs that were covered by loans and incentives. As shown, the average project cost about $9,600, and ARRA loans and incentives covered about 24 percent of those costs. Another 33 percent of the total project costs were covered by other leveraged loans and incentives.

Table 10: Summary of CCRR Program Upgrade Project Costs, Loans, and Incentives

ARRA Funding Source	Program		Number of Upgrade Projects	Project Costs ($ million)	Energy Commission ARRA Loans ($ million)	Other Leveraged Loans ($ million)	Energy Commission ARRA Incentives ($ million)	Other Leveraged Incentives ($ million)	Average Project Cost	Energy Commission ARRA Loans & Incentives		Other Leveraged Loans & Incentives	
										Average Per Project	Percent of Average Project Costs	Average Per Project	Percent of Average Project Costs
SEP	Retrofit Bay Area (ABAG)		919 SF homes	$11.66	$0.00	$0.00	$3.12	$2.79	$12,691	$3,400	27%	$3,032	24%
			1,057 MF units	$0.88	$0.00	$0.00	$0.00	$0.31	$835	$0	0%	$294	35%
	Affordable Multifamily Initiative (SFMOH)		529 MF units	$2.19	$0.20	$0.20	$0.00	$1.68	$4,131	$381	9%	$3,561	86%
	Moderate Income Sustainable Technology Program (CHF)		564 SF homes, 121 PV installations	$13.83	$12.77	$0.00	$1.08	$2.74	$24,527	$24,546	100%*	$4,853	20%**
	Home Performance (SMUD)		836 SF homes	$9.01	$0.00	$0.00	$3.12	$1.12	$10,779	$3,735	35%	$1,341	12%
			2,513 MF units	$22.11	$0.00	$0.00	$0.00	$6.54	$8,797***	$0	0%	$2,603	30%
			2,000 low income, SF homes	$4.98	$0.00	$0.00	$0.00	$4.98	$2,488	$0	0%	$2,488	100%****
	Energy Upgrade California (LGC), SCEIP, & Shared Projects	ABAG + CHF	87 SF homes, 11 PV installations	$2.13	$1.97	$0.00	$0.17	$0.42	$24,527	$24,546	100%*	$4,853	20%**
		ABAG +SCEIP	23 SF homes	$0.32	$0.00	$0.16	$0.07	$0.06	$13,735	$3,205	23%	$9,903	72%
		LGC (Only)	924 SF homes	$9.37	$0.00	$0.00	$0.00	$2.04	$10,143	$0	0%	$2,210	22%
		SCEIP - PV	184 PV installations	$6.84	$0.00	$0.00	$0.00	$2.51	$37,150	$0	0%	$13,648	37%
		SCEIP Whole-House	74 SF homes	$1.54	$0.00	$1.48	$0.00	$0.08	$20,867	$0	0%	$21,009	101%*****
		SCEIP Other EE	287 SF homes	$2.02	$0.00	$2.00	$0.00	$0.03	$7,030	$0	0%	$7,061	100%*****
		SMUD + CHF	399 SF homes, 44 PV installations	$9.79	$9.03	$0.00	$0.76	$1.94	$24,527	$24,546	100%*	$4,853	20%**

ARRA Funding Source	Program	Number of Upgrade Projects	Project Costs ($ million)	Energy Commission ARRA Loans ($ million)	Other Leveraged Loans ($ million)	Energy Commission ARRA Incentives ($ million)	Other Leveraged Incentives ($ million)	Average Project Cost	Energy Commission ARRA Loans & Incentives		Other Leveraged Loans & Incentives	
									Average Per Project	Percent of Average Project Costs	Average Per Project	Percent of Average Project Costs
EECBG	Energy Upgrade California in San Diego (San Diego)	19 SF homes	$0.14	$0.08	$0.00	$0.02	$0.03	$7,124	$5,014	70%	$1,405	20%
		7 PV installations	$0.16	$0.00	$0.00	$0.00	$0.10	$22,396	$0	0%	$14,259	64%
		884 MF units	$3.85	$0.00	$0.00	$0.00	$0.88	$4,350	$0	0%	$991	23%
	Regional Comprehensive Residential Retrofit (Fresno)	22 SF homes	$0.30	$0.00	$0.00	$0.00	$0.03	$13,468	$0	0%	$1,540	11%******
	Retrofit LA (Los Angeles)	1,961 SF homes	$18.04	$0.00	$3.53	$0.00	$6.33	$9,199	$0	0%	$5,027	55%
		3 PV installations	$0.14	$0.00	$0.00	$0.00	$0.06	$46,600	$0	0%	$20,616	44%
		720 MF units	$15.18	$0.00	$0.00	$0.00	$2.11	$21,082***	$0	0%	$2,928	14%******
Total CCRR Program		8,115 SF homes, 5,703 MF units and 370 PV installations	$134.46	$24.05	$7.37	$8.34	$36.77	$9,596	$2,312	24%	$3,150	33%

* 100 percent financing
** rebates from other sources
*** may include some non-energy project costs
**** direct install
***** 100 percent leveraged financing
****** limited leveraged rebates
Source: California Energy Commission and DNV KEMA

CHAPTER 3:
Evaluation Approach

The overall goal of the evaluation was to assess the impact of the CCRR subrecipient pilot programs, including the estimated energy savings realized from program activities. Following the finalization of an evaluation plan in January 2012, the site visits for the evaluation were completed from January 2012 through December 2012.[8]

To verify the subrecipient program estimated energy savings for whole-house upgrades to single-family homes, evaluators completed the following steps:

1. Selected a random sample of the homes that participated in a subset of the ARRA-funded CCRR subrecipient programs with targeted sampling in proportion to the number of energy assessments and upgrade projects completed by each program.
2. Conducted site visits after the completion of upgrade projects for a sample of homes that participated in subrecipient programs to independently determine pre-existing building characteristics and those pre-existing energy efficiency measures that remained unchanged by the project, as well as upgrade measure installations.
3. Collected the historical energy usage data for the sampled homes for a period of one to three years prior to the assessment and upgrade projects.
4. Collected the building simulation files that were prepared by the participating contractor (or HERS rater) at the time of the energy assessment, which included the preproject building characteristics (including pre-existing energy efficiency measures), project energy efficiency measure upgrades to be made, and estimated preproject energy use and estimated energy savings for the upgrades.
5. In some cases, asked homeowners questions about the installed measures and conditions of the home before the upgrade to better understand the building simulation file inputs that were made by the participating contractor (or HERS rater).
6. Revised the building simulations for the preproject condition to reflect evaluator-observed building characteristics and pre-existing energy efficiency measures that remained unchanged by the project, and for the postproject condition to reflect evaluator-observed building characteristics and postproject energy efficiency upgrades.
7. Based on the revised building simulations, revised the estimated preproject energy use and estimated energy savings for the installed upgrade measures, and compared the estimated energy savings of the revised models to the estimated energy savings of the contractor's models to determine a "verification factor" multiplier.

8 The scope of the evaluation was an impact study. It did not include process evaluation surveys or interviews related to market transformation assessment or attribution analysis.

8. Compared the historical energy usage to the estimated preproject energy consumption from the evaluator's revised building simulations (from step 7) to determine a "usage factor" multiplier.
9. Multiplied the estimated energy savings from the contractor's building simulations by the "verification factor" and the "usage factor" to determine the evaluator's estimated energy savings based on site visits and preproject historical energy usage.

Sample Design

The evaluators designed the sampling approach to meet the goal of developing reliable energy savings estimates across the CCRR programs while meeting statistical precision levels for estimated annual energy savings. The general goals were to achieve 10 percent relative precision at a 90 percent confidence interval. The measurement and verification (M&V) sampling was designed as a proportion of the number of upgrades completed through the contributions of those subrecipient programs for which site visits were conducted.

Evaluators selected the M&V site visit samples randomly. The sampling included targets proportional to the number of energy upgrades and assessments (including HERS ratings) by county for the CCRR programs with large geographic service areas, to more accurately represent program activity.

Table 11 shows the planned sample sizes for each subrecipient program for which whole-house, single-family site visits were conducted during two rounds of data collection. Round 1 was completed in February 2012, and Round 2 was completed in December 2012. The evaluation sampled only ABAG, SMUD, and CHF programs in Round 1. Round 2 evaluation included sample sites from ABAG, SMUD, San Diego, Fresno, and Los Angeles programs.

Table 11: Planned Sample Sizes by CCRR Subrecipient Program

ARRA Funding Source	Subrecipient Program	Round 1 Sample	Round 2 Sample
SEP	Retrofit Bay Area (ABAG)	35	10
	Moderate Income Sustainable Technology Program (CHF)	35	0
	Home Performance (SMUD)	30	10
EECBG	Energy Upgrade California in San Diego (San Diego)	0	20
	Regional Comprehensive Residential Retrofit (Fresno)	0	30
	Retrofit LA (Los Angeles)	0	30
Totals		100	100

Source: DNV KEMA

Table 12 shows the final sample size and heating and cooling system types for the sample of site visits completed. As shown, the final sample size for Retrofit Bay Area was one fewer than planned, and for CHF and Fresno, the evaluators completed one more than planned, for a total of 201 site visits completed. However, as noted in Table 12, one MIST site had no cooling system and used a hot water-based heating system, and was excluded from further evaluation.

Compared to the total number of participating homes, there were far fewer homes with cooling systems in the programs operating in the San Francisco Bay Area and San Diego areas of the state. The programs based in the Central Valley and Southern California predominantly had cooling systems.

Table 12: Completed Sample Sizes by Heating and Cooling Type and CCRR Subrecipient Program

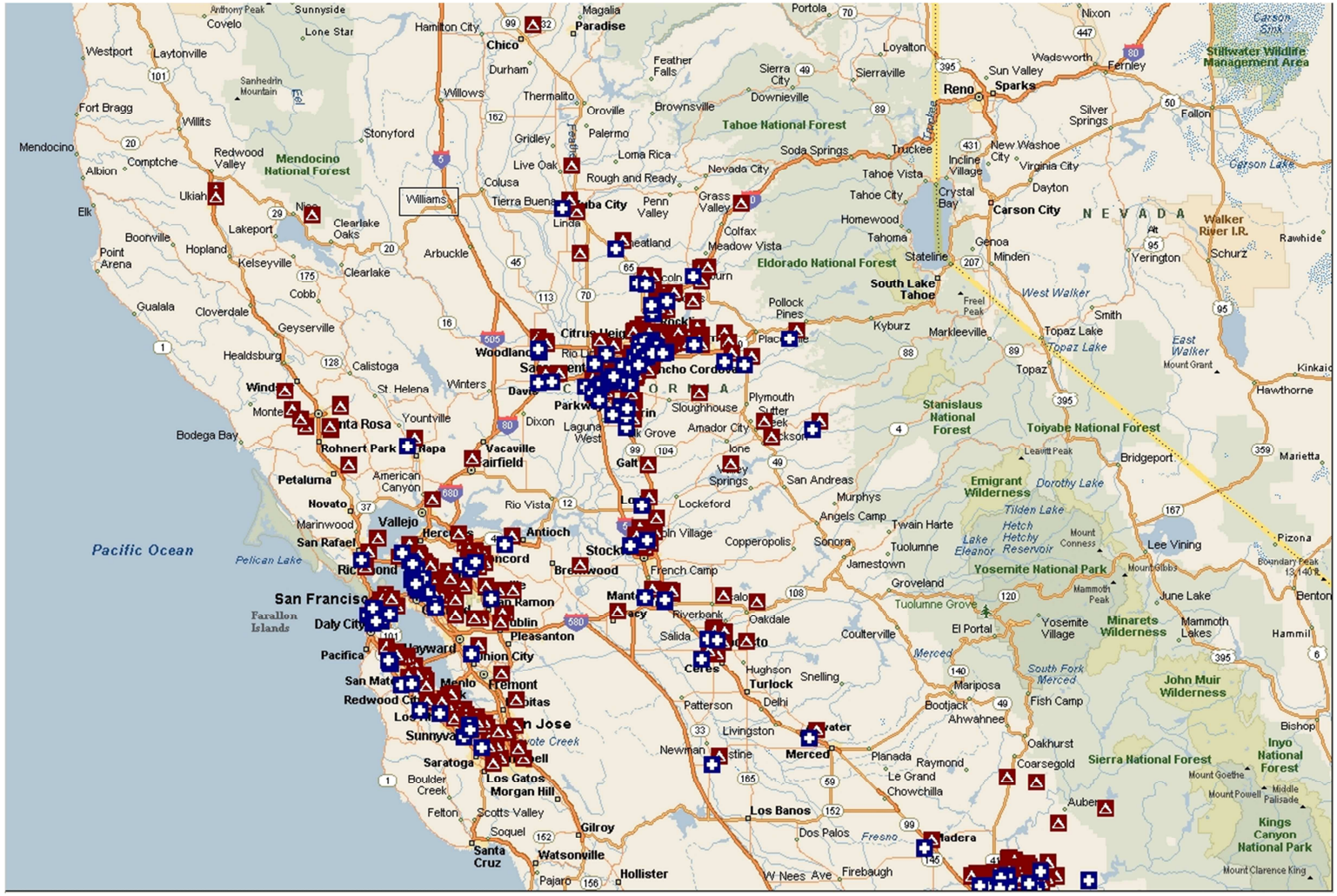
ARRA Funding Source	Subrecipient Program	Number of Homes With Gas Heat – With Air Conditioning	Number of Homes With Gas Heat – Without Air Conditioning	Number of Homes With Heat Pumps
SEP	Retrofit Bay Area (ABAG)	9	35	0
	Moderate Income Sustainable Technology Program (CHF)	32	0	3
	Home Performance (SMUD)	31	1	8
EECBG	Energy Upgrade California in San Diego (San Diego)	9	10	1
	Regional Comprehensive Residential Retrofit (Fresno)	29	1	1
	Retrofit LA (Los Angeles)	22	7	1
	Totals	132	54	14

* A total of 36 site visits were completed for CHF; however, one site had no cooling system and used a hot water-based heating system; this site was excluded from further evaluation.
Source: DNV KEMA

Figure 2, Figure 3, and Figure 4 are regional maps showing the location of sites in the CCRR subrecipient program populations and the completed sampled sites. Sampled sites are represented by blue with plus (+) symbols. The red triangles represent other locations that participated in the Energy Upgrade California program but were not recruited for site visits.

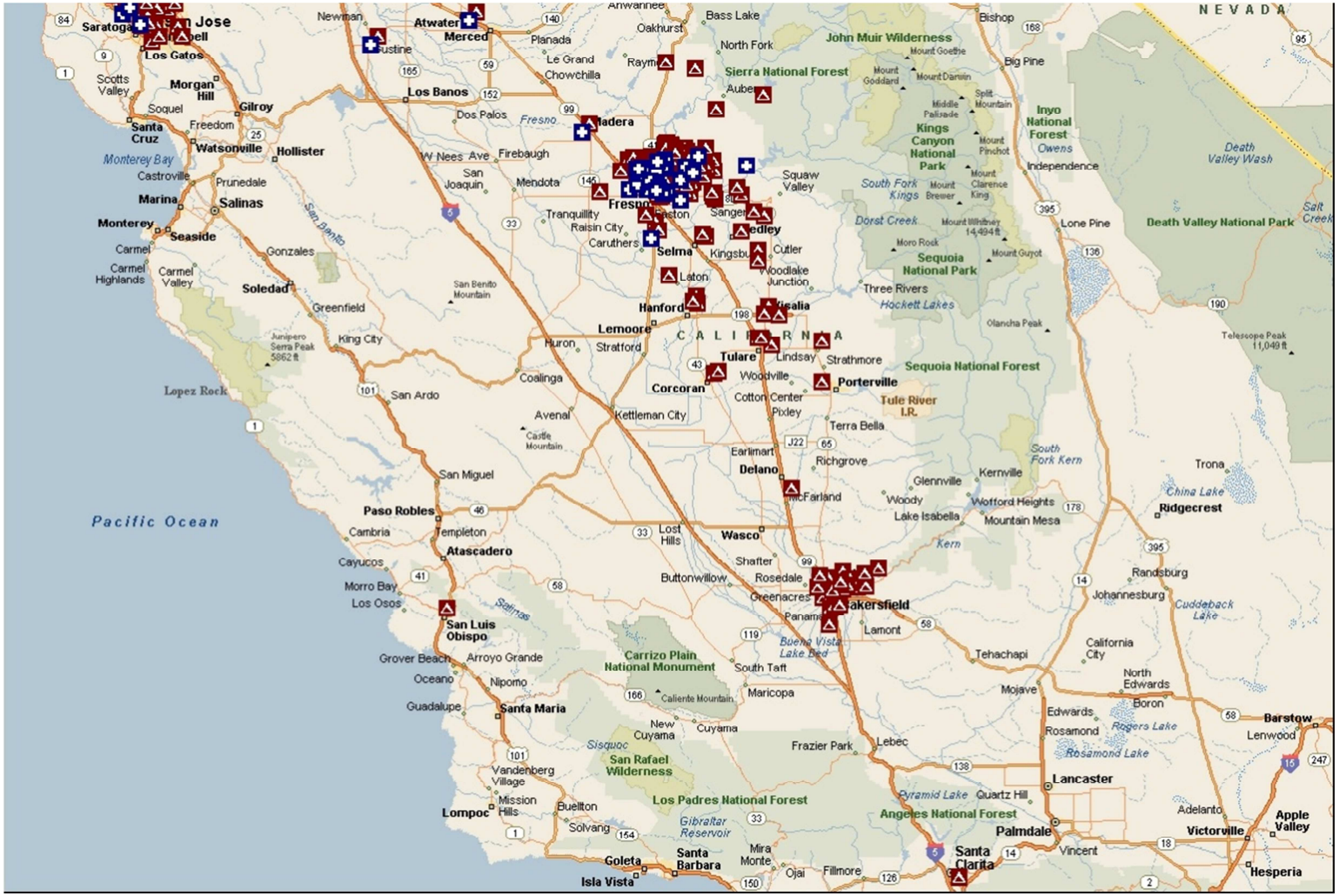
The overall recruitment faced the challenge that homeowners already had completed an extensive upgrade project, and evaluators were requesting two to three hours of time to collect data and test performance. The CPUC agreed to provide monetary incentives of $100 to homeowners in exchange for the data collected on-site, which assisted the recruitment in achieving a completion rate of roughly 25 percent. The 75 percent not recruited includes sites that refused, were unreachable after multiple attempts, missing phone numbers, and cancellations that could not be rescheduled.

Figure 2: Map of CCRR Subrecipient Program Participants and Sample Sites – Northern California



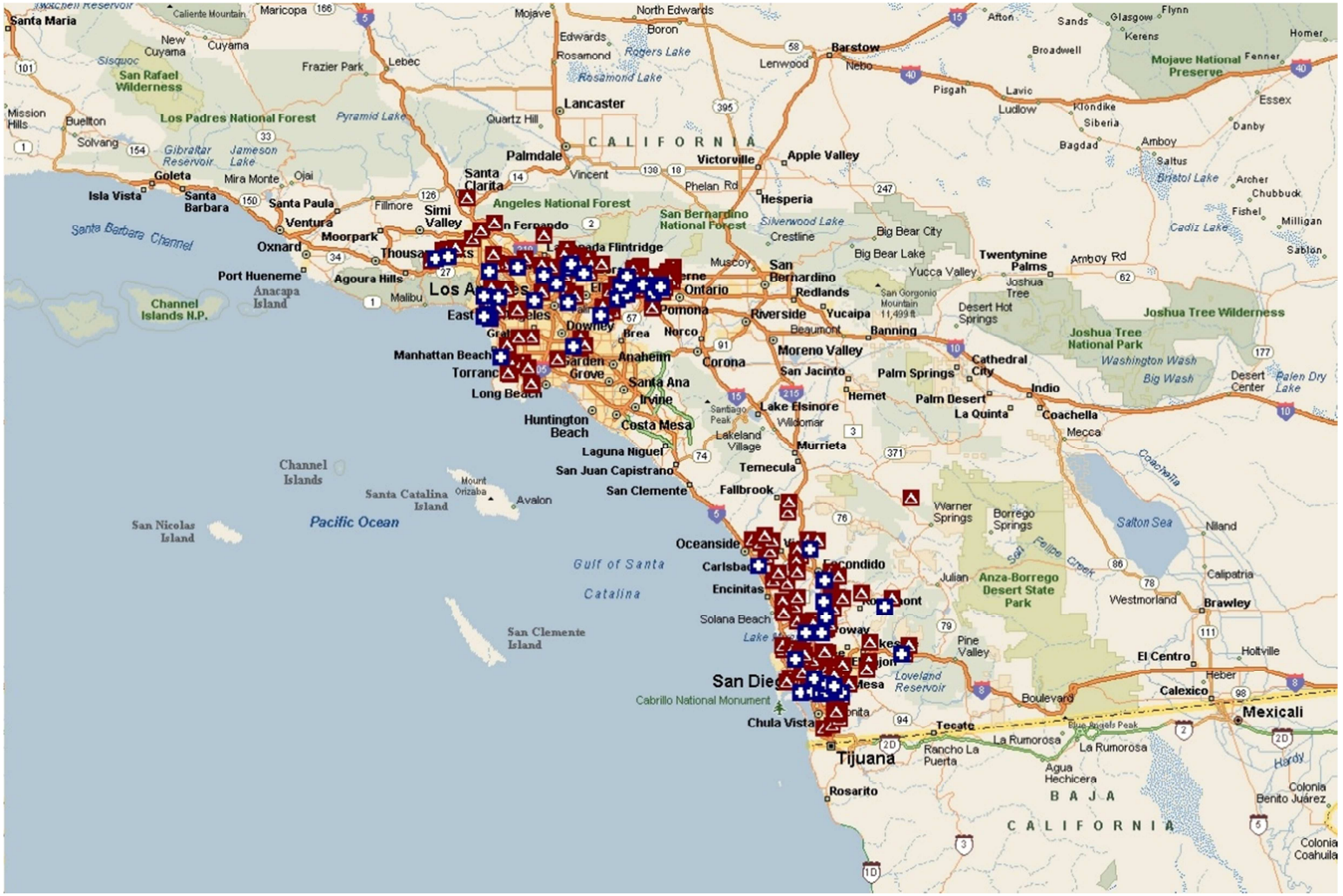
Source: DNV KEMA

Figure 3: Map of CCRR Subrecipient Program Participants and Sample Sites – Central California



Source: DNV KEMA

Figure 4: Map of CCRR Subrecipient Program Participants and Sample Sites – Southern California



Source: DNV KEMA

Data Collection Approach

Data collection was done in the following steps: site scheduling, site-specific M&V activities, and historical energy usage data collection and review.

- **Site scheduling:** For each sampled project, a telephone recruiter contacted the participant to initiate the site visit planning process, confirm project details, and schedule the site visit.
- **Site-specific M&V:** On-site data collection teams observed building characteristics and postproject energy efficiency measures, and performed testing, including blower door measurements of home air leakage, duct blaster measurements of duct leakage, and measurements of window properties. In some cases homeowners were asked to clarify uncertainties or discrepancies about the installed measures and conditions of the home before the upgrade project. For example, if attic insulation was a measure, but no new insulation was observed, then homeowners were asked if they recalled insulation work and if they paid for new attic insulation
- **Data set collection and review:** The evaluators constructed a data set for all sampled sites, including the historical electricity and natural gas usage from one to three years prior to the upgrade project, through the time of evaluation, and contractor building energy simulation data. Once the historical energy usage data set was assembled, it was examined for consistency, and anomalies were removed, including incongruous usage information, homeowner turnover, or insufficient usage information (for example, less than three months of summer and winter data for a particular period).

After the site visits were completed, the evaluators determined that sufficient or adequate building simulation data were not available to complete analysis for roughly one-fifth (1/5) of the sites (32 sites out of 201, see appendix for details). Most of the problem occurred because IOUs did not provide subrecipients access to project data and were able to provide only addresses for the sampled homes. The problems occurred primarily with the EECBG-funded sites that were visited during the second phase of the project, for which the analysis was completed after the ARRA program had terminated for the subrecipient programs being evaluated. Given that the ARRA program had terminated and the evaluators were time-constrained to complete their work, these problems with missing data were not able to be rectified.

Where possible, the evaluators recreated models from other documentation. In addition, the evaluators found that there were issues with the usage data for some sites due to periods when the home was unoccupied, where PV systems were installed masking the impact on historical energy usage resulting from the project measures, or other anomalies or gaps that made the usage data inadequate for analysis for that site. As a result of inadequate historical energy usage data, analysis was not completed for another 30 sites, leaving 139 sites out of 201 for which data was adequate for analysis. Note that 14 of the 139 sites were energy assessment only sites for the

Regional Comprehensive Residential Retrofit Program (Fresno). These sites were not part of the verification rate analysis but did have sufficient data, as well as historical usage and complete models to develop a usage factor. The usage factor was applied to the total ex ante savings for the program.

Site-Specific Analyses to Determine Estimated Energy Savings

The site-specific analyses to determine the evaluator-estimated energy savings for the CCRR programs included the following steps:

- **Participating contractor-prepared building simulations:** The evaluators collected the building simulation files,[9] completed by the participating contractor (or HERS rater) at the time of the energy assessment for each home in the site visit samples. The building simulation files included the contractor-observed and tested building characteristics (including pre-existing energy efficiency measures), project energy efficiency measure upgrades to be made, and estimated preproject energy consumption and estimated energy savings for the upgrades.
- **Evaluator-adjusted building simulations:** The evaluators adjusted the building simulation files to match the observations and testing that they completed during the postproject site visits for the sampled homes.
- **Verification factor determinations:** The evaluators determined "verification factors" for the total estimated energy consumption for each visited home. The total estimated energy consumption used the site converted British thermal units (Btus) calculation adopted by the IOU whole-house programs (1 kWh = 3,413 Btus) and 1 therm = 100,000 Btus. These conversions make no consideration of electricity system generation efficiency, transmission, and distribution losses; natural gas delivery losses; or time or season of energy use . The evaluators divided the estimated energy consumption from the evaluator-adjusted building simulation model by the estimated energy consumption from the contractor building simulation model to determine the verification factor for each home and the average verification factor for each CCRR program.[10]
- **Historical energy usage data weather normalization:** The evaluators needed to remove the impact of weather differences between the building simulation estimated energy consumption and the actual weather for the period of the historical usage. The

9 EnergyPro 5.1 based building simulation software was used by contractors and HERS raters in all Energy Upgrade California energy assessments, whether conducted to qualify for IOU program rebates or for CCRR subrecipient funding.

10 The evaluators applied the same verification factor to both the evaluator's adjusted electricity and natural gas consumption estimates as evaluator-observed differences in building characteristics and upgraded measures affect electricity and natural gas energy consumption simultaneously.

evaluators weather-normalized the historical usage data for each house by: 1) determining a linear regression equation for the historical energy usage in the period of analysis as a function of the monthly average outside temperature during that period, and 2) using that equation to calculate the adjustment of the historical usage that would have happened if the weather used in the building simulation had occurred.

- **Usage factor determinations:** The evaluators determined "usage factors" for each house by dividing the historical energy usage by the evaluator-adjusted building simulation estimated energy consumption for each sampled home. Usage factors were determined separately for electricity and natural gas. The evaluators determined the average usage factor for each CCRR program.
- **Evaluator's electricity and natural gas energy savings estimates for sampled homes:** The evaluators multiplied the ex ante estimated energy savings for each program by the verification factor (same for electricity and natural gas) and by the usage factor (different for electricity and natural gas) to determine the total evaluator-estimated energy savings for each CCRR program for which homes were site sampled.
- **Evaluator's adjustment of non-sampled estimated energy savings:** The evaluators recognize that all the whole-home upgrade projects completed in total by the Energy Upgrade California collaboration were done similarly using the same building simulation software. Deviations in energy consumption estimates are likely to be very similar across all Energy Upgrade California projects to the sampled homes observed by the evaluators, and to the comparisons to historical energy usage for those sampled homes. To establish an estimate of the energy savings for the nonsampled CCRR programs, the gross energy savings estimates for these programs were multiplied by the average verification factor and usage factor determined for the sampled CCRR programs.
- **Total CCRR evaluator-estimated energy savings:** The total evaluator-estimated energy savings for all the CCRR programs is the sum of the evaluator-estimated energy savings for the sampled and nonsampled CCRR programs.

The evaluation was conducted in the same time frame as CCRR program implementation, and it wasn't feasible to delay the data gathering, analysis and report writing aspects of the evaluation to obtain and analyze a full year of post upgrade project billing data. So while this report contains analyses using usage data for preproject periods, it does not include an evaluation of postproject estimated energy consumption compared to postproject actual energy usage.

Life-Cycle Estimated Energy Savings

There was no consistent measure level tracking of installed component measures, such as insulation, duct sealing, and new equipment, included in whole-house upgrade projects that

could be used to develop an average EUL for the energy savings for the program population. When determining the life-cycle estimated energy savings for programs, the evaluators assumed that the measure-specific EUL values fell within a range of 15 and 25 years and used an estimate of a program-level average of 20 years.[11] The evaluators multiplied the annual estimated energy savings for both electricity and natural gas by this average EUL to determine the life-cycle estimated energy savings.

Estimated GHG Emissions Reductions

The evaluation team calculated the total estimated GHG reductions that resulted from the CCRR programs. The team used a calculation method that follows guidelines and emissions conversion factors approved by the Energy Commission. It applied emissions conversion factors to evaluator-determined estimated energy savings, based on energy source, to calculate the carbon dioxide (CO_2) emissions reduction mass in pounds, which was then converted to metric tons. The team used the following factors:

- Electricity conversion factor: 690 pounds (lbs) CO_2/ megawatt-hour (MWh)
- Natural gas conversion factor: 11.69 lbs CO_2/therm
- Weight conversion: 2,204.6 lbs/metric ton

11 The CCRR upgrade projects were a mix of building envelope measures, duct sealing, and new furnaces and air conditioners, with a Database for Energy Efficient Resources (DEER) effective useful life (EUL) of 20 years, 18 years, and 15 years, respectively. DEER caps all measure EULs at 20 years (per the CPUC policy manual), even though some measures, such as windows and insulation, have longer lives as cited in the underlying studies referenced by DEER.

CHAPTER 4:
Evaluation Issues

The evaluation discovered and endeavored to address four key issues while evaluating the estimated energy savings realized from program activities. The following issues were documented and are discussed in this chapter:

- Inability to Discern Extent of Contractor Error in Determining Preproject Conditions
- Inability to Establish Valid Bill Disaggregation Results to Compare Building Simulation End-Use Estimates to End-Use Estimates Derived From Historical Energy Usage Data
- Probability That the Electricity Energy Usage of the Homes Participating in the Energy Upgrade California Program Is Lower Than Comparable California Homes
- Lack of Consistent Data Collection, Sharing Among Collaborating Programs, and Maintenance for Evaluation, Measurement, and Verification (EM&V) and Program Improvement Purposes

Inability to Discern Extent of Contractor Error in Determining Pre-project Conditions

The evaluators made verification site visits after the upgrade projects were completed. At this point, the evaluators made observations and test measurements to determine the building characteristics of each home and the existence of energy efficiency measures. At this postproject point in time, the ability of evaluators to determine the preproject conditions of energy efficiency measures was substantially limited.

At the site visits, the evaluators endeavored to verify the observations and measurements made by participating contractors in completing energy assessments and postproject "test-out" inspections. The evaluators used the results of this verification to revise the pre- and postproject inputs used in the contractor's building simulation modeling. When the preproject building characteristics and energy efficiency measure levels were unchanged by the project, the evaluators were able to complete that verification and confidently include those findings in determining the verification factor. However, when the preproject building characteristics and energy efficiency levels were changed by the project, the evaluators were able only to verify the postproject condition; the project upgrades changed the preproject conditions. In the analysis reported in Chapter 5, the evaluators had to accept the contractor's representations of the preproject conditions when calculating the evaluator's verification factors.

One of the major administrative difficulties for the Energy Upgrade California program was the extensive effort that was needed to help participating contractors accurately represent pre- and postproject conditions in the building simulation modeling and to provide an effective, but affordable, level of quality control (QC). Achieving accurate representation of site conditions in this modeling was critical because the validity of program incentive payment claims depended

on properly capturing building characteristics and energy efficiency measure levels, pre- and postproject. All Energy Upgrade California programs completed "desk audits" of building simulation input files, seeking to find erroneous simulation inputs, and frequently contractors were required to change preproject input assumptions that appeared to be QC reviews of preproject conditions reported by contractors.

Given that the evaluators for this report were unable to observe/test the preconditions of building characteristics/measures that were changed by the upgrade project and to accurately determine actual verification factors, the evaluators looked to other data that might provide information about the extent of errors in preproject simulations.

To investigate this issue further, the evaluation team and the Energy Commission examined SCE's preproject QC data[12] to identify possible areas where contractors made the type of errors that would lead to overestimating preproject energy use. One conclusion of this investigation was that the SCE preproject QC review frequently found substantial differences in the level of energy efficiency measures compared to those reported by the contractors. These differences ranged widely from substantial underestimation of preproject measures to substantial overestimation. In many cases the substantial overestimation and underestimation resulted in energy estimate impacts that on average were quite limited.

This was not the case for some of the measures, in particular for preproject duct leakage, which can greatly affect the estimated energy consumption of the building simulation model. The SCE QC data indicated that 19 percent of the sites had contractor-reported duct leakage rates more than 50 percent higher than SCE's QC data. The estimated preproject energy usage for those 19 sites would be substantially higher as a result of this discrepancy.

SCE found a need to continue its preproject QC efforts throughout the duration of the Energy Upgrade California program, even though other IOU programs did not conduct on-site preproject QC as extensively. Although SCE's QC data illuminate some preproject data showing cases of substantially high preproject contractor estimates for duct leakage, SCE's preproject QC program did appear to reduce substantial error in contractor preproject simulations to the relatively low on average levels that have been reported.

This success is noteworthy, indicating that the relatively low on average levels found in SCE's preproject QC program likely were not achieved in preproject contractor simulations by other programs, and significantly greater levels of error in contractor preproject building simulation inputs were likely the norm in the Energy Upgrade California projects of other programs that did not conduct extensive on-site preproject QC. Many of the CCRR-sampled homes were not covered by extensive on-site preproject QC.

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12 Budner, Jonathan. Southern California Edison. EUC Project Comparison Graphs and Data, April 24, 2013.

If the CCRR site evaluation had been able to observe/test preproject building characteristics/efficiency measures, evaluators likely would have found substantially lower verification factors. If lower verification factors had been found by evaluators, usage factors would have been correspondingly higher.

Inability to Establish Valid Bill Disaggregation Results to Compare End-Use Estimates Derived From Historical Energy Usage Data to Building Simulation End-Use Estimates

The evaluators established annual energy usage factors by fuel source, electricity and natural gas, by comparing the evaluator verified building simulation energy consumption estimates to historical energy usage. The evaluators considered developing energy usage factors by major end use (heating and cooling energy) but were unable to achieve valid results.

The evaluation team used the weather-normalization method and criteria consistent with the principles of Building Performance Institute (BPI) Standard 2400.[13] The BPI Standard defines criteria for the acceptability of utility billing data for comparison to building simulation data and calibration. The BPI Standard establishes two alternative approaches for comparing historical energy use to building simulations energy consumption estimates. The Detailed Calibration Approach, consistent with American Society of Heating, Refrigerating, and Air Conditioning Engineers (ASHRAE) Guideline 14-2002, calls for a regression of the historical energy usage as a function of outside temperature or heating degree days (HDDs) and cooling degree days (CDDs), determining an estimate of the baseload portion of the usage data and a portion for heating that varies dependably with HDDs and a portion for cooling that varies dependably with CDDs. The BPI Standard 2400 establishes acceptance criteria for this regression analysis to determine if the Detailed Calibration Approach can be used (Coefficient of Variation of the Root Mean Square Error [CVRMSE] of the regression results ≤ 0.20). For homes with historical energy usage data that fail to meet the acceptance criteria, BPI Standard 2400 directs that the comparison of building simulation estimated energy consumption be to total annual energy usage by fuel source, as disaggregation into baseload, heating, and cooling energy would not be valid for comparison.

The historical energy usage data for a very high percentage of the CCRR sampled homes failed to meet BPI Standard 2400 acceptance criteria for both heating and cooling. This appears to be largely due to the high variability of energy usage among the sampled homes, and the low correlation of energy usage with how hot or cold it is outside. The expectation for the regression analysis is that for a portion of the historical energy usage, there will be a direct (positive) relationship between CDDs and electricity usage (assuming that as CDDs increase, electricity

13 Building Performance Institute, Inc. BPI-2400-S-2011 Standardized Qualification of Whole-House Energy Savings Estimates. Consensus Document, November 30, 2011-Version 2.

will increase) and between HDDs and natural gas usage (assuming that as HDDs increase, natural gas usage will increase). The BPI 2400 CVRMSE criteria is not satisfied only if there is a positive relationship, but also requires the relationship to be significant, and not just incidental. For electricity the historical usage of the sampled homes often showed an indirect (negative) relationship with CDDs – when it gets hotter outside the electricity usage went down (this happened frequently in milder climates like the bay area, but also occurred in areas of the state, like Sacramento, that have hot summers). This did not happen as much for natural gas, but even though the relationship was positive it was so poorly correlated that the BPI Standard 2400 criteria was not met. The historical energy usage of the sampled homes failed to meet the BPI 2400 significant, positive relationship criteria 75 percent of the time for electricity and 91 percent of the time for natural gas. When the BPI 2400 criteria is not met, the Standard concludes that the usage data is not reliable and valid for disaggregating the data from the energy bills by end use (cooling and heating), and so efforts to calibrate building simulation estimates to actual energy usage should be done at the energy source level – total annual electricity and natural gas. The evaluation team detailed the analysis results in Appendix D and E.

The evaluation team also considered an alternative approach of assuming that the historical energy usage for the average of the lowest two months per year represented baseload energy use, the historical electrical energy usage above that level represented cooling energy use, and the historical natural gas use above that level represented heating energy usage. However, it has long been recognized in EM&V literature (for example, 1986 *Energy and Buildings: Special Issue Devoted to Measuring Energy Savings: The Scorekeeping Approach*[14]) that the total normalized annual consumption is much more reliably determined than attempting to separate that consumption into end-use components. This problematic nature of simple attempts to disaggregate end-use consumption is exacerbated in mild climates, where cooling use is low and historical energy usage is sometimes erratic. The analysis that was completed on the historical energy usage data of the sampled homes bore out these conclusions of prior researchers.

DNV KEMA found, consistent with BPI Standard 2400, that the historical energy usage data for the sampled homes did not support the use of that data for a comparison at the end-use level to the building simulation estimated energy consumption. DNV KEMA concluded the data would only validly support comparison of the building simulation estimated consumption to the total historical annual energy usage by fuel type (electricity and natural gas).

14 Fels, M.F., ed., *Energy and Buildings: Special Issue Devoted to Measuring Energy Savings: The Scorekeeping Approach*, February/May 1986, (9:1&2).

Probability That the Electricity Energy Usage of the Homes Participating in the Energy Upgrade California Program Is Lower Than Comparable California Homes

The evaluation team compared the preproject electricity usage data of the CCRR sampled homes to the *2009 California Residential Appliance Saturation Study* (RASS)[15] data, which provides estimates of total energy consumption data for all California homes. The RASS study has a sample size of more than 20,000 homes to allow for subsets of the data to be analyzed based on dwelling and demographic characteristics, such as climate zone, presence of air conditioning, home vintage, home size, and a range of demographic variables. To facilitate a comparison between homes that participated in the CCRR subrecipient programs and the RASS study results, the evaluation used filters on the RASS website to establish datasets of nonparticipant homes located in the climate zones where the CCRR program operated, and datasets that had similar home characteristics, including presence of central air conditioning, home vintage, and home size.

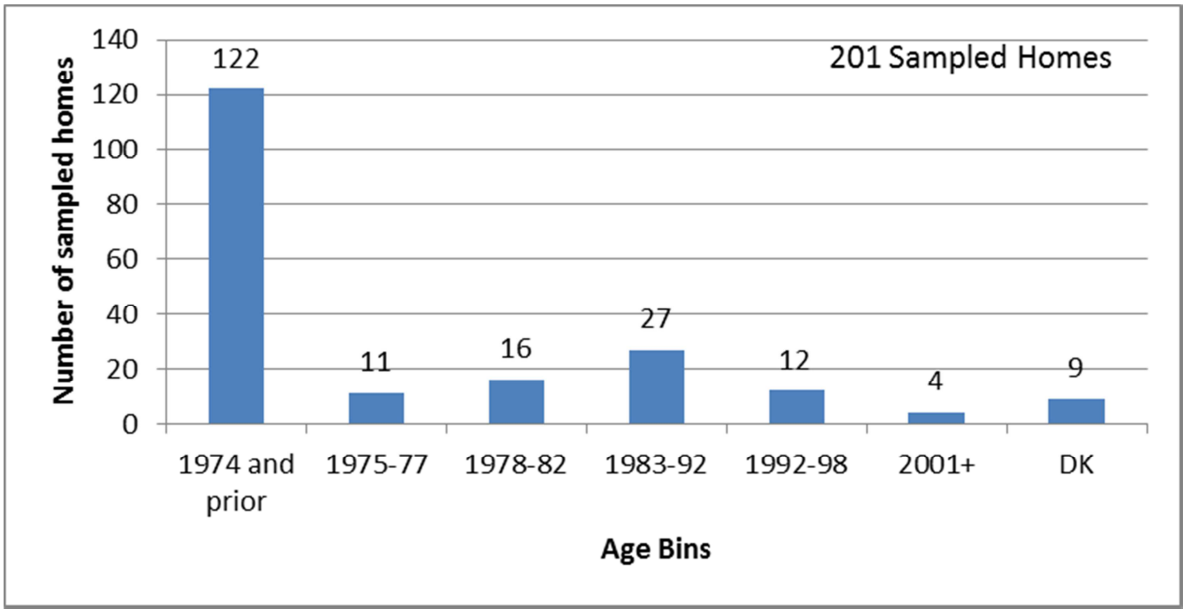
Characteristics of the CCRR Sample

The evaluators first assessed the CCRR sample characteristics for home age and home size, as shown in Figure 5 and Figure 6. These characteristics were then used to appropriately filter the RASS sample such that comparisons between CCRR sample homes and RASS sample homes were as similar as possible, with respect to these two characteristics.

As shown in Figure 5, the majority of the 201 CCRR sample homes were built prior to 1974, with the vast majority built prior to 1992. The average construction year for the 122 homes in the "1974 and prior" vintage bin was 1949, with the oldest reported year of construction being 1900. The average construction year for all homes with reported construction was 1962. At least 85 percent of the sampled homes were older than 1992. The category DK represents a response of "don't know."

15 KEMA, Inc. 2010. *2009 California Residential Appliance Saturation Study.* California Energy Commission. Publication number: CEC-200-2010-004-ES.

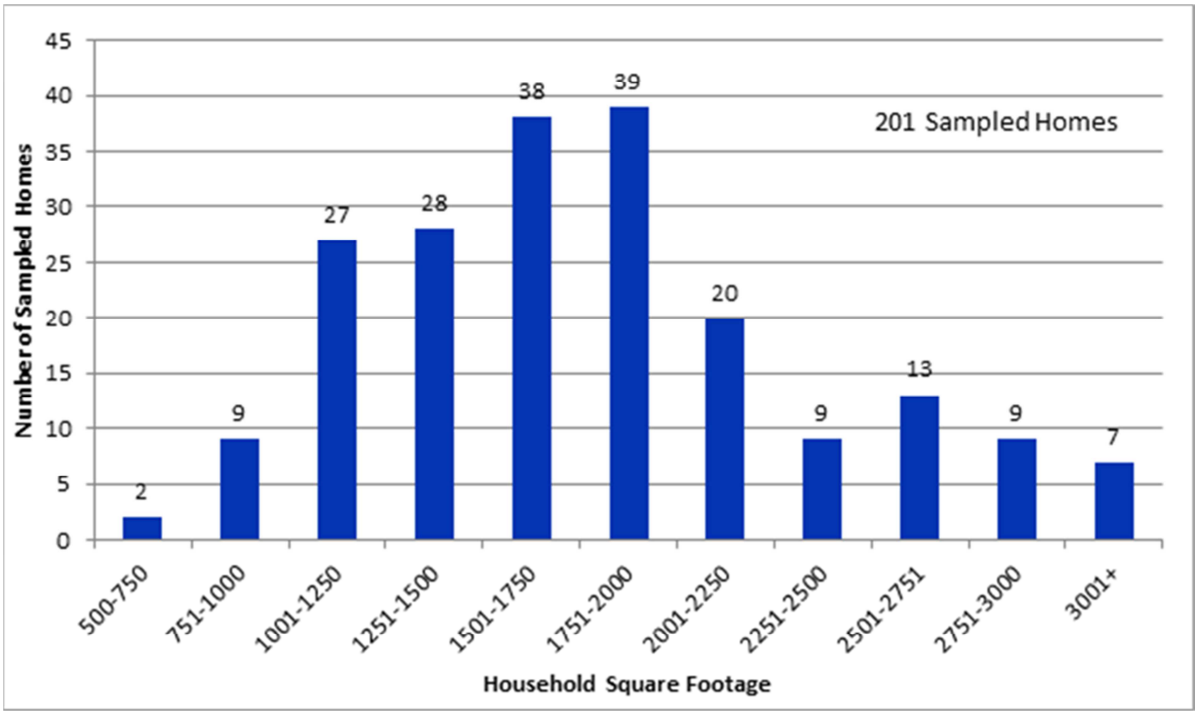
Figure 5: Age of Sampled Homes



Source: DNV KEMA

Figure 6 shows the distribution of home sizes for the CCRR sample homes. A more even distribution was observed for home sizes as compared to home vintage. The CCRR sample home sizes ranged from 525 square feet to 7,221 square feet of conditioned floor area, with the average square footage across all sampled homes being 1,810 square feet. More than 80 percent of the sampled homes were larger than 1,250 square feet.

Figure 6: Square Footage of Sampled Homes



Source: DNV KEMA

Comparison of Average Total Electricity Consumption

Table 13 compares the weather-normalized average total annual historical electricity usage for the CCRR program sample and the RASS dataset of nonparticipant homes with comparable characteristics by climate zone. The table is divided into two sections: the first comparing results for homes with no air conditioning, and the second comparing results for sites with air conditioning.

Table 13: Climate Zone Comparisons of CCRR Homes and RASS Total Electricity Usage For Homes With and Without Air Conditioning

Note: Comparisons between the cells with sufficiently large CCRR sample sizes are shown with a light blue background. The cells with white backgrounds have sample sizes that are too small for the comparisons to be significant.

Title-24 Climate Zone	CCRR Sample With No AC**	RASS 2009 Total Electricity Usage With No AC (kWh/yr)	CCRR Total Electricity Usage With No AC(kWh/yr)	CCRR Building Simulation Estimated Total Electricity Consumption - With No AC(kWh/yr)	CCRR Sample With AC	RASS 2009 Total Electricity Usage With AC(kWh/yr)	CCRR Total Electricity Usage With AC(kWh/yr)	CCRR Building Simulation Estimated Total Electricity Consumption With AC (kWh/yr)
3	25	6,266	5,541	6,743	0	7,120		
4	3	6,433	7,534	17,840	3	9,229	7,343	8,397
7	9	6,282	5,488	5,667	3	7,627	5,890	6,988
9	1	7,269	7,490	13,488	13	9,392	7,836	10,633
10	0	6,218			6	8,522	8,650	10,239
11	0	6,487			11	13,053	8,937	14,265
12	1	6,518	2,513	5,882	36	9,458	8,882	12,251
13	1	7,603	3,874	8,506	18	10,078	8,940	17,181

* The CCRR sample of homes "With No AC" and "With AC" total 124 sites. Only sites that had both acceptable and sufficient usage data and building simulations for estimated energy consumption are included in the table. Sampled sites with heat pumps were excluded from this analysis.
** = air-conditioning
Source: RASS 2009 website queries run by Energy Commission and DNV KEMA

The comparisons may not be statistically conclusive since the number of CCRR sample sizes is significantly fewer than the RASS sample sizes. A specific calculation of statistical significance of the differences was not possible because the extrapolated populations are reported in RASS, not the sample sizes. However, where the CCRR sample sizes are the largest, these data indicate that CCRR program participants used less electricity than the average California home with comparable characteristics, which may be a contributing factor to lower usage factors.

The building simulation total estimated electricity consumption is higher than the RASS for homes with air conditioning in all climate zones where there are an adequate number of CCRR sampled homes for comparison. In these cases, the CCRR building simulation energy estimates are substantially closer to the RASS average usage than to the average usage from the energy bills of the CCRR sampled homes. One possibility may be that participants in the Energy Upgrade California program may tend to be attracted to the program because they already have an interest in/motivation to be energy conserving in their practices, and the program supports their investment in making physical improvements to their homes. This tendency toward lower electrical energy usage behavior may be related to the finding that the historical energy usage data for the sampled homes were not sufficiently correlated to weather to enable valid bill disaggregation to heating and cooling end uses. These hypotheses could not be tested with the data collected during the site visit or with available secondary data.

Lack of Consistent Program Data Collection, Sharing Among Collaborating Programs, and Maintenance for EM&V Purposes

At the outset of the Energy Upgrade California collaboration, ARRA subrecipients agreed to not collect detailed project information for projects that were participating in IOU whole-house programs, to avoid redundancy and customer burden. This agreement was made on the condition that the IOUs would share the data with their Energy Upgrade California partners, the ARRA subrecipients. Unfortunately, the IOUs did not actively share project information with subrecipients. Over the term of the ARRA program, some subrecipients, who were able to invest substantial resources to obtain this data from the IOUs and/or to conduct redundant data collection and organization, had greater success in gaining access to project data. This situation led to difficulty by the evaluators in consistently obtaining project data across subrecipients. In the future, more effective data tracking systems need to be developed and implemented.

The DOE actively encouraged partnerships and leveraging of nonfederal funds, which were a foundation to the Energy Commission's programs, particularly the CCRR program. ARRA funds were used for a wide range of market transformation initiatives, including workforce development and participant recruitment, information, and support, in addition to project rebates and financing. Leveraged funding also contributed to the total market transformation effort, as well as to direct project incentives and financing. Evaluating the effects of this combination of efforts was complicated, and making conclusions related to the causality attribution of program effects to separate portions of the collaboration was not feasible. In multi-family buildings in particular, energy upgrade projects are most likely to be completed if

they are combined with non-energy projects at the same time to leverage multiple incentives and minimize tenant disruption. This often led to difficulty in separating out the costs of the non-energy projects, and led to lower cost effectiveness conclusions than actually were the case.

More effective design, evaluation, and improvement of programs call for a comprehensive database to enable sharing of data across all program collaborators, recognizing the need for data security by establishing effective access protections, safe data transfer, and data storage. An effective database would be designed to capture through effective data collection key information needed to evaluate the program. The database should include project details with attention to data that have been properly quality-controlled for both the preproject and postproject conditions. The database should also include funding through rebates and financing that contributed to building owner decisions to make upgrades, both estimated energy consumption and energy savings, and pre- and postproject energy usage data from the utilities. When energy upgrade projects are enabled by leveraging funding from other sources, and by being conducted at the same time as non-energy upgrades, care should be taken to separate out project costs for the non-energy upgrade portion of the projects. IOUs must fully cooperate with this data sharing for the database to be successful.

CHAPTER 5:
Evaluation Findings

This chapter presents the overall findings from the site evaluation of the sampled homes for each CCRR program. The next section discusses observation and testing findings from the site visits, followed by the overall verification factors and precision estimates achieved from the evaluation sample. The final section presents the gross energy savings results for the overall program, including summaries for each CCRR subrecipient. Additional results for the sampled sites are provided in Appendix A and Appendix B. Program totals in this chapter are limited to whole-house, single-family energy upgrade programs and do not include non-whole-house single-family, multifamily, or PV generation impacts that were not covered by the site visit evaluations.

Findings From Site Observations and Testing

The evaluation team visited each sampled home site after the upgrade project was completed to verify the postproject building characteristics and energy efficiency measures, including performance testing of building envelope leakage and duct leakage, using blower doors, and duct blasters, respectively. For homes that received only energy assessments or HERS ratings, where no upgrades were completed during the ARRA period, these visits were conducted to verify the postassessment building characteristics and existing energy efficiency measures. As mentioned in Chapter 4, these site visits were conducted after contractors had completed upgrade projects, so the evaluators were unable to verify the preproject conditions that were changed by upgrades that were completed. The purpose of the building simulations was to assess the estimated energy savings between pre- and postproject conditions. Since the other building characteristics that were being modeled did not change between pre- and postproject, they would be less likely to be incorrect and any error would be likely to have limited impact on the energy savings estimates (which is what this evaluation found). In addition, the postproject conditions were subject to IOU quality assurance inspections, which should have unearthed most errors. On the other hand, most IOU programs conducted limited quality assurance inspections of preproject conditions, and errors of preproject conditions could substantially change the expected energy savings for the project. Not being able to evaluate preproject building characteristic errors, therefore, creates a substantial opportunity for incorrectly estimating the verification factor.

Postproject Site Findings

The site visit evaluations were designed to determine the differences between building characteristics and energy efficiency measure levels reported by the participating contractors and those that the evaluators actually observed and tested after the project was completed. Participating contractors used pre- and postproject observations and testing to establish inputs to building simulation models to estimate pre- and postproject energy consumption and project

energy savings. From the differences in postproject building characteristics and energy efficiency measures observed by the evaluators, the evaluators revised the building simulation models to recalculate pre- and postproject estimated energy consumption and project energy savings to determine verification factors for the sampled homes. As discussed in Chapter 4, the evaluators made their site visits after upgrade projects were completed, so the preproject conditions of any building characteristics or efficiency measures that were changed by the project were not determinable.

The largest differences identified between the evaluator observations and testing of postproject conditions and those used by participating contractors in building simulation inputs tended to occur because:

- **Discrepancies with building envelope characteristics**. In many cases these discrepancies affected both pre- and postproject building simulation models. Consistent errors in both runs do not substantially affect the percentage savings value but do affect the magnitude of estimated pre- and postproject energy consumption. The postproject reported building envelope leakage levels were reported accurately by contractors for the most part. Where differences in postproject levels were found, the impact on savings was minimal.
- **Default or target values for duct leakage parameters.** In a substantial number of the sampled homes, contractors used default or targeted values in the building simulation models as opposed to properly tested values. For example, contractors entering a value of 10 percent as the default leakage value after sealing on some sites caused the largest discrepancies between contractor reported and evaluator measured savings.
- **Default values for HVAC efficiencies.** For HVAC efficiencies, contractors often entered default values and did not find the correct efficiency for existing or new units. DNV KEMA found significant differences when furnace and air conditioning units were researched by model number, both for standard and high-efficiency models.

Table 14 summarizes the primary areas of discrepancies that resulted in significant energy differences in building simulations, which the evaluators found during the site visit evaluation. Many of the model inputs were different from site observations, but for many sites, there were a mixture of errors, such that often there were no single drivers of estimated energy differences.

Table 14: Primary Building Characteristic or Measure Differences Associated With Discrepancies Between Contractor and Evaluator Building Simulation Model Energy Estimates

ARRA Funding Source	Subrecipient Program	Sample of Models Available	Building Envelope Leakage	Duct Leakage	Envelope Character-istics	HVAC Efficiency	Mixture
SEP	Retrofit Bay Area (ABAG)	43	2	2	13	5	21
	Moderate Income Sustainable Technology Program (CHF)	36	1	3	15	3	14
	Home Performance (SMUD)	39	0	2	8	5	24
EECBG	Energy Upgrade California in San Diego (San Diego)	19	1	1	8	1	8
	Regional Comprehensive Residential Retrofit (Fresno)	16	1	0	2	1	12
	Retrofit LA (Los Angeles)	16	2	1	1	2	10
Total		169	7	9	47	17	89

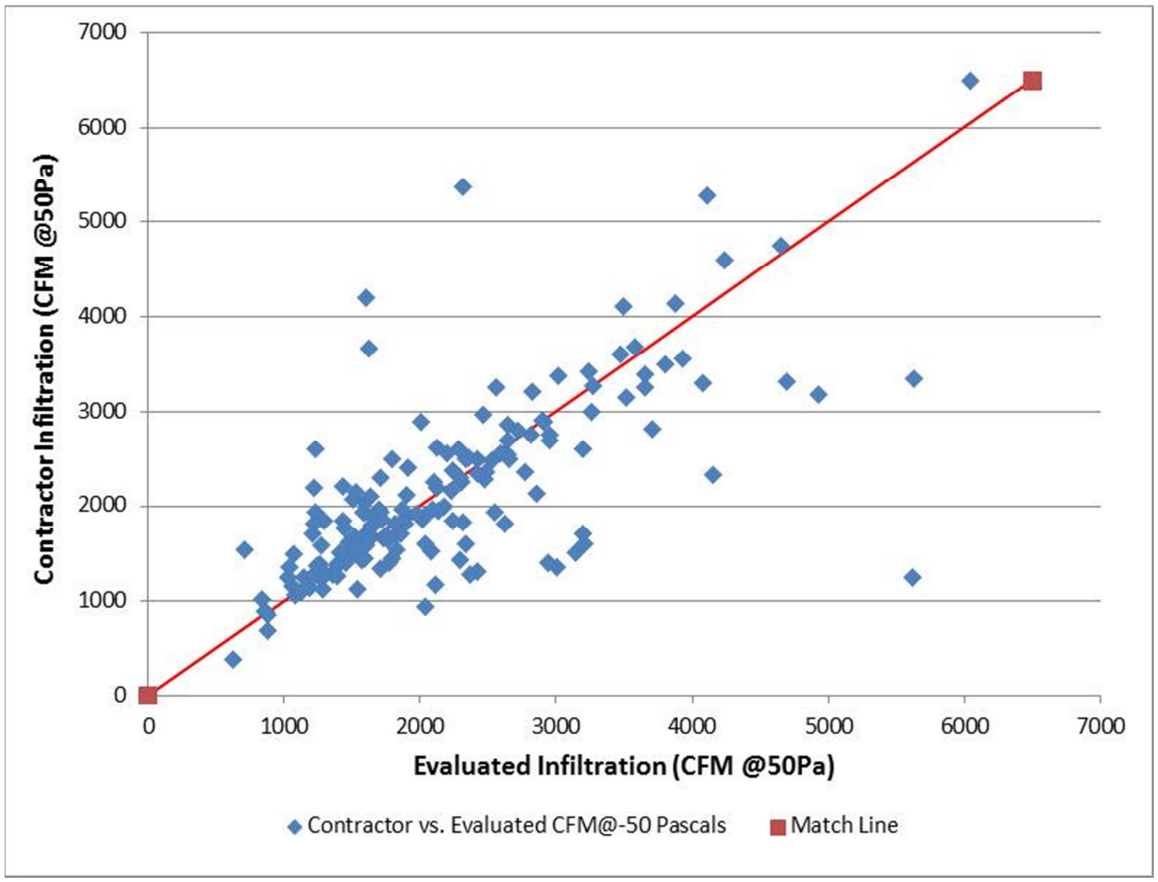
Source: DNV KEMA

The following sections discuss contractor findings related to building envelope leakage and duct leakage testing.

Building Envelope Leakage

Figure 7 graphs the postproject tested building envelope leakage, measured by both the participating contractor and the evaluator, as a single point for each site. Most points fall within a 5 percent range, indicating a majority of postproject tests were performed correctly. Points far above the match line indicate the contractor-reported infiltration was higher than the evaluator test result. Values above the line may indicate improper contractor tests, where a window or door may have been open during the test. Values far below the match line may indicate cases where sealing was not completed to the extent reported by the contractor, or internal doors may have been closed during the test such that the entire home volume was not represented in the test.

Figure 7: Comparison of Building Envelope Test Results



Source: DNV KEMA

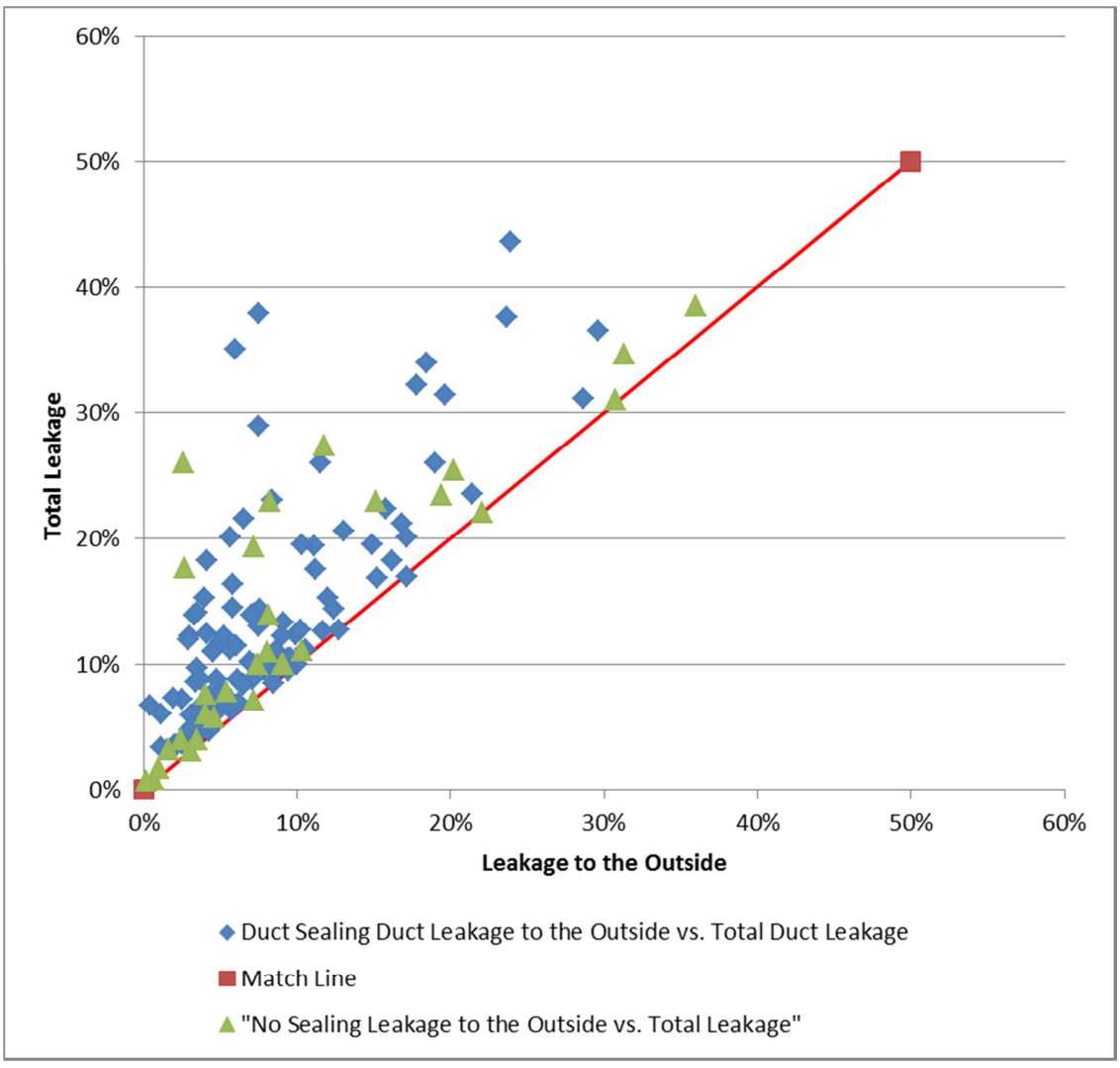
Duct Leakage

The evaluation team completed two duct leakage tests: 1) total duct leakage, and 2) duct leakage to the outside. The difference in the measurements between these two tests is the proportion of total leakage that goes outside the conditioned space. Leakage to outside contributes to wasted energy that clearly can be saved through duct sealing. Duct leakage inside the building envelope likely would have less impact on energy usage because although the conditioned air may be poorly distributed and lead to comfort issues that may increase energy usage, it is generally dumped to the conditioned space where it may contribute to improving general comfort. In October 2011, CalCERTS[16] directed HERS raters to measure only duct leakage to outside as a way to avoid overestimation of energy usage. Measuring duct leakage to outside also is specified by BPI Standards. However, the Energy Upgrade California program commonly allowed either total duct leakage or duct leakage to outside to be reported for program purposes.

16 CalCERTS is the HERS Provider approved by the Energy Commission for oversight of whole-house HERS ratings.

The evaluators were not able to determine whether the participating contractors that performed the duct testing for the sampled homes measured total duct leakage or leakage to outside. Figure 8 shows a comparison of the two tests performed by the evaluators for each sampled site. Results close to the line indicate all or most of the total leakage was to the outside. (Values will not fall below the line.) Values far above the line indicate sites with relatively high total leakage, but a large proportion of the leakage was to conditioned space. The blue diamond indicates sites where duct sealing was claimed for energy savings credit, and the green triangle represents sites where only an initial test was performed, but no duct sealing measures were installed.

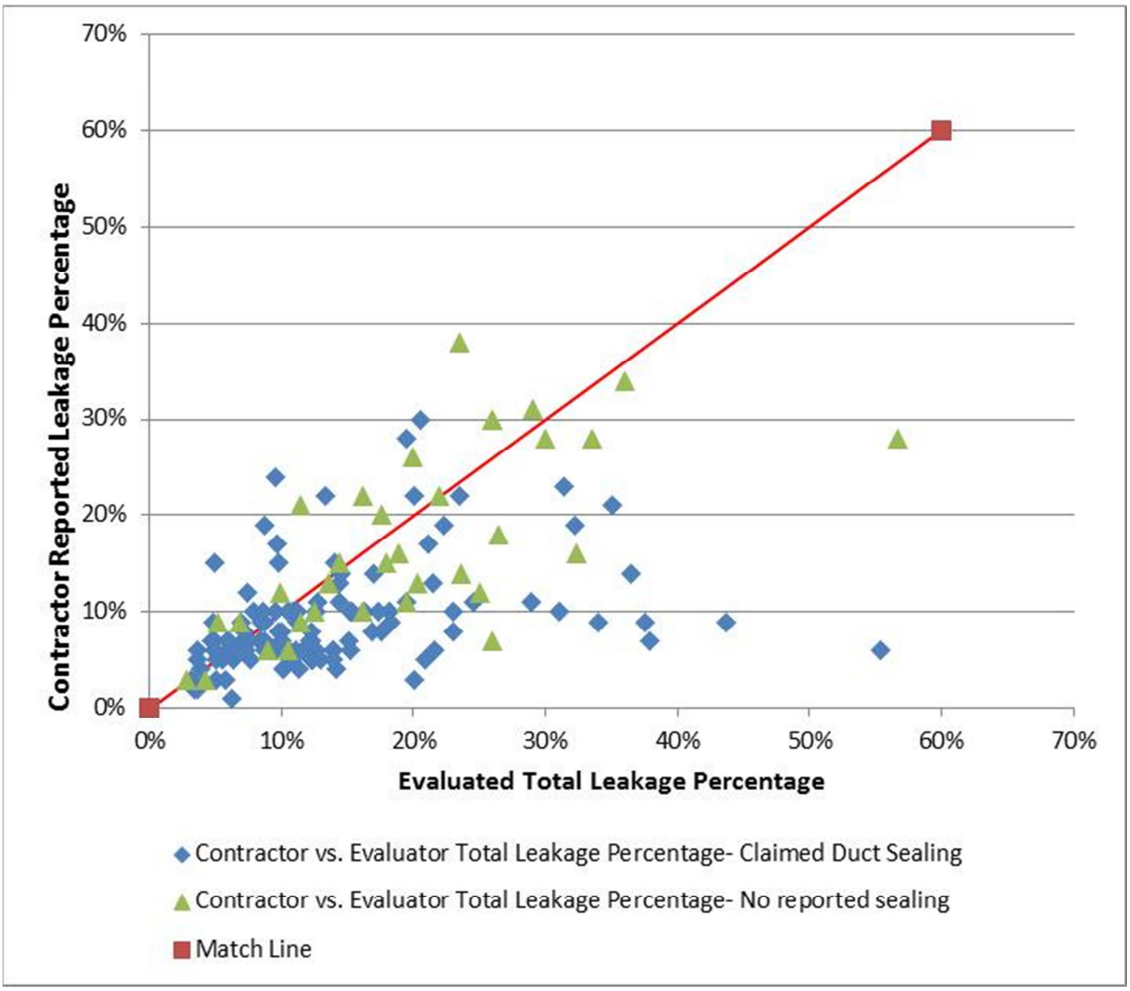
Figure 8: Comparison of Evaluator Total Leakage and Leakage to Outside Test Results



Source: DNV KEMA

Figure 9 graphs the postproject tested duct leakage, measured by both the participating contractor and the evaluators, as a single point for each site. The blue diamond indicates sites where duct sealing was claimed for energy savings credit, and the green triangle represents sites where only an initial test was performed but no duct sealing was claimed for energy savings credit. Both sets of values indicate that there were discrepancies (both higher and lower) between the contractor-reported total duct leakage and the evaluated total duct leakage. In several cases, the contractor-reported leakage was a nominal 10 percent, while the evaluated leakage was often higher. This nominal 10 percent is perceived as a normal leakage to outside level for existing duct systems that have been tested and sealed. Systems rarely have exactly 10 percent leakage after duct sealing, and exact values like this should be flagged by program QC processes in the future. While the overall impact of the discrepancies was minimal on average, close attention should be given to reported values of exactly 10 percent, which may indicate the test was not performed.

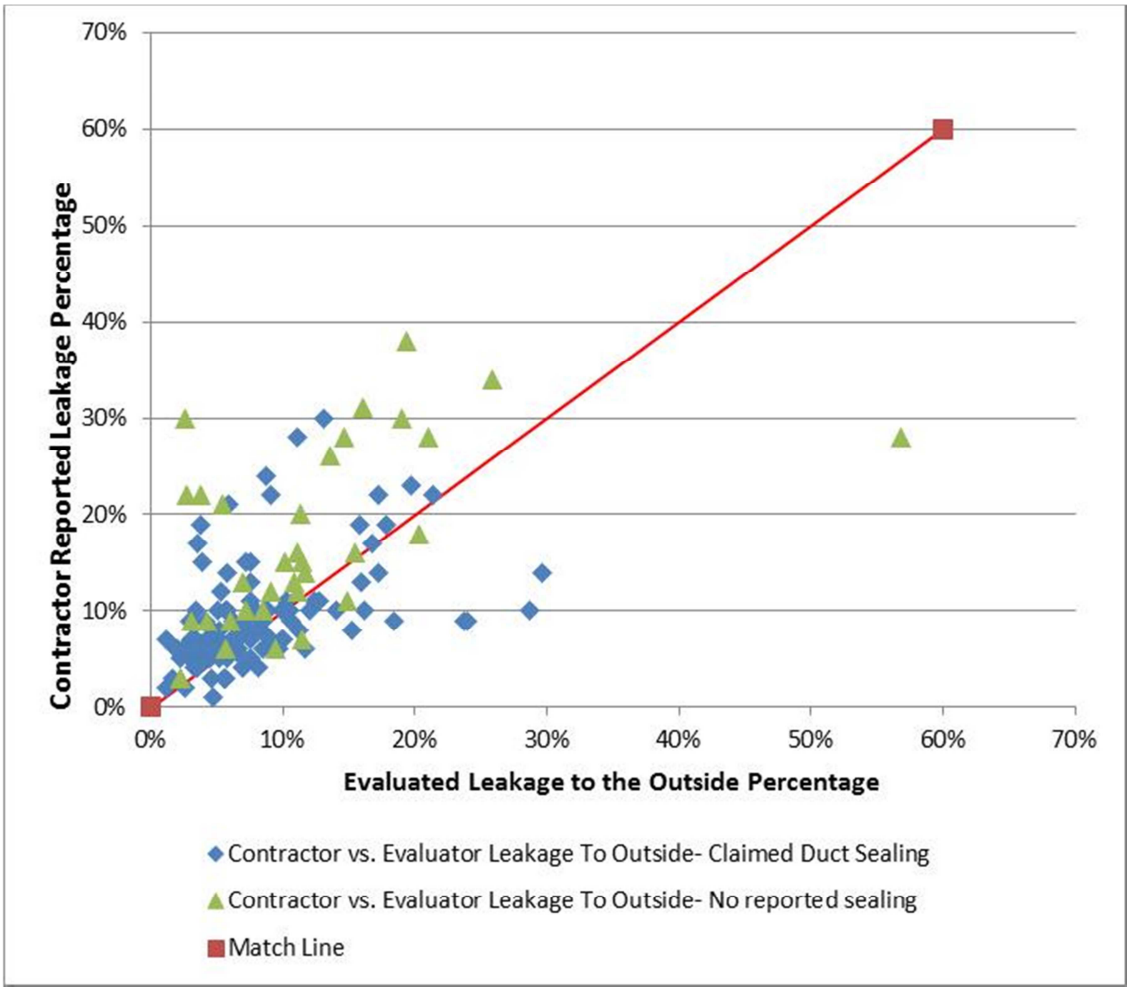
Figure 9: Comparison of Contractor-Reported and Evaluated Total Duct Leakage Results



Source: DNV KEMA

Figure 10 graphs the postproject duct leakage, measured by the participating contractor and the evaluator's leakage to outside values, as a single point for each site. The blue diamond indicates sites that received duct sealing measures, and the green triangle represents sites where only an initial test was performed but no duct sealing was claimed for energy savings credit.

Figure 10: Comparison of Contractor-Reported and Evaluated Leakage to Outside Results



Source: DNV KEMA

Table 15 displays the postproject duct leakage averages reported by contractors in contrast to the evaluator's average measurements for total leakage, as well as leakage to the outside. Sites reporting duct sealing and sites reporting no duct sealing are averaged separately. Based on the findings, the evaluators estimate that, on average, contractors who sealed ducts were using leakage to outside in simulation models more often, and contractors who did only energy assessments were using total leakage more often in the simulation models.

Table 15: Reported Duct Leakage Averages

	Contractor Leakage Average	Evaluator Total Leakage Average	Evaluator Leakage-to-Outside Average
With Duct Seal	9.0%	14.0%	8.0%
No Duct Seal	17.0%	20.0%	12.0%

Source: DNV KEMA

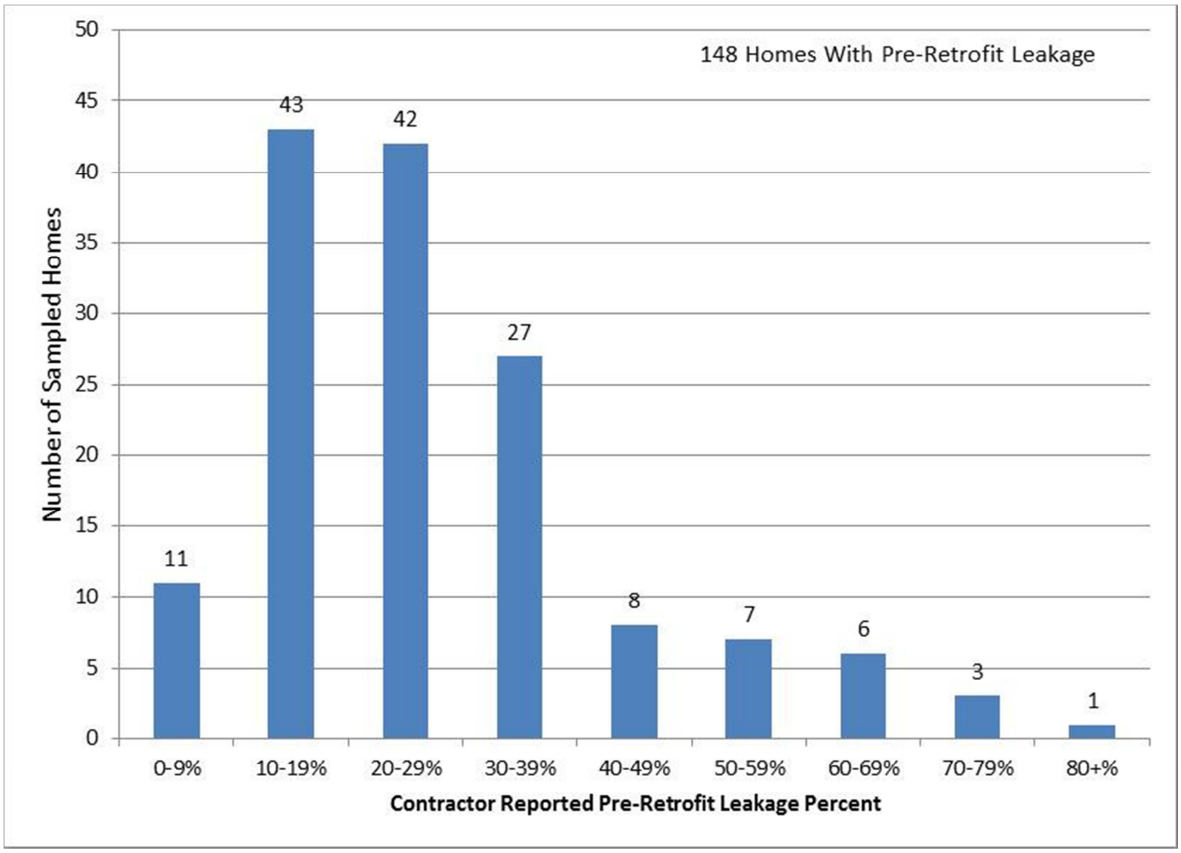
Analysis of Potential for Preproject Building Characteristics and Efficiency Measures Error

Preproject conditions of building characteristics and efficiency measures that were changed by the upgrade projects could not be evaluated in the site visits. Any discrepancies in preproject conditions would likely lower the verification factors and raise the usage factors found in the evaluation. The evaluators endeavored to explore discrepancies in preproject conditions by reviewing the preproject inputs to the sample of contractor models.

Overestimation of the severity of preproject conditions is a recognized cause of excessively high estimates of preproject energy consumption and estimated energy savings. In October 2011, CalCERTS directed HERS raters to limit the severity of building simulation inputs for preproject conditions for several energy efficiency measures unless documentation could be provided showing clear evidence of a more severe condition. This is consistent with guidance provided nationally for energy assessments by BPI Standard 2400 and other BPI Standards, and Residential Energy Services Network (RESNET) guidelines. The CalCERTS guidance directed raters to use extreme caution when modeling preproject homes with duct leakage greater than 40 percent or building envelope leakage greater than 6.0 Specific Leakage Area (SLA).

In Figure 11, evaluators plotted the distribution of contractor-reported preproject duct leakage to show the number of sites with greater than 40 percent leakage, the cutoff level in the CalCERTS guidance. While a majority of sites had preproject duct leakage within the guideline, 17 percent of sites reported preproject duct leakage that exceeded 40 percent.

Figure 11: Distribution of Preproject Duct Leakage in Contractor Models



Source: DNV KEMA

In Table 16, evaluators compare the average overall energy savings for the 148 sites within the preproject leakage bins. The "Duct Leakage Percentage" column defines the distribution of the leakage bins, while the "CCRR Quantity" column identifies the number of sites reporting pre-leakage percentage levels within each bin. The estimated energy savings – from both evaluator postproject inspections and total CCRR and evaluated annual energy savings for the sites in each bin – were summed and then divided by the number of sites in each bin claiming duct sealing for energy savings credit as part of energy upgrades. (Sites that received only energy assessments and for which no upgrades were performed during the ARRA period were not included in this analysis.) The "Evaluator % Difference" is determined by subtracting "Contractor Average Estimated Energy Savings" from the "Evaluator Average Estimated Energy Savings," and then dividing by the "Evaluator Average Estimated Energy Savings." Savings estimate disparities between contractors and the evaluator are substantially higher in the 40+ percent leakage bins.

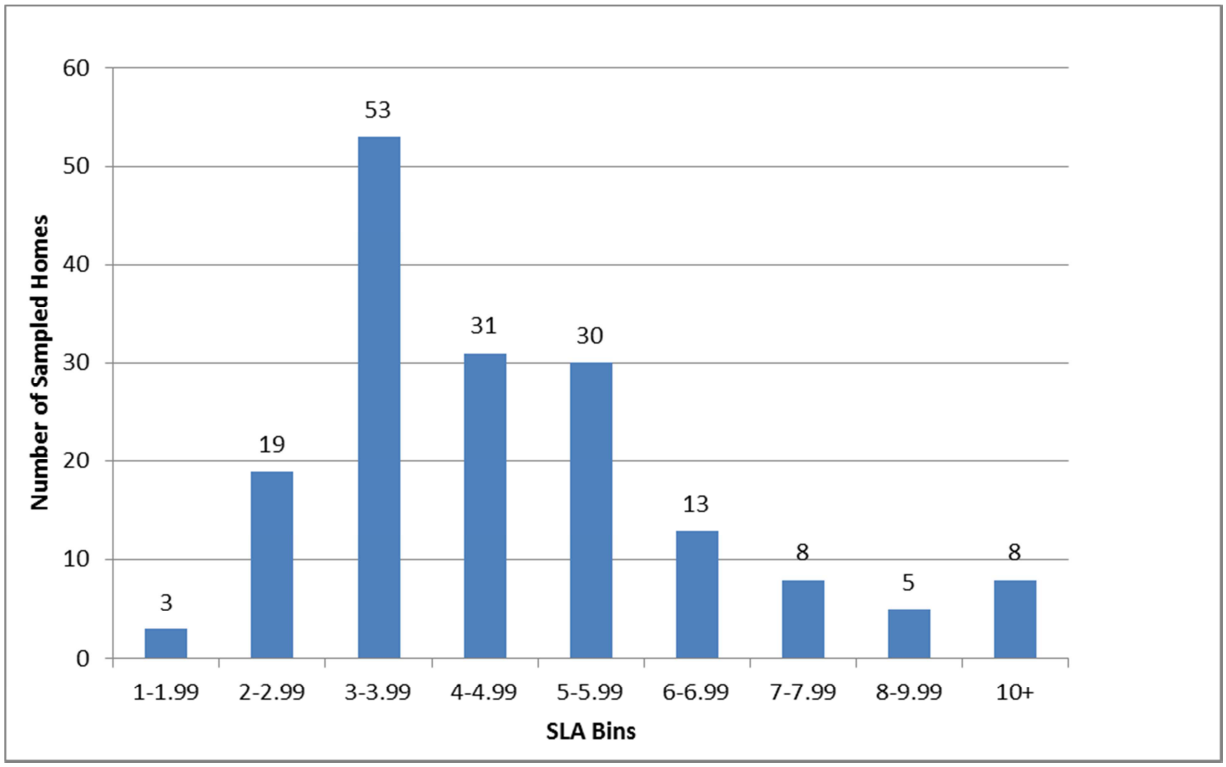
Table 16: Average Estimated Energy Savings Comparison for Sites in Preproject Duct Leakage Bins

Duct Leakage Percentage	CCRR Quantity	Evaluator Average Estimated Energy Savings (kBtu*)	Contractor Average Estimated Energy Savings (kBtu)	Evaluator % Difference
0-9%	11	18,656	18,878	-1.2%
10-19%	43	32,261	33,621	-4.0%
20-29%	42	30,418	33,249	-8.5%
30-39%	27	44,159	46,727	-5.5%
40-49%	8	38,285	45,383	-15.6%
50-59%	7	56,938	61,669	-7.7%
60-69%	6	47,498	57,518	-17.4%
70-79%	3	30,996	40,562	-23.6%
80+%	1	90,668	108,207	-16.2%

* kBtu = kilo British thermal unit
Source: DNV KEMA

In Figure 12, evaluators plotted the distribution of contractor-reported preproject building envelope leakage to show the number of sites with greater than 6.0 SLA, the cutoff level in the CalCERTS guidance. While a majority of sites had preproject leakage within the guideline, 20 percent of sites reported preproject building envelope leakage that exceeded 6.0 SLA.

Figure 12: Distribution of Preproject Building Envelope Leakage in Contractor Models



Source: DNV KEMA

Overall, the investigation of preproject conditions revealed a limited correlation between extreme preproject inputs outside the CalCERTS direction and energy savings discrepancies. Although 17 percent and 20 percent of the sampled homes had inputs in the extreme ranges for duct leakage and building envelope leakage, respectively, other discrepancies at the same sites often drove the verification factor. The high preproject duct leakage sites show a trend where the high preproject duct leakage sites are also some of the largest savings differences due to discrepancies between the evaluator and contractor data.

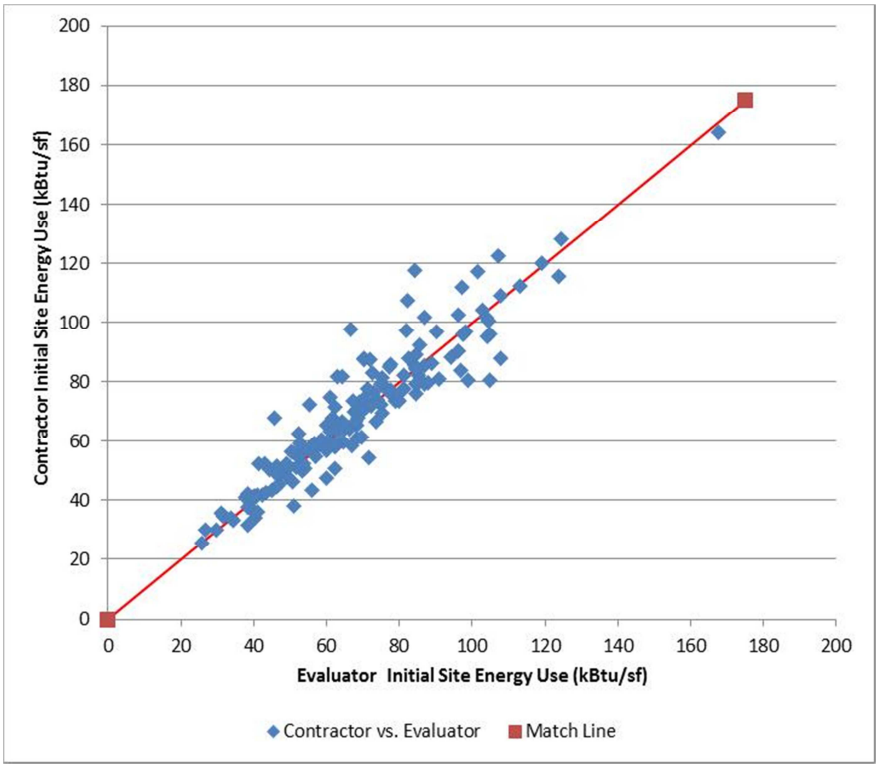
Comparison of Evaluator and Contractor Building Simulation Estimated Savings for Sampled Sites

The evaluators used the data on postproject building characteristics and measure levels collected from all sampled sites to rerun the contractors' building simulation models, and compared to the results from the contractors' models. The comparisons of estimated preproject energy consumption, estimated postproject energy consumption, and estimated energy savings are presented in this section.

Preproject Estimated Energy Consumption

The estimated energy consumption results of the evaluator rerunning of the building simulation models with evaluator-observed building characteristics and measure levels compared to the participating contractor-estimated energy consumption determined the evaluator's verification factor for each site. As mentioned in the method section, this evaluation did not assess the preproject condition for building characteristics and energy efficiency measures that were upgraded by the project. Thus, those inputs to EnergyPro were not able to be observed or measured. As a result, the evaluator's verification factors assume that all the building simulation inputs that the contractors made for preproject building characteristics and preproject energy efficiency measures that were covered up by energy upgrades were correct. Figure 13 displays the difference between the contractor and evaluator preproject estimated energy consumption (per square foot) for each site in the sample based on the evaluator postproject site visits. Discrepancies could result only from differences in the building characteristics that were not changed by the installation of measures. Recognizing that evaluators were unable to observe the actual preproject conditions that were of fundamental importance (for example, the preproject conditions for the measures that were upgraded), there is close agreement in the limited comparison that was possible for the building characteristics that were the same before and after the project. The errors that were found in the simulation for these unchanged characteristics, which would be expected to be of little consequence to the accuracy of the simulations, were, not suprisingly, mostly small discrepancies (both positive and negative), leading to an overall average result of almost zero difference in the two results.

Figure 13: Comparison of Preproject Estimated Energy Consumption (per Square Foot per Year)



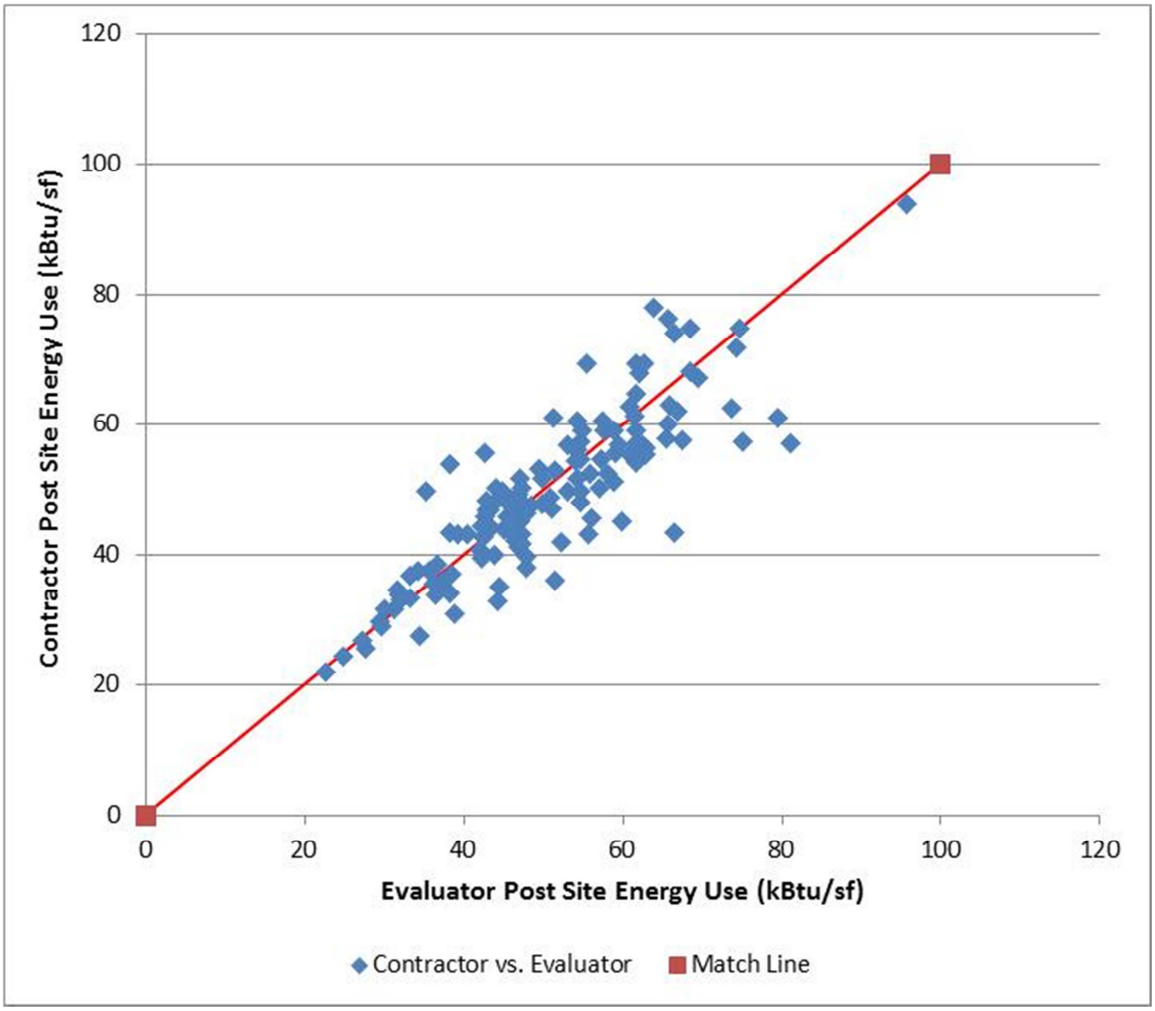
Note: Accuracy of comparison limited because evaluator was unable to observe preproject conditions changed by the upgrade project
Source: DNV KEMA

Postproject Estimated Energy Consumption

Figure 14 displays the difference between contractor and evaluator postproject estimated energy consumption (per square foot) for each site in the sample. As shown, there was close agreement between the contractor and evaluator postproject results with mostly small discrepancies (both positive and negative), leading to an overall average result of almost zero difference in the two results. The fact that the postproject result is almost identical to the preproject result is another indication that the preproject comparison was not able to assess the potentially substantial deviation that may have occurred in the preproject condition of building characteristics and measures.

The energy savings estimated for the upgrade project are the difference between the preproject estimated energy consumption (Figure 13) and the postproject estimated energy consumption (Figure 14). Given that the evaluator was not able to observe differences in preproject building characteristics and energy efficiency measures at the postproject site evaluation point, and the agreement of the contractor-reported and evaluated results for postproject estimated energy consumption, evaluators expected to be able to identify only relatively small discrepancies in the estimates of percentage savings.

Figure 14: Comparison of Postproject Estimated Energy Consumption (per Square Foot per Year)



Source: DNV KEMA

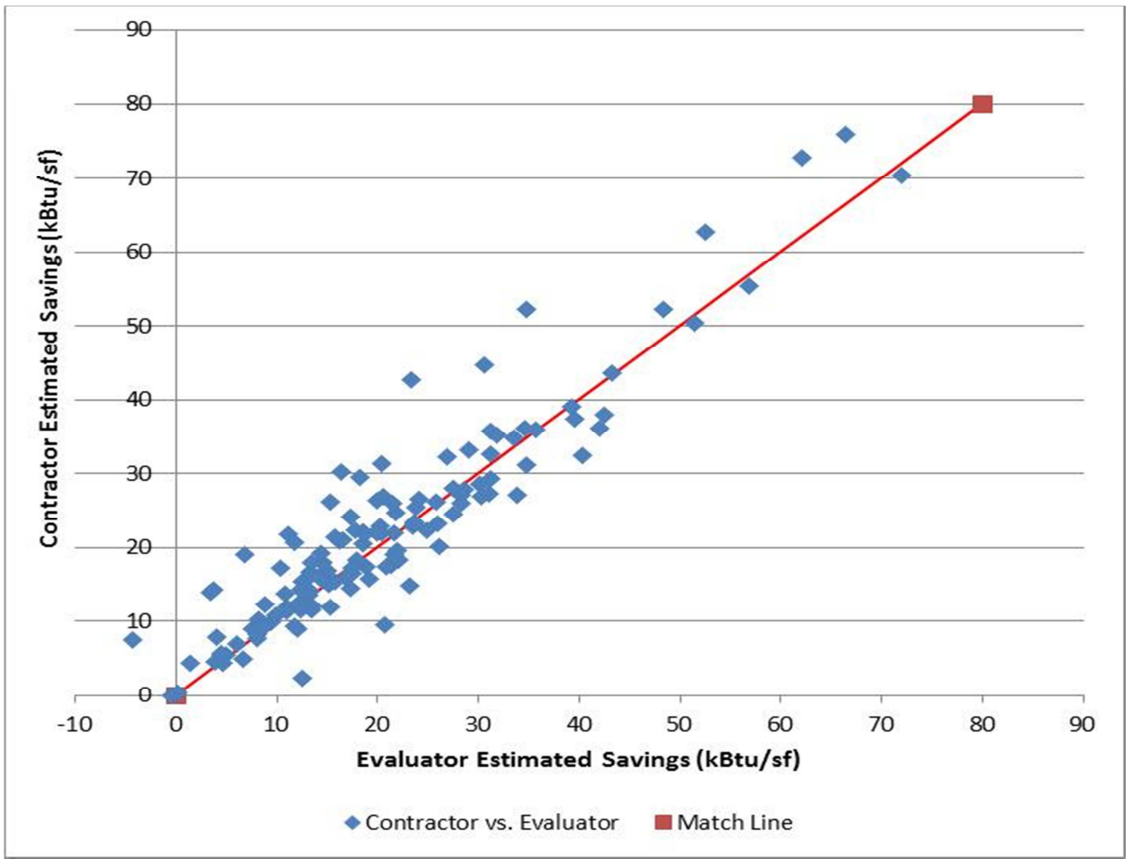
Energy Savings Results

Figure 15 shows the difference in participating contractor- and evaluator-estimated energy savings per square foot for each site based on evaluation only of postproject conditions.

Differences for sites below the line indicate evaluator-estimated savings that were higher than contractor-reported savings, and differences for sites above the line indicate evaluator-estimated savings that were lower than contractor-reported savings per square foot. Greater-than-reported savings may be a result of adjusting only the postproject condition. For example, if the evaluator found that postproject duct leakage was lower than reported by the contractor and given that the preproject leakage was unchanged (because the evaluator was unable to observe errors in the preproject conditions), the savings from duct sealing estimated by the evaluator for the site would be greater than those estimated by the contractor.

The results were highly variable, but there were many minor discrepancies and a few major discrepancies. The verification factors were less than 100 percent due to lower estimated consumption in the evaluator models, primarily as a result of the larger discrepancies illustrated by the points above the match line.

Figure 15: Comparison of Estimated Savings in Energy per Square Foot



Note: Accuracy of comparison limited because evaluator was unable to observe preproject conditions changed by the upgrade project.
Source: DNV KEMA

Verification Factors by CCRR Subrecipient Program

Table 17 and Table 18 present the verification factors by the CCRR subrecipient programs. The verification factors reflect the differences between contractor and evaluator building simulation estimated energy savings based on evaluator site visit observations and testing only of postproject building characteristics and energy efficiency levels. Verification factors account for estimated energy savings differences that would have occurred through improved data collection and data entry into the building simulation models by participating contractors (or HERS raters). The verification factors are based on the estimated total site energy consumption differences for the building simulation models prepared by the participating contractors, as compared to those prepared by the evaluators based only on postproject site observations and testing. The same total site energy consumption verification factors were applied by the evaluators to both electricity and gas savings. The evaluators were not able to verify the preproject conditions of those building characteristics and measures that were changed by the project, so these verification factors assume the same preproject inputs that the contractors made to building simulation models for any building features that were changed by the project.

Table 17: Verification Factors by CCRR Subrecipient Program – Electric (Whole-House, Single-Family)

Subrecipient Program	Subrecipient Program	Estimated Annual Ex Ante Electricity Savings (kWh)	Estimated Annual Ex Post Electricity Savings (kWh)	Verification Factor
SEP	Retrofit Bay Area (ABAG)	1,114,638	1,092,345	98%
	Moderate Income Sustainable Technology Program (CHF)	2,417,072	2,223,706	92%
	Home Performance (SMUD)	3,430,696	2,950,399	86%
EECBG	Energy Upgrade California in San Diego (San Diego)	31,069	26,409	85%
	Regional Comprehensive Residential Retrofit (Fresno)	121,200	121,200	NA
	Retrofit LA (Los Angeles)	4,094,671	3,685,204	90%
Subtotal		11,209,346	10,099,263	90%
Energy Upgrade California (LGC), Energy Independence Program (SCEIP), and Shared Projects		3,632,596	3,269,336	90%
Total		14,841,942	13,368,599	90%

Source: DNV KEMA

Table 18: Verification Factors by CCRR Subrecipient Program – Natural Gas (Whole-House, Single-Family)

Program	Subrecipient Program	Estimated Annual Gross Ex Ante Natural Gas Savings (therms)	Estimated Annual Gross Ex Post Natural Gas Savings (therms)	Verification Factor
SEP	Retrofit Bay Area (ABAG)	358,262	351,097	98%
	Moderate Income Sustainable Technology Program (CHF)	126,649	116,517	92%
	Home Performance (SMUD)	259,251	222,956	86%
EECBG	Energy Upgrade California in San Diego (San Diego)	2,757	2,343	85%
	Regional Comprehensive Residential Retrofit (Fresno)	4,690	4,690	NA
	Retrofit LA (Los Angeles)	258,644	232,780	90%
Subtotal		1,010,253	930,383	91%
Energy Upgrade California (LGC), Energy Independence Program (Sonoma), and Shared Projects		379,760	345,581	91%
Total		1,390,013	1,275,964	91%

Source: DNV KEMA

Usage Factor

The modeled energy consumption was compared to weather-normalized historical energy usage data to develop subrecipient program-level differences reported as usage factors. Unlike the verification factor, the usage factor reflects the inability of the building simulation modeling tool to match historical energy usage. Of the 200-site sample, the analysis excluded sites with missing bills, incomplete building simulation models, or solar generation.

Table 19 presents the average of the usage factors that were determined for each site for each CCRR subrecipient program for those sites where upgrades were completed. The evaluation estimated program savings with these usage adjustment factors. The average usage factors were applied to the total verification factor adjusted program-level energy savings from evaluator building simulation models to determine the final estimated energy savings results. In total, Table 19 includes 125 sites for electricity and 126 sites for natural gas.

Table 19: Usage Factors for Average Electricity and Natural Gas Consumption – Sites With Reported Upgrades

ARRA Funding Source	Subrecipient Program	Electric Consumption (kWh)		Electricity Usage Factor	Natural Gas Consumption (therms)		Gas Usage Factor
		Evaluator Modeled Preproject Estimated Consumption	Weather-Normalized Historical Usage		Evaluator Modeled Preproject Estimated Consumption	Weather-Normalized Historical Usage Consumption	
SEP	Retrofit Bay Area (ABAG)	8,178	6,184	76%	1,005	538	58%
	Moderate Income Sustainable Technology Program (CHF)	15,007	9,090	61%	797	421	63%
	Home Performance (SMUD)	13,044	9,995	77%	891	615	69%
EECBG	Energy Upgrade California in San Diego (San Diego County)	9,546	10,214	107%	415	209	50%
	Regional Comprehensive Residential Retrofit (Fresno)	9,942*	5,769*	58%*	478*	335*	70%*
	Retrofit LA (LA County)	9,777	6,453	66%	384	358	93%

* Homes sampled for the Regional Comprehensive Residential Retrofit program (Fresno) had energy assessments only with no upgrades; the usage factors were determined by comparing preproject estimated energy consumption from the energy assessment files to historical energy usage for each sampled home.
Source: DNV KEMA

Evaluator-Estimated Energy Savings

Evaluators calculated estimated energy savings for the sampled sites using the verification factors from the evaluator-adjusted energy building simulations and the usage factors, as described above. Then the savings estimates for the sampled sites were extrapolated to all other single family homes that received upgrades as a result of the contributions of each CCRR subrecipient program. No estimated energy savings were calculated for sites that had received an energy assessment, but for which no upgrades were completed during the ARRA period.

The evaluators found that the ex ante energy savings expected to be saved by the subrecipient programs were substantially higher than would be indicated by the preproject, historical energy usage data. These ex ante savings were based on building simulations completed by participating contractors that overestimated the historical energy usage. The reasons for those differences appear to originate from the following:

- Contractors incorrectly captured preproject building characteristics – while the verification factor was intended to address this issue, evaluators were unable to observe important preproject conditions because site visits were after these conditions were changed by upgrade projects;
- Homeowner energy using behavior is highly variable, program participant energy usage frequently was not strongly dependent on climate, and may be lower than typical statewide energy usage patterns;
- Building simulation software used for the Energy Upgrade California program did not allow occupant behavior assumptions to be modified to attempt to match individual home circumstances, and using the capability of the software to compare simulation estimates of energy consumption to actual energy usage was not encouraged to be used by EUC program administrators;
- Program incentives were based on percentage energy savings not on the magnitude of the energy savings that were estimated by simulation software.
- Building simulation software algorithms were based on historical modeling approaches that are in need of update.[17]

Table 20 and Table 21 summarize the evaluator-determined estimated energy savings for the whole-house, single-family components of the CCRR programs. Data for the subrecipient programs for which the evaluators conducted site visit evaluations are shown at the top of these tables with subtotals for those programs. Since evaluators did not conduct site visits for LGC or Sonoma County, projects that received only ARRA funding from these two programs are listed

17 The Energy Commission has recently completed a substantial upgrade of residential modeling algorithms for the CBECC-Res software that is used for Building Energy Efficiency Standards.

after the subtotals in the tables. The amount after the subtotals also includes Shared Projects that received funding from both ABAG and CHF, both SMUD and CHF, or both ABAG and Sonoma County. The verification factors and usage factors determined for the subtotals were also applied to Energy Upgrade California (LGC), Energy Independence Program (Sonoma County), and Shared Projects.

Table 20: Evaluation Results – Annual Program-Level Electricity Savings (Whole-House, Single-Family)

ARRA Funding Source	Subrecipient Program	Estimated Annual Gross Ex Ante Electricity Savings (kWh)	Verification Factor	Estimated Annual Gross Ex Post Electricity Savings (kWh)	Electricity Usage Factor	Estimated Annual Gross Usage-Adjusted Electricity Savings (kWh)
SEP	Retrofit Bay Area (ABAG)	1,114,638	98%	1,092,345	76%	830,182
	Moderate Income Sustainable Technology Program (CHF)	2,417,072	92%	2,223,706	61%	1,356,461
	Home Performance (SMUD)	3,430,696	86%	2,950,399	77%	2,271,807
EECBG	Energy Upgrade California in San Diego (San Diego County)	31,069	85%	26,409	107%	28,258
	Regional Comprehensive Residential Retrofit (Fresno)*	121,200	NA	121,200	58%	70,296
	Retrofit LA (LA County)	4,094,671	90%	3,685,204	66%	2,432,235
Subtotal		11,209,346	90%	10,099,263	69%	6,989,239
Energy Upgrade California (LGC), Energy Independence Program (Sonoma) and Shared Projects**		3,632,596	90%	3,269,336	69%	2,255,842
Total		14,841,942	90%	13,368,599	69%	9,245,081

* NA = not applicable, site visits for Fresno Regional Comprehensive Residential Retrofit were for homes that did energy assessments but not upgrades.
** Site visits were not conducted for Energy Upgrade California (LGC) and Energy Independence Program (Sonoma). Shared Projects received services from more than one subrecipient program.
Source: Energy Commission and DNV KEMA

Table 21: Evaluation Results – Estimated Annual Program-Level Natural Gas Savings (Whole-House, Single-Family)

ARRA Funding Source	Subrecipient Program	Estimated Annual Gross Ex Ante Natural Gas Savings (therms)	Verification Factor	Estimated Annual Gross Ex Post Natural Gas Savings (therms)	Natural Gas Usage Factor	Estimated Annual Gross Usage Adjusted Natural Gas Savings (therms)
SEP	Retrofit Bay Area (ABAG)	358,262	98%	351,097	58%	203,636
	Moderate Income Sustainable Technology Program (CHF)	126,649	92%	116,517	63%	73,406
	Home Performance (SMUD)	259,251	86%	222,956	69%	153,839
EECBG	Energy Upgrade California in San Diego (San Diego)	2,757	85%	2,343	50%	1,172
	Regional Comprehensive Residential Retrofit (Fresno)*	4,690	NA*	4,690	70%	3,283
	Retrofit LA (Los Angeles)	258,644	90%	232,780	93%	216,485
Subtotal		1,010,253	91%	930,383	72%	651,821
Energy Upgrade California (LGC), Energy Independence Program (Sonoma), and Shared Projects**		379,760	91%	345,581	72%	248,819
Total		1,390,013	91%	1,275,964	72%	900,640

* NA = not applicable, site visits for Fresno Regional Comprehensive Residential Retrofit were for homes that did energy assessments but not upgrades.
** Site visits were not conducted for Energy Upgrade California (LGC) or Energy Independence Program (Sonoma). Shared Projects received services from more than one subrecipient program.
Source: Energy Commission and DNV KEMA

Estimated Life-Cycle Energy Savings Results

The estimated life-cycle savings resulting from the whole-house, single-family projects implemented through the CCRR programs totaled nearly 185 GWh and more than 18 million therms, as shown in Table 22. Adding impacts from multifamily projects, non-whole-house single-family projects, and solar photovoltaic system installations to the single-family whole-house projects yields about 424 gigawatt-hours and 25 million therms of life-cycle energy savings, and about 63 gigawatt-hours of life-cycle electricity generation.

The evaluators assumed that the measure expected useful lives fell within a range of 15 and 25 years and used a program-level average of 20 years.[18]

18 The CCRR retrofits upgrade projects were a mix of building envelope measures with a DEER EUL of 20 years, duct sealing with a DEER EUL of 18 years, and new furnaces and air conditioners with a DEER EUL of 15 years. The DEER caps all measure EULs at 20 years (per the CPUC policy manual), even though some measures, such as windows and insulation, have longer lives, as cited in the underlying studies referenced by DEER. For the CCRR analysis, the overall average EUL of 20 years was used to reflect the mix of these longer life measures, as well as measures with EULs of fewer than 20 years.

Table 22: Evaluation Results – Estimated Program-Level, Life-Cycle Savings (Whole-House, Single-Family)

ARRA Funding Source	Subrecipient Program	Estimated Annual Gross Usage-Adjusted Electricity Savings (kWh)	Estimated Life-Cycle Gross Usage-Adjusted Electricity Savings (kWh)	Estimated Annual Gross Usage-Adjusted Natural Gas Savings (therms)	Estimated Life-Cycle Gross Usage-Adjusted Natural Gas Savings (therms)
SEP	Retrofit Bay Area (ABAG)	830,182	16,603,640	203,636	4,072,720
	Moderate Income Sustainable Technology Program (CHF)	1,356,461	27,129,220	73,406	1,468,120
	Home Performance (SMUD)	2,271,807	45,436,140	153,839	3,076,800
EECBG	Energy Upgrade California in San Diego (San Diego)	28,258	565,160	1,172	23,440
	Regional Comprehensive Residential Retrofit (Fresno)	70,296	1,405,920	3,283	65,660
	Retrofit LA (Los Angeles)	2,432,235	48,644,700	216,485	4,329,700
Subtotal		6,989,239	139,784,780	651,821	13,036,440
Energy Upgrade California (LGC), Energy Independence Program (Sonoma), and Shared Projects*		2,255,842	45,116,840	248,819	4,976,380
Total		9,245,081	184,901,620	900,640	18,012,820

*Site visits were not conducted for Energy Upgrade California (LGC) and Energy Independence Program (Sonoma). Shared Projects received services from more than one subrecipient program.
Source: DNV KEMA

Estimated GHG Emissions Reductions

The evaluation team also calculated the estimated GHG emissions reductions resulting from the whole-house, single-family projects in the CCRR programs, as shown in Table 23. GHG emissions reductions accrue when energy is saved or renewable energy replaces fossil generation. Evaluators calculated annual program-related emissions reductions from the usage-adjusted energy savings.

Adding impacts from multifamily projects, non-whole-house single-family projects, and solar photovoltaic system installations to the single-family whole-house projects yields 14,530 metric tons of CO_2 annually and 290,599 metric tons of CO^2 over the life of the energy efficiency upgrades.

Table 23: Evaluation Results – Estimated Program-Level GHG Emissions Reductions (Whole-House, Single-Family)

ARRA Funding Source	Subrecipient Program	Estimated Annual GHG Reductions (metric tons CO_2)	Estimated Life-Cycle GHG Reductions (metric tons CO_2)
SEP	Retrofit Bay Area (ABAG)	1,340	26,792
	Moderate Income Sustainable Technology Program (CHF)	814	16,276
	Home Performance (SMUD)	1,527	30,536
EECBG	Energy Upgrade California in San Diego (San Diego)	15	301
	Regional Comprehensive Residential Retrofit (Fresno)	39	788
	Retrofit LA (Los Angeles)	1,909	38,183
Subtotal		5,644	112,876
Energy Upgrade California (LGC), Energy Independence Program (Sonoma), and Shared Projects*		2,025	40,508
Total		7,669	153,384

* Site visits were not conducted for Energy Upgrade California (LGC) and Energy Independence Program (Sonoma). Shared Projects received services from more than one subrecipient program.
Source: DNV KEMA

CHAPTER 6: Recommendations

The overall goal of this evaluation was to assess the impact of the CCRR pilot program implementation and verify the energy savings realized from upgrade projects during 2011 and 2012. The evaluation team developed verification factors based on postproject site visit evaluations to assess contractor observation and testing of building characteristics and energy efficiency measures for input into building simulation modeling. The team also separately developed usage factors to determine differences between evaluator building simulation energy consumption estimates and historical energy usage data. The evaluation team produced a set of recommendations for encouraging improvement of the CCRR programs going forward.

Evaluation Recommendations

The evaluation team developed recommendations based on the evaluation results to inform sustained Energy Upgrade California programs. Overall recommendations include the following:

- **Target inefficient homes with greatest consumption:** Consider offering higher incentives for homes that can demonstrate higher preproject energy consumption per square foot, as well as a higher expected savings postproject. The evaluation results indicate the participating homes likely use less energy preproject than comparable, nonparticipating homes. In addition, the EUC program has high participation in California's milder climate zones with only limited participation in areas of the state with hot summers and/or cold winters, such as the Central Valley, Riverside and eastern San Diego counties, and the high and low desert.
- **Improve energy savings realization:** The evaluation found that the building simulation modeling by program participating contractors led to overestimated energy consumption values (and thus overestimated energy savings). Evaluators found that the EnergyPro software's embedded usage weather normalization and graphing process designed to be compared to historical energy usage was not required to be used by the programs and was rarely used by participating contractors. Contractors also had limited ability to modify building simulation program inputs to better match usage data. Investor- and publicly owned utilities should enable historical usage data to be readily available to participating contractors for easy comparison to building simulation estimated energy consumption. Current efforts sponsored by the CPUC (with consultation from the Energy Commission) should continue, including CalTEST and CalTRACK. CalTEST is a specification that will place limits on the inputs that participating contractors are allowed to assume about preproject building characteristics. CalTRACK is a system that will require building simulation software to be compared on an ongoing basis to energy usage and be adjusted to match estimated

energy consumption to that energy usage. CalTEST includes limitations on preproject distribution efficiency (including duct leakage measured to outside, and other duct losses) and on equipment efficiency in the absence of verification of manufacturer model-specific data. Recommendations for energy upgrades should be informed by this comparison and adjustment.

- **Contractor training:** Contractors need initial and refresher training for using program-approved building simulation models and, in particular, for using CalTEST limited and valid inputs that are less likely to lead to higher estimated energy consumption compared to what historical usage indicates is reasonable.
- **Develop a comprehensive database for projects, including assessment-only sites and upgrades:** Major challenges during the evaluation included lack of consistent documentation and simulation files for both energy assessments and upgrades. The evaluators make the following recommendations to ensure a comprehensive database:
    - Maintain records on preproject conditions, such as insulation levels, equipment model information, and window types, and require photographic records. For measures that cannot be demonstrated through photographs, such as building envelope leakage and duct leakage, limit preproject conditions consistent with national BPI Standards and normal levels observed of program participants; allow deviation only when observed through on-site preproject QC by program administrators.
    - Maintain a list of all projects and keep a record of all funding sources of energy assessments and upgrades, including rebates and financing from each source. When energy upgrades are conducted in parallel with other building improvements for non-energy purposes, ensure that project costs are clearly separated for the energy upgrade portion of the work.
    - Store all building energy simulation files in a format that is easily accessible for QC, evaluation, and future program analysis and follow-up. For example, a future program could follow-up on recommended measures from the assessment.
    - The database should be designed to actively enable sharing of data with all program administrators that have a stake in the effective delivery of the EUC program and with the participating contractors and other market actors that are engaged in the program, recognizing the need for data security by establishing effective access protections, and safe data transfer and data storage. IOUs must fully cooperate with this data sharing for the database to be successful.

CHAPTER 7:
Glossary

AB 758	California Assembly Bill 758 (Skinner, 2009), Comprehensive Energy Efficiency Program for Existing Buildings
ABAG	Association of Bay Area Governments
AC	air-conditioning
ARRA	American Recovery and Reinvestment Act of 2009
ASHRAE	American Society of Heating, Refrigerating, and Air Conditioning Engineers
BPI	Building Performance Institute
Btu	British thermal unit
CalCERTS	Home Energy Ratings System (HERS) Provider approved by the Energy Commission for oversight of whole-house HERS ratings
CCRR	California Comprehensive Residential Retrofit
CDD	cooling degree day
CHF	CRHMFA
CO_2	carbon dioxide
CPUC	California Public Utilities Commission
CRHMFA	formerly known as California Rural Home Mortgage Finance Authority
CVRMSE	Coefficient of Variation of the Root Mean Square Error
CWIB	California Workforce Investment Board
DEER	Database for Energy Efficient Resources
DNV KEMA	DNV KEMA Energy & Sustainability
DOE	United States Department of Energy
EECBG	Energy Efficiency and Conservation Block Grant
EM&V	evaluation, measurement, and verification
Energy Commission	California Energy Commission
EnergyPro	EnergyPro 5 Software, Residential Performance Module
EnergyPro Model	a model produced using EnergyPro 5 Software, Residential Performance Module
EUL	effective useful life
ex ante	energy savings estimates for energy efficiency measures developed by the program implementers

ex post	energy savings estimates for an energy efficiency measure developed by the evaluation team
FHFA	Federal Housing Finance Agency
GETUP	short name for contractor training effort by Energy Upgrade in San Diego
GHG	greenhouse gas
GWh	gigawatt-hour
HDD	heating degree day
HERS	Home Energy Rating System
HVAC	heating, ventilation, and air conditioning
IOU	investor-owned utility
Joint Powers Authority	an entity permitted under California law, whereby two or more public authorities can operate collectively
kBtu	Thousand British thermal units
kW	kilowatt
kWh	kilowatt-hour
lbs	pounds
LA	Los Angeles
LGC	Local Government Commission
M&V	measurement and verification
MF	multifamily
MIST	Moderate Income Sustainable Technology
MWh	megawatt-hour
NA	not applicable
PACE	Property Assessed Clean Energy Financing
pascal	unit of pressure
PG&E	Pacific Gas and Electric Company
PV	photovoltaic
QC	quality control
RASS	Residential Appliance Saturation Study
REN	Regional Energy Network
RESNET	Residential Energy Services Network
SCE	Southern California Edison
SCEIP	Sonoma County Energy Independence Program

SDG&E	San Diego Gas & Electric Company
SEP	State Energy Program
SF	single-family
SFMOH	San Francisco Mayor's Office of Housing
SLA	Specific Leakage Area
SMUD	Sacramento Municipal Utility District
SoCalGas	Southern California Gas
therm	a unit of heat equivalent to 100,000 British thermal units
WIB	local workforce investment board
yr	Year