Baseline Characterization Market Effects Study of Investor-Owned Utility Residential and Small Commercial HVAC Quality Installation and Quality Improvement Programs in California (Work Order 054)

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Executive Summary

Objectives and Methodology

This report presents the findings of a baseline market characterization study focused on the California Investor Owned Utilities' (IOUs') Quality Installation (QI), Quality Maintenance (QM), and Upstream HVAC Equipment Programs. HVAC is a major, definable market in California accounting for sizable portions of peak demand and energy use as well as savings potential. The CPUC investor-owned utilities (IOUs) have designed programs to increase the quality of HVAC installation (QI), the quality of HVAC maintenance (QM), and the market share of high-efficiency systems. With a particular focus on residential and small commercial customers, this study sought to establish a baseline for a range of current maintenance and installation practices and the market shares of highly efficient systems that have been recently installed. These data will assist the CPUC in future retrospective assessments of the market effects attributable to these programs. The key objectives of this study included the following:

- To use a prospective focus to provide a baseline for CPUC HVAC programs that will facilitate the CPUC's future assessments of the market effects that may be attributed to HVAC programs.
- To estimate the proportion of contractors adhering to QI and QM practices, thus addressing the market transformation indicators established for the HVAC programs.
- To estimate the current levels of secondary indicators such as customer awareness, contractor qualification, program participation, customers receiving regular system maintenance, and installation practices in order to facilitate future estimates of the influence of the IOU programs and other factors on the use of IOU-promoted methods outside the IOU programs.
- To summarize estimates of market share, sales, penetration, and saturation of energy-efficient HVAC equipment for residential and small commercial customers—largely obtained from other research—to provide a baseline for future retrospective studies.
- To develop a system for obtaining ongoing measurements of market share, sales, and penetration of energy-efficient equipment, again to facilitate future comparative studies.

This multi-faceted study made use of data collected from contractors, customers, program managers, and others involved in the California HVAC market. It relied substantially on other work orders for information inputs and data collection, necessitating substantial coordination with those data collection efforts. This often involved adding key questions to surveys being conducted by the other work orders. The surveys and studies that this study drew upon include the following:

- A telephone survey of 297 residential customers and 300 small commercial customers conducted specifically for this study.

- Interviews with seven IOU program staff members and eight independent HVAC distributors conducted specifically for this study.
- A survey of 20 independent HVAC distributors conducted by DNV GL for the Residential and Small Commercial HVAC Impact Evaluation (Work Order 32).
- Technical assessments at 50 participant and 50 non-participant residential installation sites, and 50 residential and 30 commercial maintenance sites, conducted by DNV GL for the Residential and Small Commercial HVAC Impact Evaluation (Work Order 32).
- A survey of 245 residential and small commercial contractors from the California HVAC Contractor & Technician Behavior Study, conducted by Energy Market Innovations for Southern California Edison and Pacific Gas & Electric. The study also included field observation of 16 technicians on service or maintenance visits for a residential system with intentionally implemented faults.
- A survey of 7,890 commercial customers, on-site assessments at 197 commercial facilities where new HVAC systems had recently been installed, and a survey of 123 contractors who install commercial HVAC systems, all conducted by ITRON for the Commercial Market Share Tracking Study (Work Order 24).
- On-site assessments in 1,987 homes conducted by DNV GL for the California Lighting and Appliance Saturation Study (Work Order 21).

Baseline Overview

The study objective was to provide a baseline for the Market Transformation Indicators (MTIs) established for CPUC HVAC programs. As part of the energy-efficiency program planning process for the 2010-2012 cycle, the Energy Division (ED) required that program administrators specify program performance metrics (PPMs) and Market Transformation Indicators (MTIs) that could be used to assess progress toward operational objectives and longer-term goals. The ED and its consultants reviewed and refined the PPMs and MTIs submitted by the program administrators for use in program tracking and evaluation.[1] This study also proposed several secondary indicators for MTI-2, MTI-3, and MTI-4.[2]

Overall, the study found significant market shares of energy-efficient HVAC equipment sold in 2011 and 2012 in California. However, the study also found low baseline values for adherence to Quality Installation (QI) and Quality Maintenance (QM) practices. The latter findings resulted in recommendations for increased customer education and contractor training presented at the end of this section.

[1] Table 6-3 in the conclusions summarizes the baseline values and suggested tracking for the Market Transformation Indicators (MTIs) established for CPUC HVAC programs.
[2] Table 6-4 in the conclusions summarizes the current baseline values and suggested tracking frequency for the secondary indicators.

Market Shares of Energy-Efficient Equipment

Market shares of energy-efficient HVAC equipment in the residential and small commercial markets in 2011 and 2012 in California were significant.

- Overall nearly one-half (46%) of the HVAC units sold were single-phase air-cooled and four out of every ten of these (40%) met Tier 1[3] or better efficiency standards.
- The next largest market share (23%) was for air-cooled three-phase packaged and split equipment; more than one-half of these units (56%) met Tier 1 or better efficiency standards.[4] Just over eight out of ten (81%) of the remaining unit types met Tier 1 or better efficiency standards.

The California Energy Efficiency Strategic Plan calls for 15% of HVAC equipment shipments optimized for California's climate by 2015 and 70% by 2020. The market transformation indicator of progress toward this goal is annual sales of climate-appropriate air conditioning.

- Using Tier 1 or better as a proxy for climate appropriate AC, this study estimates that 57% of HVAC units sold to residential and small commercial customers in 2011 and 2012 met the criterion.
- Thus, based on a Tier 1 standard, the current estimate of sales exceeds the goal set by the California Energy Efficiency Strategic Plan for 2015 and approaches the more ambitious goal for 2020. Only 13.5% of HVAC units sold in 2011 and 2012 would meet a higher climate-appropriate standard of Tier 2 or better.

Proposed Market Share Tracking System

The study scope included developing a proposal for a market share tracking system that would recruit distributors to provide quarterly data. The proposed system was modeled largely along the lines of the Energy Center of Wisconsin's (ECW) successful Furnace and Air Conditioning Tracking System (FACTS). The proposed approach would provide a systematic process for periodic reporting of market share by efficiency level and sales.

Quality Installation Findings

Quality Installation (QI) Baseline. The baseline for QI in California is relatively low.

- Only a minority of contractors (42% residential; 36% small commercial) were aware of ACCA Standard 5 and a small minority said they adhere to all of its specifications (14% of all residential contractors; 8% of all small commercial contractors).

[3] Performance tiers were defined using the 2010-2012 SCE Qualifying Minimum Equipment Efficiencies & Incentive Levels for Commercial Air Conditioners (see Appendix A). The number of tiers and tier standards, defined based on minimum unit SEER, EER, or IEER ratings, vary by HVAC unit type and capacity.

[4] Single-phase air-cooled equipment was predominantly residential, and three-phase equipment was almost exclusively commercial.

- Thirty-five percent of residential contractors and 19% of small commercial contractors said they were currently participating or had ever participated in an IOU QI program.[5] However, only 10% of residential contractors and 8% of small commercial contractors said they were currently participating in such a program.[6]
- When asked about other certifications, more than one-half (53% residential; 59% small commercial) of installation contractors said their technicians were not certified by any organization. Only two-fifths (40%) of residential installation contractors and just over one-fourth (27%) of small commercial installation contractors hold NATE certifications, which are promoted by the IOU programs.

Awareness of QI. QI awareness among customers is fairly low.

- Less than one-fifth of residential respondents (16%) and small commercial respondents (17%) had heard of the term quality installation. Even after it was described to them, only about a quarter of all customers (25% residential; 28% small commercial) said they had heard of QI, and almost none of those customers could identify any QI guidelines or programs.
- When asked about the specific QI and rebate programs offered by their IOU, 10% to 21% of residential customers and 8% to 16% of small commercial customers said they had heard of particular IOU programs.

Barriers to QI. Barriers to QI included unwillingness to pay for it.

- Not surprisingly, contractors reported that the greatest barrier to QI is customers not wanting to pay for it (63% residential; 66% small commercial).

QI Field Assessments. The QI field assessments found a mixed record of compliance with Title 24 among installations in the overall HVAC replacement market. However, system performance metrics in the overall market were generally not as poor as assumed by the QI program.[7]

- **Duct Leakage.** The field assessments found that many systems have duct leakage greater than the Title 24 specification of <15% and the program efficient case assumption of 12%, but the average of 17% shows they were not as leaky as the baseline 24% duct leakage assumed by the QI program.
- **System Airflow.** The Title 24 minimum and efficient case assumption specifies system airflow at 400 CFM/ton. System airflows of 300 CFM/ton measured during the program

[5] This figure was likely overstated as a result of respondents including any IOU program they had participated in, even though they were specifically asked about the Quality Installation program.
[6] This self-reported participation rate is likely to be overstated by contractors responding to the survey since only a very small percentage of installation contractors, ranging from 1% to 3%, depending on the IOU, have been trained and/or qualified by the IOUs. Program training, generally to ACCA Standard 5 and/or ENERGY STAR® QI, is a prerequisite for participation.
[7] WO32 is developing savings estimates based on field findings, but these were not available for inclusion in this report.

non-participant site visits were even lower than the 350 CFM/ton baseline assumed by the QI program.

- **System Oversizing.** While there both was both undersizing and oversizing relative to Manual J, systems not participating in the program were oversized by an average of 13%, which is lower than the baseline assumption of 20%.

Table ES-1 summarizes these findings.

Table ES-1 QI Field Observations and Assumptions for the Program Baseline and Efficient Case

Statistic	Field Observations (mean)	QI Program Baseline Assumptions	QI Efficient Case Assumptions
Total System Duct Leakage	17%	24%	12%
System Airflow (CFM per ton)	300	350	400
System Oversizing	13%	20%	0%

The field assessments used Title 24 and manufacturer diagnostics to verify that proper refrigerant charge was present in all the systems tested. However, recent studies have found that the Title 24 and other diagnostics used to verify refrigerant charge are flawed; thus the results of this field assessment are considered to be indeterminate.

Quality Maintenance Findings

Quality Maintenance (QM) Baseline. As in the case of QI, the baseline for QM in California is also relatively low.

- A minority of contractors (45% residential; 34% small commercial) were aware of ACCA Standard 4 or ANSI/ASHRAE/ACCA Standard 180 and a small minority said they adhere to all of the appropriate specifications (10% of all residential contractors; 7% of all small commercial contractors).
- Thirty percent of residential contractors and 22% of small commercial contractors said they were currently participating or had ever participated in an IOU QM program.[8] However, only 16% of residential contractors and 6% of small commercial contractors said they were currently participating in such a program.[9]

[8] Again, this figure was likely overstated due to the respondents including any IOU program they had participated in, even though they were specifically asked about the Quality Maintenance program.

[9] As in the case of QI, this self-reported participation rate is likely to be overstated by contractors responding to the survey since only a small percentage of maintenance contractors, ranging from 1% to 10% depending on the IOU, have been trained and/or qualified by the IOUs. Program training, generally to the ANSI/ACCA Standard 4 (residential) or ANSI/ASHRAE/ACCA Standard 180-2008 (commercial), is a prerequisite for participation. Note also that the IOU programs vary in their definitions of what constitutes qualified and trained contractors. In the PG&E program, contractors are qualified after receiving training. In the SCE and SDGE programs, the number of

- When asked about other certifications, more than one-half (55% residential; 56% small commercial) of maintenance contractors said their technicians were not certified by any organization. About two-fifths (39%) of residential maintenance contractors and three out of ten (30%) small commercial maintenance contractors said they hold NATE certifications, which are promoted by the IOU programs.

Awareness of QM. QM awareness among customers also is fairly low.

- Just over one-fifth of residential respondents (21%) and small commercial respondents (22%) had heard of the term quality maintenance. Even after it was described to them, fewer than one-half of all customers (40% residential; 36% small commercial) said they had heard of QM, and almost none of those customers could identify any QM guidelines or programs.
- When asked about specific QM programs, 10% to 21% of residential customers and 13% to 16% of small commercial customers said they had heard of the particular programs offered by their IOU (PG&E and SDG&E programs include both QI and QM).

Barriers to QM. As was the case for QI, barriers to QM included unwillingness to pay for.

- As in the case for QI, contractors reported that the greatest barrier to QM is customers not wanting to pay for it (52% residential; 64% small commercial).

Frequency of Maintenance and Service. The incidence of regularly scheduled maintenance of HVAC systems is fairly low among residential customers and moderate among small commercial customers.

- Reflecting customers' propensity to call HVAC contractors only when their systems need repairs, once service calls for repairs are excluded, 24% of residential customers and 58% of small commercial customers said they have maintenance done on their HVAC systems every year.
- One-third (33%) of residential customers and one-quarter (25%) of small commercial customers said they never have maintenance done, except for repairs.[10]
- The contractor surveys had a slightly different approach to estimating maintenance frequency. Sixty-four percent of residential maintenance contractors and 79% of small commercial maintenance contractors said they market maintenance contracts. Excluding the contractors who do not market contracts, 27% of residential contractors and 41% of small commercial contractors said that almost all of their maintenance customers renew their contracts each year.

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contractors trained is the number of contractors who received sales/operations training, and the number of contractors qualified is the number enrolled.

[10] These statistics are based on customer responses. It may be that customers are receiving some regular maintenance services when their systems are being repaired, but are not aware of this.

QM Field Assessments. In general, the QM field assessments determined that the performance metrics among non-program systems were consistent with and validated the QM program assumptions of sub-optimal performance.

- **Duct Leakage.** The field assessments found that residential system total duct leakage relative to nominal flow (23% for heating and 20% for cooling) is fairly close to the QM program baseline assumption of 24%. Leakage to the outside relative to the measured airflow (27% for heating and 32% for cooling) is slightly higher than the baseline.
- **System Airflow.** The residential (331 CFM per ton for cooling) and commercial (359 CFM per ton for cooling) system airflows were not significantly different from the QM program baseline of 350 CFM per ton. These values are all well below the QM program requirements.

Table ES-2 summarizes these findings.

Table ES-2 QM Field Observations and Assumptions for the Program Baseline and Efficient Case

Statistic	Field Observations (mean)	QM Program Baseline Assumptions	QM Efficient Case Assumptions
Total System Duct Leakage (using nominal heating airflow)	23%	24%	12%
Total System Duct Leakage (using nominal cooling airflow)	20%	24%	12%
Residential System Airflow in Cooling Mode (CFM per ton)	331	350	400
Commercial System Airflow (CFM per ton)	359	350	400

As noted for the QI field assessments, verifications of the refrigerant charge are considered to be indeterminate.

Field Observations of Technicians. Field observations of technicians conducting maintenance calls on a system with intentionally implemented faults yielded particularly important QM insights, and also served as a reminder that self-reports by contractors are not always accurate. Overall, the typical "maintenance" services provided were below the standards of ACCA 4 utility "quality maintenance" program goals and industry best practices as judged by the expert technician.

- During field observations, almost all of the technicians attempted some of basic maintenance tasks, but few performed the tasks correctly. Performance level was not related to the technician's certifications, training, years on the job, or participation in utility programs. Some of the most important tasks for energy-efficient operation were frequently not even attempted. There was, in fact, a disconnect between contractors' stated practices and technicians' practices in the field.

- Post-observation interviews indicated that observed technicians were not knowledgeable about ACCA Standard 4, and none of the 13 observed technicians stated that they use the standard in their regular work.

Attribution of Market Effects

To assess the market effects of the program in future years, following completion of the field assessments every four years, we recommend assessing what portion of changes in practices may be attributed to the IOU programs. To accomplish this, we recommend using a Delphi panel of industry experts who would examine the observed changes in the market indicators along with self-reports from contractors and customers on the reasons for changing practices. The panelists would also examine the program theory models as to how the observed changes relate to the primary and secondary indicators, and records of program activities such as training, number of qualifying contractors, and customer education.

Recommendations

Program Design and Operation

The findings from this study led to the following recommendations pertaining to the design and operation of the HVAC subprograms:

- Focus on educating customers about the value of QI and QM. "Quality" is a generic term; many contractors will claim that they provide "quality" services. Customers need to be educated about the specifics (in lay terms) of QI and QM and the resulting energy savings. Customer education may also encourage the scheduling of regular maintenance visits, and also target those who are changing out HVAC systems such as through major renovations, and also those who are building or buying new homes.
- Collaborate with industry leaders to train contractors so that they have their NATE certifications in place. Industry leaders may also help promote IOU program qualification requiring more stringent ACCA/ASHRAE/ENERGY STAR standards to contractors, and educate customers about the value of QI and QM program-qualified contractors.
- Step up efforts to have contractors participate in the IOU training programs. Agreeing on a common definition across IOUs of qualification requirements is a first step. Without this, it will be difficult to sell the value of "program-qualified contractors" to contractors and consumers.
- Seek to increase the market share of more efficient systems by educating customers about the energy savings and other benefits associated with more efficient HVAC systems and the rebates available. As with the first recommendation above, effective strategies and messages should be explored with customer focus groups or surveys prior to launch.

- Specific recommendations from the field assessments include the following:
  - Continue to promote the use of software to perform system sizing calculations to reduce oversizing.
  - Research approaches to measuring refrigerant charge and develop diagnostics that are more reliable for maintenance.
  - Perform duct sealing as the primary residential maintenance measure.
  - Research approaches to repairing or replacing commercial economizers, reducing rooftop unit leakage (unit and economizers), and optimizing fan efficiency.

Research and Tracking

The following recommendations pertain to research and tracking of program indicators:

- Implement a market share tracking system based on the model developed by this study so that a systematic process for periodic reporting of market shares by efficiency level and sales is in place going forward.
- Periodically assess the market transformation indicators and secondary indicators suggested by this study through contractor and customer interviews and on-site assessments of HVAC installations and maintenance, as suggested in Table ES-1 and Table ES-2.
- Create more secondary indicators that can be measured through field assessments. Examples are increasing the number of systems properly sized within one-half ton of design load, increasing fan airflow (CFM per ton) and efficiency (Watts per CFM), reducing duct leakage to the outside in existing ducts, and reducing the number of new ducts in conditioned space. These indicators could be assessed through on-site assessments every four years.
- The on-site observations of maintenance work on a system with intentionally implemented faults provided invaluable information about the state of maintenance services available to most customers and should be repeated regularly.
- Further focus group research may be required to assess the extent to which customers (and contractors) are able to differentiate "Quality Installation" and "Quality Maintenance" from the generic term "quality" to which all contractors would lay claim. This research could explore alternative terms and messaging to identify those to which customers are most responsive.
- Continue to study differences in the performance of installed or maintained HVAC units between HVAC contractors who participate in IOU programs and/or are NATE certified, and HVAC contractors who do not participate in IOU programs and/or are not NATE certified. These differences are likely to get smaller as the HVAC market is being transformed, but are likely to significant for at least the next several years.

1 Introduction

HVAC is a major, definable market in California, accounting for a sizable portion of peak demand and energy use as well as savings potential. The CPUC investor-owned utilities (IOUs) have designed programs to increase the quality of HVAC installation (QI), the quality of HVAC maintenance (QM), and the market share of high-efficiency systems. With a particular focus on residential and small commercial customers, this HVAC Baseline Market Characterization Study is a multi-faceted effort designed to establish a baseline for a range of current maintenance and installation practices and the market shares of highly efficient systems that have been recently installed. This will assist the CPUC in assessing the market effects attributable to these programs in the future.

1.1 Report Objectives

The HVAC Baseline Market Characterization Study thus has a prospective rather than retrospective focus with the following primary objectives:

- To use a prospective focus to provide a baseline for CPUC HVAC programs that will facilitate the CPUC's assessment of the market effects that may be attributed to HVAC programs in the future.
- To estimate the proportion of contractors adhering to QI and QM practices to address the market transformation indicators established for the HVAC programs.
- To estimate the current levels of secondary indicators such as customer awareness, contractor qualification, program participation, customers receiving regular system maintenance, and installation practices in order to facilitate future estimates of the influence of the IOU programs and other influences on the use of IOU-promoted methods outside the IOU programs.
- To summarize estimates of market share, sales, penetration, and saturation of energy-efficient HVAC equipment for residential and small commercial customers—largely obtained from other research—to provide a baseline for future retrospective studies.
- To develop a system for obtaining ongoing measurements of market share, sales, and penetration of energy-efficient equipment, again to facilitate future comparative studies.

These objectives are intended to provide a baseline for the Market Transformation Indicators (MTIs) established for CPUC HVAC programs. As part of the energy-efficiency program planning process for the 2010-2012 cycle, the Energy Division (ED) required that program administrators specify program performance metrics (PPMs) and Market Transformation Indicators (MTIs) that could be used to assess progress toward operational objectives and longer-term goals. The ED and its consultants reviewed and refined the PPMs and MTIs submitted by the program administrators for use in program tracking and evaluation.

Table 1-1 shows the four HVAC subprograms and the four MTIs associated with them.

Table 1-1: CPUC HVAC Subprograms and Market Transformation Indicators

Subprogram	Subprogram Name	MTI	MTI Description
HVAC-1	Upstream HVAC Equipment Subprogram	MTI-1	Market share of climate-appropriate HVAC equipment.
HVAC-2	Residential Energy Star Quality Installation Subprogram	MTI-2	Percentage change in the use of Quality Installation guidelines among all California Residential HVAC installation contractors.
HVAC-3	Commercial Quality Installation Subprogram	MTI-3	Percentage change in the use of Quality Installation guidelines among all California Commercial HVAC installation contractors.
HVAC-4	Quality Maintenance Development Subprogram	MTI-4	Percent change in the employment of Quality Maintenance practices among all California HVAC contractors and technicians.

In addition to the four MTIs listed in Table 1-1, this study identified several secondary indicators, shown in Table 1-2, that may also be tracked to assess the HVAC subprograms' progress in promoting QI (SIQIs) and QM (SIQMs). Note that unaided awareness is a more valid measure for SIQI-2 and SIQM-2.

Table 1-2: Suggested Secondary Indicators Assessing HVAC Subprograms Progress

Quality Installation	Quality Maintenance
Percent Change in…	
Contractor awareness of QI and ACCA standards (SIQI-1)	Contractor awareness of QM and ACCA/ASHRAE standards (SIQM-1)
Customer awareness of the concept of QI (SIQI-2)	Customer awareness of the concept of QM (SIQM-2)
Contractors currently participating in QI programs (SIQI-3)	Contractors currently participating in QM programs (SIQM-3)
Customer awareness of rebate and QI programs (SIQI-4)	Customer awareness of QM programs (SIQM-4)
Technicians with training in QI (SIQI-5)	Technicians with training in QM (SIQM-5)
Proportion of contractors who obtain building permits for HVAC installations (SIQI-6)	Proportion of customers who have regular maintenance of their HVAC systems (SIQM-6)

1.2 Methodology Overview

This multi-faceted study made use of data collected from contractors, customers, program managers, and others involved in the California HVAC market. The study looked at the entire market for HVAC sales, installation and maintenance practices, including the small portions of contractors currently participating in QI and QM programs. It relied substantially on other work orders for information inputs and data collection, necessitating substantial coordination with

those data collection efforts. This study often added key questions addressing its objectives to surveys of the other work orders. The studies summarized in Table 1-3 contributed to key findings presented in this report.

Table 1-3: HVAC Studies Used to Examine Market Effects

Work Order	Study / Survey	Surveyed Group	Conducted by	Current Status
	California HVAC Contractor & Technician Behavior Study, Final Report, September 2012	245 residential and small commercial contractors	Energy Market Innovations for Southern California Edison and Pacific Gas & Electric	Published September 2012. Available in CALMAC
WO 54	Telephone surveys of residential customers and small commercial customers conducted between August and October 2012	297 residential customers and 300 small commercial customers	NMR for the CPUC	This report
WO 54	HVAC Distributor Interviews	8 independent HVAC distributors	NMR for the CPUC	This report
WO 54	IOU Interviews	7 HVAC program staff members	NMR for the CPUC	This report
WO 24	Commercial Market Share Tracking Study	7,890 commercial customers surveyed; on-sites for 197 commercial customers that had recently installed new HVAC systems;123 contractors who install commercial HVAC systems surveyed	Itron	Draft report submitted to CPUC
WO 21	California Lighting and Appliance Saturation Study (CLASS 2012)	1,987 home on-sites	DNVGL	In progress
WO 32	Residential and Small Commercial HVAC Impact Evaluation	20 independent HVAC distributors	DNVGL	In progress
WO 32	Residential and Small Commercial HVAC Impact Evaluation	50 participant and 50 non-participant residential installation on-sites; 50 residential and 30 commercial maintenance on-sites	DNVGL	In progress

- The California HVAC Contractor & Technician Behavior Study provided baseline information on HVAC maintenance and installation, company characteristics, and assessment of the contractors' understanding and use of standards, selling practices, and business models. The study included an online contractor survey conducted in May and June of 2012 with 245 contractors——126 serving residential customers and 119 serving small commercial customers. The study also included field observations of 16 technicians on service or maintenance visits for a residential system with intentionally-implemented faults. NMR used information from this overall study, in conjunction with training and qualification data provided by the IOUs, to estimate the percentages of contractors trained and qualified in QI and QM.
- For this study, NMR conducted telephone surveys of 297 residential customers and 300 small commercial customers between August and October 2012. We explored awareness and understanding of quality maintenance, maintenance recommendations received from contractors, maintenance intervals, use of maintenance contracts, and perceived impact of maintenance on utility bills. For customers with recent installations, the surveys also explored awareness and understanding of quality installation, experience with installation contractors, perceived knowledge of installation contractors, perceived quality of recent installations, and perceived impact of the new systems on utility bills. We assigned customers to two climate zone groups using the 2009 California Residential Appliance Saturation Study (RASS) data associated with the 16 climate zones established in California Energy Commission's Title 24.[11] The eight climate zones with the fewest cooling degree days (CDDs) per year formed the Mild region, and the other eight climate zones with the most CDDs formed the Inland region.[12] The sample size of 297 residential customers provides survey results at the 90% confidence level with precision of +/-5.9%. The sample size of 300 small commercial customers provides survey results at the 90% confidence level with +/-4.9% precision.
- For this study, NMR conducted interviews with seven program staff members at Pacific Gas &Electric (four), Southern California Edison (one), and San Diego Electric & Gas (two) focused on understanding the IOUs' approaches to promoting QI and QM. The interviews covered program design, performance, and measures of success.
- WO 32 (Residential and Small Commercial HVAC Impact Evaluation) conducted interviews with 20 independent HVAC distributors covering 18 companies that participated in the HVAC Distributor Incentive Program in 2011 and 2012 and two companies that did not participate in the program. Interviewers obtained information on annual sales of HVAC equipment such as packaged and split-system AC units.

[11] KEMA, Inc., "2009 California Residential Appliance Saturation Study," CEC-200-2010-004-ES, October 2010, http://www.energy.ca.gov/appliances/rass/.
[12] A CDD is a day where the average temperature was 65°F or higher.

Interviewers also asked respondents to provide estimates of the percentage of their sales by SEER rating and by CPUC HVAC program tier.

- The Commercial Market Share Tracking (CMST) Study consisted of a telephone survey of 7,890 commercial customers; on-site assessments at 197 commercial customer facilities customer facilities where new HVAC systems had recently installed; and a survey of 123 contractors who install commercial HVAC systems. The on-site assessments and contractor survey focused on customers installing small, single-zone, split or packaged HVAC units (under 65,000 Btuh) with direct expansion.
- The California Lighting and Appliance Saturation Study (CLASS 2012) conducted on-sites of 1,987 homes, including 1,433 homes with cooling systems.
- WO 32 (Residential and Small Commercial HVAC Impact Evaluation) conducted field assessments of 50 participant and 50 non-participant residential HVAC installations, 50 residential existing systems, and 30 commercial existing systems. The study identified qualifying respondents from the WO54 customer surveys, the WO24 CMST study, and the WO21 CLASS study. The field assessments focused on measurements that could be compared to the energy code requirements and baseline assumptions for quality installation (QI) and quality maintenance (QM). Onsite data collection included:
  - Residential – Building characteristics and information for load calculations, duct leakage measurements, heating and cooling airflow and power measurements, and measurements of Title 24 refrigerant charge verification diagnostics;
  - Commercial - Building characteristics for the zone served by the unit, ventilation and cooling airflow and power measurements, economizer functionality assessment, and measurements of Title 24 refrigerant charge verification diagnostics

1.3 Report Organization

This report has six main sections. The first is this introductory section. The second section discusses current market shares of high-efficiency HVAC equipment. The next two sections address quality installation (QI) and quality maintenance (QM). The fifth section presents a proposed market share tracking system with a systematic process for periodic reporting of different types of HVAC sales by efficiency level in the future. The sixth and final section summarizes the findings and conclusions that may be drawn from this study and offers several recommendations aimed at increasing program effectiveness.

2 HVAC Market Shares

One goal of the CPUC investor-owned utility programs is to increase the market share of high-efficiency systems. In this section, we report results obtained by the following recent studies of market share and penetration of high-efficiency residential and commercial HVAC equipment to address MTI-1:

- WO21: Residential On-site Study: California Lighting and Appliance Saturation Study (CLASS 2012) Draft Final Report by the CLASS team (Work Order 21) - Estimates of saturation of energy-efficient residential HVAC equipment.[13]
- California Commercial Market Share Tracking Draft Study by the CMST/CSS team (Work Order 24) - Estimates of saturation of energy-efficient commercial small HVAC equipment.[14]
- DNV GL (Work Order 32) interviews with 20 independent HVAC distributors conducted in August 2013 covering 18 companies that participated in the HVAC Distributor Incentive Program in 2011 and 2012 and two companies that did not participate in the program. Estimates of market share of energy-efficient residential and non-residential HVAC equipment.[15]
- NMR interviews with 8 independent HVAC distributors in California conducted between April 23 and May 6, 2013 (Work Order 054) - Estimates of California distributor market share of energy-efficient residential and non-residential HVAC equipment.[16]

2.1 Overview of Key Findings

Market shares of energy-efficient HVAC equipment sold to residential and small commercial customers in 2011 and 2012 in California were significant. Overall nearly one-half (46%) of the HVAC units sold were single-phase air cooled and four out of every ten of these (40%) met Tier 1[17] or better efficiency standards. The next largest market share (23%) was for air cooled three-phase packaged and split equipment; more than one-half of these units (56%) met Tier 1 or better efficiency standards.[18] Just over eight out of ten (81%) of the remaining unit types met Tier 1 or better efficiency standards.

[13] WO21: Residential On-site Study: California Lighting and Appliance Saturation Study (CLASS 2012) Draft Final Report
[14] California Commercial Market Share Tracking Draft Study
[15] KEMA, Final DNV KEMA Distributor Survey
[16] NMR Group, Inc., Distributor Market Share Survey Memo, May 9, 2013.
[17] Performance tiers were defined using the 2010-2012 SCE Qualifying Minimum Equipment Efficiencies & Incentive Levels for Commercial Air Conditioners (see Appendix A). The number of tiers and tier standards, defined based on minimum unit SEER, EER, or IEER ratings, vary by HVAC unit type and capacity.
[18] Single-phase air cooled equipment was predominantly residential and three-phase equipment was almost exclusively commercial.

The California Energy Efficiency Strategic Plan calls for 15% of HVAC equipment shipments optimized for California's climate by 2015 and 70% by 2020. The market transformation indicator of progress toward this goal is annual sales of climate-appropriate air conditioning. Using Tier 1 or better as a proxy for indicating climate appropriate AC, this study estimates that overall 57% of HVAC units sold to residential and small commercial customers in 2011 and 2012 met the criterion. Thus, based on a Tier 1 standard, the current estimate of sales exceeds the goal set by the California Energy Efficiency Strategic Plan for 2015 and approaches the more ambitious goal for 2020. Only 13.5% of HVAC units sold in 2011 and 2012 would meet a higher climate-appropriate standard of Tier 2 or better.

2.2 HVAC Saturation in the California Residential Market by Unit Type and Efficiency Level

The 2012 California Statewide Residential Lighting and Appliance Efficiency Saturation Study (CLASS report)[19] completed 1,987 onsite surveys of single-family, multi-family and mobile home residences in the service territories of the California Investor Owned Utilities (IOUs). The results of the onsite assessments were extrapolated to the full population of California. This study found that 80% of the primary cooling systems in California residences in 2012 were central systems with capacities typically fewer than five tons.[20] The remaining 20% of California homes with cooling systems used space cooling units with the majority (92%) having capacities under one ton.

Table 2-1 shows the percentage distribution of central HVAC cooling system unit types in California homes in 2012. Split-system AC, packaged system AC, split--system heat pump, and packaged system heat pump are all air-cooled equipment and typically single-phase in residential applications.[21] These units make up 95% of existing residential central cooling systems in California. The majority of central units (76%) are split-system AC.

[19] WO21: Residential On-site Study: California Lighting and Appliance Saturation Study (CLASS 2012) Draft Final Report

[20] Unlike the CMST, they were not studying recently installed systems.

[21] Ductless mini-split and ductless multi-split units were not identified separately in the CLASS report, but if they were present in California homes they likely would have been counted as either split-system heat pumps or split-system AC units.

Table 2-1: Saturation of Residential Central HVAC Cooling Systems in California by Unit Type[22] [23]

HVAC Unit Type	Existing Primary Heating System Types
Sample Size	*1207*
Split-system AC	76%
Packaged System AC	15%
Split-system Heat Pump	2%
Packaged System Heat Pump	1%
Common Building	1%
Evaporative Cooler	5%
All Central HVAC Systems	100%

Table 2-2 shows the efficiency distribution derived from these data. The largest percentages of central units of all types had efficiencies in the 10-11.99 SEER range (43%) and in the 13-13.99 SEER range (25%). The survey found that only a small percentage (8%) of the central HVAC units had SEER values of 14 or higher. No information on the efficiency of existing common building or evaporative cooler type central HVAC units was obtained in the CLASS study; however, as shown in Table 2-1, they represent less than 6% of the systems.

[22] WO21: Residential On-site Study: California Lighting and Appliance Saturation Study (CLASS 2012) Draft Final Report Note that central cooling units comprise 80% of the cooling systems in California and the remaining 20% of the market consists of space cooling units.

[23] WO21: Residential On-site Study: California Lighting and Appliance Saturation Study (CLASS 2012) Draft Final Report

Table 2-2: Saturation of Residential Central HVAC Cooling Systems in California by Efficiency Level and Unit Type[24] [25]

Residential HVAC Unit Type	Less than 10 SEER	10-11.99 SEER	12-12.99 SEER	13-13.99 SEER	14-15.99 SEER	16 or Higher SEER
Split-system A/C (n=689)	13%	43%	12%	26%	6%	1%
Package System A/C (n=55)	5%	41%	27%	19%	8%	-
Split-system Heat Pump (n=20)	11%	36%	2%	17%	25%	8%
Package System Heat Pump (n=1)	-	-	100%	-	-	-
All Types (n=765)	12%	43%	13%	25%	7%	1%

Percentages by unit type may not add to 100% because of rounding.

2.3 High Efficiency HVAC Market Share in the California Commercial Market

The California Commercial Market Share Tracking Draft Study (CMST report) provided data on the efficiencies of small single--zoned HVAC air conditioning units (including heat pumps) recently installed by non-residential customers. The study focused on split- and packaged-single zone HVAC systems with DX cooling, and packaged-single zone systems with evaporative cooling, less than or equal to 65,000 Btuh. It provided findings based on a survey of 123 contractors who collected information on the efficiency of recent sales, and on-site data collection on recent purchases at 193 end user businesses installing new HVAC systems. The on-site visits resulted in inspections of 893 HVAC units installed between 2009 and 2012. Table 2-3 shows a comparison of the HVAC unit efficiency rating distribution derived from the HVAC contractors' survey, the end-user survey covering 2011-12 installations, and the end-user survey covering 2009-12 installations. The 2009-2012 end-user survey results appear to be most representative of the current market for these types of HVAC units since these results are based on a large sample of verified unit performance ratings, and they are in the middle of the more current 2011-12 estimates from the contractor survey and the end-user survey.

[24] Note that central cooling units comprise 80% of the cooling systems in California and the remaining 20% of the market consists of space cooling units.
[25] Ibid

Table 2-3: Market Share of Non-residential Small HVAC Air Conditioning Units in California by Efficiency Level[26]

Reference Survey	Base Efficiency	High Efficiency			
	< 14 SEER	14-14.99 SEER	15-15.99 SEER	16-16.99 SEER	>17 SEER
CMST End-user survey, 2011-12 (n= 420 units)	65%	0%	13%	17%	5%
HVAC Contractor Survey, 2011-12 (n= 123 contractors, weighted by HVAC revenue)	78%	14%	4%	4%	-
CMST End-user survey, 2009-12 (n= 893 units)	73%	5%	10%	10%	2%

2.4 HVAC Market Share (Sales) in California by Unit Efficiency Level and Type

The interviews with 20 independent HVAC distributors yielded market data on the sales of HVAC systems installed in California in 2011 and 2012. Eight of these distributors provided estimates of the percentage of their sales by CPUC HVAC program tier and by unit type. These respondents also provided estimates of the number of units sold by eight unit types with no capacity limits. NMR estimated these eight distributors to account for more than 35% of the California HVAC market, based on distributor interviews it conducted to assess the level of consolidation in the market. Table 2-4 shows the distribution of weighted average sales volume percentages across efficiency levels, weighted by each respondent's share of total units sold, for each unit type.

Performance tiers were defined using the 2010-2012 SCE Qualifying Minimum Equipment Efficiencies & Incentive Levels for Commercial Air Conditioners[27] (see Appendix A). The number of tiers and tier standards, defined based on minimum unit SEER, EER, or IEER ratings, vary by HVAC unit type and capacity. Almost two-thirds of single-phase air-cooled HVAC units (60%) sold in 2011 and 2012 fall into Tier 0 and do not meet minimum program standards for this type of unit. Most of the rest of this unit type (40%) are rated at Tier 1, the lowest qualifying efficiency level for single-phase air-cooled equipment. At the other end of the spectrum, most ductless multi-split units sold are higher-efficiency units with over three-quarters (78%) of units sold rated at Tier 2 and most of the remaining units rated at Tier 1. Air-cooled three-phase and-water cooled units were sold over a wide range of efficiency levels from Tier 0 to Tier 4.

[26] California Commercial Market Share Tracking Study, Draft Report

[27] Southern California Edison Commercial HVAC Distributor Incentive Program, 2010-2012 Qualifying Minimum Equipment Efficiencies & Incentive Levels for Commercial Air Conditioners and Heat Pumps. https://www.cainstantrebates.com/ca_media/er/img/SCE_HVAC_Incentive_Levels_2012.pdf

Table 2-4: Estimated Distribution of HVAC Market Share by Efficiency Level and Unit Type[28]

HVAC Unit Type	Tier 0	Tier 1	Tier 2	Tier 3	Tier 4
Air-cooled 3-phase (n= 8 distributors)	44%	39%	10%	4%	2%
Water source HP / evap. cooled AC (n= 7 distributors)	23%	51%	26%	NA	NA
Single-phase air-cooled (n= 6 distributors)	60%	40%	NA	NA	NA
Ductless mini-splits (n= 4 distributors)	22%	60%	18%	0%	NA
Ductless multi-splits (n= 2 distributors)	1%	21%	78%	NA	NA
Overall (n=8 distributors)	43%	44%	12%	1%	1%

Responding distributors represent over 35% of HVAC market share in California, except for ductless multi-splits where 2 distributors represent approximately 17% of HVAC market share.
Some distributors reported equipment sales of units in tiers that were higher than available. These were included in the highest tier for the unit type.
Percentages may not add to 100% because of rounding.

2.4.1 Residential versus Non-residential HVAC Market Share by Unit Type

The distributors who reported number of units sold by type and sales distribution by efficiency level also estimated the percentage of each equipment type sold to residential and non-residential markets. Again, their estimates were weighted by their relative sales volume to obtain a weighted average percentage of each unit type sold in each market (Table 2-5).

Both air-cooled three-phase HVAC units and water-cooled units were almost exclusively sold in non-residential markets. All of the responding distributors estimated that 100% of their air-cooled three-phase HVAC units were sold in the non-residential market. All except one distributor reported that 100% of their water-cooled units were sold in the non-residential market (weighted average 98%). Single-phase air-cooled packaged and split equipment was predominantly sold in the residential market (90%). Ductless mini-split and multi-split units sales volume was shared by the residential and non-residential markets, with a weighted average of two-thirds of the mini-split equipment sales volume occurring in the residential market (67%) and a little more than two-thirds of the multi-split equipment sales volume occurring in the non-residential market (70%).

[28] Interviews with 20 independent HVAC distributors conducted in August 2013 covering 18 companies that participated in the HVAC Distributor Incentive Program in 2011 and 2012 and two companies that did not participate in the program

Table 2-5: Estimated Residential and Non-Residential HVAC Market Shares by Unit Type[29]

HVAC Unit Type	% Residential	% Non-residential
Air-cooled three-phase packaged and split equipment (n= 8 distributors)	0%	100%
Water source HP or water/evaporative cooled AC (3-phase & single-phase) (n= 7 distributors)	2%	98%
Single phase air-cooled equipment (n= 6 distributors)	90%	10%
Ductless mini-splits (n= 4 distributors)	67%	33%
`Ductless multi-splits (n= 2 distributors)	30%	70%

Responding distributors represent over 35% of HVAC market share in California, except for ductless multi-splits where 2 distributors represent approximately 17% of HVAC market share.
Percentages may not add to 100% because of rounding.

The California Energy Efficiency Strategic Plan calls for 15% of HVAC equipment shipments optimized for California's climate by 2015 and 70% by 2020. The market transformation indicator of progress toward this goal is annual sales of climate-appropriate air conditioning. Using Tier 1 or better as a proxy for indicating climate appropriate AC, this study estimates that overall 57% of HVAC units sold to residential and small commercial customers in 2011 and 2012 met the criterion. Thus, based on a Tier 1 standard, the current estimate of sales exceeds the goal set by the California Energy Efficiency Strategic Plan for 2015 and approaches the more ambitious goal for 2020. Only 13.5% of HVAC units sold in 2011 and 2012 would meet a higher climate-appropriate standard of Tier 2 or better.

2.4.2 Estimated Sales and Market Share in California by Unit Type

The total number of units sold in California in 2012 by HVAC unit type was estimated by adding the number of units by type as reported by the eight distributors who provided that information and extrapolated to all of California based on the approximately 35% market share represented by these distributors. The market share percentage of each HVAC unit type was then determined from these totals (Table 2-6).

This analysis yielded an estimate of 186,000 total units sold in California in 2012. Single-phase air-cooled packaged and split units made up almost half of the market (46%). Air-cooled three-phase packaged and split equipment accounted for nearly one-quarter of the market (23%).

[29] Interviews with 20 independent HVAC distributors conducted in August 2013 covering 18 companies that participated in the HVAC Distributor Incentive Program in 2011 and 2012 and two companies that did not participate in the program

Table 2-6: Estimated Sales and Market Share in California by HVAC Unit Type[30]

HVAC Unit Type	Estimate of Sales	Estimated Market Share
Air Cooled Three-Phase Packaged & Split Equipment	42,743	23%
Water Source HP; Water/Evap. Cooled AC (3-phase & single-phase)	17,971	10%
Single-phase Air Cooled	84,531	46%
Ductless Mini-Split	31,543	17%
Ductless Multi-Split	8,894	5%
Total	185,683	100%

Percentages may not add to 100% because of rounding.

[30] Ibid.

3 Quality Installation

Several aspects of Quality Installation (QI) are covered in this section: industry standards, contractor and customer awareness and attitudes, contractor and customer experiences and practices, the California IOU programs promoting QI, and field assessments of homes with recently installed HVAC systems.

3.1 Overview of Findings

The baseline for Quality Installation (QI) in California is relatively low. Only a minority of contractors (42% residential; 36% small commercial) were aware of ACCA Standard 5 and a small minority said they adhere to all of its specifications (14% of all residential contractors; 8% of all small commercial contractors). Thirty-five percent of residential contractors and 19% of small commercial contractors said they were currently participating or had ever participated in an IOU QI program.[31] However, only 10% of residential contractors and 8% of small commercial contractors said they are currently participating in such a program. This self-reported participation rate is likely to be overstated by contractors responding to the survey since only a very small percentage of installation contractors, ranging from 1% to 3%, depending on the IOU, have been trained and/or qualified by the IOUs. Program training, generally to ACCA Standard 5 and/or ENERGY STAR® QI, is a prerequisite for participation.

When asked about other certifications, more than one-half (53% residential; 59% small commercial) of installation contractors said their technicians were not certified by any organization. Note that only two-fifths (40%) of residential and just over one-fourth (27%) of small commercial installation contractors hold NATE certifications, which are promoted by the IOU programs.

QI awareness among customers is fairly low. Less than one-fifth of residential respondents (16%) and small commercial respondents (17%) had heard of the term quality installation. Even after it was described to them, about a quarter of all customers (25% residential; 28% small commercial) said they had heard of QI, and almost none of those customers could identify any QI guidelines or programs. When asked about the specific QI and rebate programs offered by their IOU, 10% to 21% of residential customers and 8% to 16% of small commercial customers said they had heard of particular IOU programs. Not surprisingly, contractors report the greatest barrier to QI is customers not wanting to pay for it (63% residential; 66% small commercial).

Another potential barrier to QI (which also applies to QM) is the presence of unlicensed HVAC contractors. According to the California Contractors State License Board (CLSB), there are between 12,000 and 16,000 HVAC contractors who have C-20 licenses.[32] However, the CLSB

[31] This figure was likely over-stated as a result of respondents including any IOU program they had participated in, even though they were specifically asked about the Quality Installation program.
[32] The CSLB C-20 license is for Warm-Air Heating, Ventilating and Air-Conditioning Contractors.

estimates that there may be about 3,000 unlicensed HVAC contractors operating in California.[33] The presence of these unlicensed contractors who do not pull the necessary building permits for HVAC installations or who perform shoddy, low-cost maintenance jobs may be placing additional cost pressure on contractors, potentially weakening adherence to QI and QM.

The QI field assessments, which are discussed at length in Section 3.6 and in Appendix F, found a mixed record of compliance with Title 24 among installations in the overall HVAC replacement market. However, system performance metrics in the overall market were generally not as poor as assumed by the QI program.[34] The field assessments found that many systems have duct leakage greater than the Title 24 specification of <15% and program efficient case assumption of 12%, but the average of 17% shows they were not as leaky as the baseline 24% duct leakage assumed by the QI program. The Title 24 minimum and efficient case assumption specifies system airflow at 400 CFM/ton. System airflows of 300 CFM/ton measured during the program non-participant site visits were even lower than the 350 CFM/ton baseline assumed by the QI program. There is undersizing and oversizing relative to Manual J, with systems not participating in the program oversized by an average of 13% which is lower than the baseline assumption of 20%. Table 3-1 summarizes these findings. The field assessments used Title 24 and manufacturer diagnostics to verify that proper refrigerant charge was present in all the systems tested. However, recent studies have found that the Title 24 and other diagnostics used to verify refrigerant charge are flawed; thus the results of this field assessment are considered to be indeterminate.

Table 3-1: QI Field Observations and Assumptions for the Program Baseline and Efficient Case

Statistic	Field Observations (mean)	QI Program Baseline Assumptions	QI Efficient Case Assumptions
Total System Duct Leakage	17%	24%	12%
System Airflow (CFM per ton)	300	350	400
System Oversizing	13%	20%	0%

[33] The CSLB staff member noted that this estimate is of contractors and not technicians.
[34] WO32 is developing savings estimates based on field findings, but these were not available for inclusion in this report.

3.2 Industry Standards for Quality Installation

In California, the same industry standards are understood statewide to constitute the guidelines for quality installation. All three IOUs utilize the American National Standards Institute (ANSI)/ Air Conditioning Contractors of America (ACCA) Standard 5 for residential and commercial quality installation. ACCA Standard 5[35] covers:

- Design procedures and tasks required before the equipment is installed. These include building ventilation requirements, building heat gain/loss load calculations, proper equipment capacity sizing, and ensuring that all heating and cooling equipment are properly matched systems.
- Equipment installation requirements. These include verifying that the airflow through the indoor blower unit is within acceptable CFM ranges; ensuring that the HVAC system has the proper refrigerant charge; ensuring all electrical requirements are met; ensuring the equipment combustion is "on-rate" for gas-fired or oil-fired equipment and at the equipment nameplate value; ensuring proper sizing, design, material selection and assembly of the combustion gas venting system; and ensuring the system operational and safety controls are properly selected and functioning.
- Distribution aspects. These include ensuring the ducts are properly sealed and air leakage is minimized; and ensuring room airflows meet the design/application requirements.
- System documentation and owner education aspects. These include providing records pertaining to the installation, operation and maintenance to be performed on the system to the owner; and educating the owner on the operation and maintenance of the system, including the benefits of planned system maintenance.

Although ACCA Standard 5 is said to apply to both residential and commercial quality installation, there is less consensus regarding the industry standard best suited to govern commercial QI activities in California. The IOUs have utilized ENERGY STAR® guidelines for commercial QI, with reportedly mixed results.[36]

[35] Summarized from ACCA Standard 5, HVAC Quality Installation Specification; full text is found in Appendix A
[36] Based on interviews with seven IOU HVAC program staff members conducted by NMR in 2012

3.3 Quality Installation Awareness and Attitudes

Both the contractor and customer surveys examined awareness of quality installation, focusing on ACCA standards and guidelines as well as what role QI played in the selection of a contractor, addressing some of the secondary indicators identified in Table 1-2 (SIQI-1, SIQI-2). The surveys also examined the perceived benefits of QI from both the contractors' and customers' perspectives and the contractors' perceived barriers to implementing QI.

3.3.1 Awareness of Quality Installation and ACCA Standards

Over two-fifths of the residential contractors (42%) and over one-third of small commercial contractors (36%) who had reported that some of their company's business consisted of installation jobs said that they are aware of the ACCA Standard 5. (Table 3-2)

Table 3-2: Awareness of ACCA Standard 5 among Contractors[37]

Aware of ACCA Standard 5	Residential Installation Contractors	Small Commercial Installation Contractors
Sample Size	*116*	*114*
Yes	42%	36%
No	49	56
Don't know	7	8
No answer	2	--

Fewer customers were aware of quality installation. Less than one-fifth of residential respondents (16%) and small commercial respondents (17%) had heard of the term quality installation. When interviewers aided respondents with a definition of QI,[38] one-quarter of all residential respondents (25%) and more than one-quarter of all small commercial respondents (28%) recognized the term. Mild region small commercial customers (37%) were significantly more likely than Inland small commercial customers (21%) to have heard of QI when aided (Table 3-3).

Table 3-3: Unaided and Aided Awareness of Quality Installation by Customers[39]

Heard of Quality Installation	Residential Customers			Small Commercial Customers		
	Inland	Mild	Total	Inland	Mild	Total
Sample Size	*236*	*61*	*297*	*235*	*65*	*300*
Unaided	16%	16%	16%	14%	20%	17%
Aided	25%	25%	25%	21%	37%†	28%

† Significantly different from Inland customers at the 90% confidence level.

[37] Online contractor survey of 245 contractors conducted during May and June of 2012

[38] Interviewers defined how *quality installation* requires that a new commercial AC system is selected and installed according to specific industry standards and guidelines so as to ensure the proper performance of the system.

[39] Telephone surveys of 297 residential customers and 300 small commercial customers conducted between August and October 2012

Even the few customers with aided awareness of QI, however, were largely unaware of any QI guidelines or programs. (Note that the great majority of customers (75% of residential customers and 72% of small commercial customers) had no awareness of QI and thus were not asked this question.) Seven percent of all residential customers said they were aware of QI guidelines. When asked to identify any guidelines or programs by name, only one respondent (5% of those aware of QI guidelines) was able to identify any, mentioning SCE's Professional Air Conditioning Installation Rebate Program. Similarly, 5% of all small commercial customers said they were aware of QI guidelines, but less than one-half of these respondents (6 of 14) were able to list specific guidelines or programs. Most frequently they mentioned ENERGY STAR (3) and SCE's Professional Air Conditioning Installation Rebate Program (2) (Table 3-4).

Table 3-4: Awareness of Quality Installation Guidelines and Programs by Customers[40]

Aware of Any Guidelines	Residential Customers			Small Commercial Customers		
	Inland	Mild	Total	Inland	Mild	Total
Sample Size	*236*	*61*	*297*	*235*	*65*	*300*
No	16%	21%	19%	17%	30%†	23%
Yes	8	5	7	3	7	5
Not aware of Quality Installation[Ψ]	75	75	75	79†	63	72
Awareness of Specific Quality Installation Guidelines (Multiple Responses)*						
Sample Size	*17*	*3*	*20*	*10*	*4*	*14*
SCE Professional AC Installation Rebate Program	1	0	5%	1	1	2
ENERGY STAR	--	--	--	2	1	3
PG&E AC Quality Care Rebate Program	--	--	--	1	--	1
ACCA Standard 9	--	--	--	1	--	1
ACCA Standard 5	--	--	--	1	--	1
Aware but unable to name specific guidelines and programs	16	3	95	5	3	8

† Significantly different from Inland or Mild customers at the 90% confidence level.

*Results are reported as unweighted counts where sample size is less than 20.

Ψ The survey design filtered the questions asked of respondents so that if respondents were not aware of a topic, they were not asked further questions pertaining to it. Thus the respondents reported here were not asked this question but their responses are included so as to provide percentages based on the total sample of customers.

Customers who had HVAC systems installed within the past two years were asked if they had specifically asked about QI guidelines when choosing a contractor to install their new systems. (Note that the great majority of customers (96% of residential customers and 95% of small commercial customers) either had not purchased new cooling equipment or had no awareness of QI and thus were not asked this question.) Most respondents aware of QI recalled specifically

[40] Telephone surveys of 297 residential customers and 300 small commercial customers conducted between August and October 2012

asking their contractor about it during the selection process, but they represent a small fraction of all respondents—2% of all residential customers and 4% of all small commercial customers. These percentages are subject to measurement error; it may thus be assumed that almost no customers ask their contractors about QI. More importantly, most customers who had HVAC systems installed within the past two years were not aware of QI (60% of residential customers and 67% of small commercial customers) and thus could not ask their contractors about it. (Table 3-5)

Table 3-5: Customer Selection of Installation Contractor and QI Guidelines[41]

Specifically Asked About Quality Installation Guidelines When Selecting Contractor	Residential Customers			Small Commercial Customers*		
	Inland	Mild	Total	Inland	Mild	Total
Sample Size	*236*	*61*	*297*	*235*	*65*	*300*
Yes	1%	3%	2%	3%	6%	4%
No	2†	--	1	1	1	1
Don't know/Refused	1	--	<1	<1	--	<1
Have not purchased new cooling equipmentΨ	89	93	90	81	89†	85
Purchased new equipment but not aware of Quality InstallationΨ	7	5	6	14†	4	10

*Equipment includes the following types of equipment: Split Systems, Packaged Systems, Package terminal AC or Heat Pumps, and Individual AC or Heat Pump Units.

† Significantly different from Inland or Mild customers at the 90% confidence level.

Ψ The survey design filtered the questions asked of respondents so that if respondents were not aware of a topic, they were not asked further questions pertaining to it. Thus the respondents reported here were not asked this question but their responses are included so as to provide percentages based on the total sample of customers.

Customer awareness of QI in general and specific programs and guidelines may not be necessary to ensure quality installation for new HVAC systems in a market where the baseline is already relatively high. However, the HVAC contractor responses and field observations reported throughout this study highlight the need for customers to be aware of and value QI, at least until progress toward market transformation is further along.

3.3.2 Meaning of Quality Installation

The surveys asked both installation contractors and customers for their definitions of quality installation; as would be expected, the contractors provided much more specific responses. Residential installation contractors most commonly cited having the correct system and duct sizing (19%) and being in compliance with city/state codes (e.g. Title 24) (19%). About one-fifth of small commercial installation contractors (21%) cited being in compliance with city/state codes and 15% cited having the correct system and duct sizing (Table 3-6). Note also that about one-third of contractors did not answer this question. Additionally, in view of the field

[41] Telephone surveys of 297 residential customers and 300 small commercial customers conducted between August and October 2012

assessments described in Section 3.6, there may be a disconnect between contractors' survey responses and their technicians' actual practices in the field.

Table 3-6: Contractors' Definitions of "Quality Installation"[42]

Definitions	Residential Installation Contractors	Small Commercial Installation Contractors
Sample Size (multiple response)	*116*	*114*
'Correct' system and duct sizing	19%	15%
In compliance with city/state codes (e.g. Title 24)	19%	21%
Duct sealing	16%	12%
Installed to manufacturer specifications	14%	7%
A clean looking or 'neat' system	11%	9%
Customer is satisfied	9%	8%
Peak/optimum performance	9%	10%
Measure refrigerant charge	6%	4%
Work is permitted/passes permit inspection	4%	4%
Test for duct leakage	5%	3%
Standards-based (ACCA 5,180, BPI, NCI, IHACI, SMACNA, LEED)	3%	2%
Calculate sizing with Manual J	3%	3%
Other	55%	61%
No answer/Didn't answer question	36%	33%

The survey[43] asked customers with unaided awareness of QI what they understood the term to mean. Note here that the great majority of customers (84% of residential customers and 83% of small commercial customers) had no unaided awareness of QI and thus were not asked this question. Of those that did respond, residential customers most commonly associated QI with high standards of quality (3% of all respondents), unspecified installation standards (2%), attention to duct sizing and leakage (2%), installer qualifications (2%), and compliance with code (2%). Small commercial respondents most commonly associated QI with work being properly done (3%) and installer qualifications (3%).

3.3.3 Quality Installation Perceived Benefits and Barriers

The survey asked installation contractors if they agreed or disagreed that proper HVAC installation provided specific benefits. A large majority strongly agreed that proper HVAC installation benefits include increasing energy savings and reducing electric bills, increasing customer comfort, improving a system's reliability, prolonging a system's operational lifespan, preventing expensive repairs, and improving indoor air quality (Table 3-7).

[42] Online contractor survey of 245 contractors conducted during May and June of 2012
[43] Telephone surveys of 297 residential customers and 300 small commercial customers conducted between August and October 2012

Table 3-7: Installation Contractors' Perceived Benefits of Proper HVAC Installation[44]

(Percent that strongly agree benefit is provided)

Benefit	Residential Installation Contractors	Small Commercial Installation Contractors
Sample Size	*116*	*114*
Increase energy savings and reduce electric bills	83%	74%
Increase customer comfort	76%	73%
Improve a system's reliability	80%	66%
Prolong a system's operational lifespan	81%	71%
Prevent expensive repairs	76%	61%
Improve indoor air quality	70%	56%

The survey[45] asked customers with unaided and aided awareness of QI to identify its benefits in an open-ended question. Only 25% of residential customers and 28% of small commercial customers were asked this question as the rest had no awareness of QI. Residential respondents most commonly suggested that achieving safe operating conditions (6%), increasing energy savings and reducing energy bills (5%), and improving the reliability of their systems (4%) are the benefits of QI. Similarly, small commercial respondents most commonly suggested that the benefits of QI are increasing energy savings and reducing energy bills (9%), improving the reliability of their systems (6%), and achieving safe operating conditions (4%).

Customers and contractors, who were aware of the term, thus agreed that QI is expected to increase energy savings and reduce bills. Customers also mentioned, unprompted, the remaining five benefits that contractors were asked to rate: improving a system's reliability, preventing expensive repairs, prolonging a system's lifespan, ensuring indoor air quality, and ensuring comfort. Note, however, that three-quarters of residential customers and close to three-quarters of small commercial customers (72%) did not identify any QI benefits since they had no awareness of QI.

[44] Online contractor survey of 245 contractors conducted during May and June of 2012

[45] Telephone surveys of 297 residential customers and 300 small commercial customers conducted between August and October 2012

On average, residential customers who were aware of QI estimated that QI has the potential to reduce their electric bill by 17% while small commercial customers thought it has the potential to reduce their electric bill by 26% (Table 3-8). Note that the great majority of customers (75% of residential customers and 72% of small commercial customers) had no awareness of QI and thus were not asked this question. On average, Inland residential customers (21% decrease) thought they would achieve significantly greater savings than did Mild region residential customers (13% decrease). Inland region small commercial customers (29% decrease) also estimated they would achieve somewhat greater savings on average than did Mild region small commercial customers (22% decrease). Again, most respondents provided no response because they were either not aware of QI or did not provide an estimate of anticipated bill reductions.[46]

Table 3-8: Customers' Anticipated Savings on Electric Bills from Quality Installation[47]

Anticipated Percentage Savings	Residential Customers			Small Commercial Customers		
	Inland	Mild	Total	Inland	Mild	Total
Sample Size	*236*	*61*	*297*	*235*	*65*	*300*
0%	2%	7%	5%	1%	6%†	3%
1 to 10%	5	4	5	3	2	3
11 to 20%	3†	--	1	3	7	5
21 to 30%	2	1	1	1	1	1
31 to 40%	<1	--	<1	1	0	1
41 to 50%	--	--	--	2	3	3
More than 50%	2	2	2	1	1	1
Don't know/Refused	11	11	11	7	16†	11
Not aware of Quality Installation Ψ	75	75	75	79†	63	72
Average percentage savings	21%†	13%	17%	29%	22%	26%
Median percentage savings	10%	2%	7%	20%	20%	20%

† Significantly different from Inland or Mild customers at the 90% confidence level.

Ψ The survey design filtered the questions asked of respondents so that if respondents were not aware of a topic, they were not asked further questions pertaining to it. Thus the respondents reported here were not asked this question but their responses are included so as to provide percentages based on the total sample of customers.

The market for quality installation services is hindered by a lack of education or training about QI—among customers, a reluctance to pay for QI services is indicative of a lack of perception of its value; and, among contractors, a lack of technician or contractor knowledge of the what is needed to perform quality installation indicates a need for contractor training. Installation contractors reported that the top barrier to implementing high quality installation services is that customers do not want to pay for it; this was cited by close to two-thirds of residential (63%) and small commercial (66%) installation contractors. Data showing tangible value from QI, such as

[46] Note that there is no estimate of actual bill reductions resulting from QI; these findings are simply meant to gauge customer expectations.

[47] Telephone surveys of 297 residential customers and 300 small commercial customers conducted between August and October 2012

bill savings, would be useful in educating customers and increasing their willingness to pay for it. The second most common barrier was the technicians' or contractors' lack of knowledge, cited by one-quarter to one-third of respondents (Table 3-9).

Table 3-9: Contractors' Barriers to Implementing High Quality Installation Services[48]

Barriers	Residential Installation Contractors	Small Commercial Installation Contractors
Sample Size (multiple response)	*116*	*114*
Customers don't want to pay for it	63%	66%
Technicians' knowledge of what is necessary	27%	34%
Contractors/owner's knowledge of what is necessary	25%	35%
Available technical training in the market	16%	20%
Access to the right diagnostic tools	16%	16%
Access to quality maintenance checklists	15%	16%
Time constraints	3%	2%
Costs to contractor	2%	1%
Poor enforcement of permits, "lowball" contractors	2%	2%
Contractors spreading disinformation about requirements for installation	2%	--
Other	3%	3%
There are no barriers	22%	13%
No answer	3%	--

Another potential barrier to QI (which also applies to QM) is the presence of unlicensed HVAC contractors. According to the California Contractors State License Board (CLSB), there are between 12,000 and 16,000 HVAC contractors who have C-20 licenses.[49] However, the CLSB estimates that there may be about 3,000 unlicensed HVAC contractors operating in California.[50] The presence of these unlicensed contractors who do not pull the necessary building permits for HVAC installations or perform shoddy, low-cost maintenance jobs may be placing additional cost pressure on contractors, potentially weakening adherence to QI and QM.

[48] Online contractor survey of 245 contractors conducted during May and June of 2012.
[49] The CSLB C-20 license is for Warm-Air Heating, Ventilating and Air-Conditioning Contractors.
[50] The CSLB staff member noted that this estimate is of contractors and not technicians.

3.4 Quality Installation Experiences and Practices

Both the contractor and customer surveys examined quality installation experiences and practices, focusing on the duration of the installation visit and the installation services performed. The installation services areas covered included contractor adherence to ACCA Standard 5 and other formal policies and guidelines, the installation tasks performed, customer follow up, and the customers' rating of installations. The contractors' self-reported adherence to ACCA Standard 5 provides a baseline for MTI-2 and MTI-3.

3.4.1 Duration of Installation Visit

Only 10% of the residential customers surveyed had installed central AC systems within the last two years. These customers estimated varying amounts of time were required for their contractors to complete their installations. One-half of these respondents reported that the visits lasted ten hours or fewer; the average duration of the installations estimated by residential customers was 10.5 hours.[51]

Fifteen percent of the small commercial customers surveyed had cooling equipment installed within the past two years. One-half of these customers reported that the visits lasted less than eight hours; the average duration of the installations estimated by small commercial customers was 9.8 hours.[52]

3.4.2 Installation Services Performed

As noted in Section3.3.1, only 42% of residential and 36% of small commercial installation contractors are aware of ACCA Standard 5. About two-fifths of all residential (41%) and one-third (31%) of all small commercial installation contractors said that they adhere to some or all of ACCA Standard 5's specifications on a job; these responses were given by all residential and the vast majority of small commercial installation contractors who indicated awareness of ACCA Standard 5. However, only a minority of contractors who were aware of ACCA Standard 5 said they adhere to all of its specifications; overall only 14% of residential and 8% of small commercial installation contractors gave this response (Table 3-10).

[51] Telephone surveys of 297 residential customers and 300 small commercial customers conducted between August and October 2012

[52] Online contractor survey of 245 contractors conducted during May and June of 2012

Table 3-10: Installation Contractor Adherence to ACCA Standard 5[53]

Adherence	Residential Installation Contractors	Small Commercial Installation Contractors
Sample Size	*116*	*114*
Adhere to all of the standard's specifications on a job	14%	8%
Adhere to some of the standards specifications on a job	27	23
Aware of the standard but do not adhere to it on a job	--	4
Not aware of ACCA Standard 5	49	56
Did not know if aware of ACCA Standard 5	7	8
Did not indicate whether aware of ACCA Standard 5	2	--
No answer	1	1

Three percent of all residential and small commercial customers[54] said they thought that their contractor adhered to QI guidelines. This percentage is based on the small number of respondents who both had recently installed new HVAC equipment and were aware of QI. There were no respondents who believed their contractor had not adhered to QI guidelines.

Three-quarters of residential and close to three-fifths (59%) of small commercial installation contractors said their companies have a formal policy or set of guidelines that technicians are required to follow for installation procedures (Table 3-11).

Table 3-11: Contractors with Formal Policies or Guidelines that Technicians Are Required to Follow for Installations[55]

Formal policies or guidelines	Residential Installation Contractors	Small Commercial Installation Contractors
Sample Size	*116*	*114*
Yes	75%	59%
No	21	40
Don't know	3	1
No answer	2	1

The on-line survey of contractors provided a list of equipment, duct, and verification and maintenance work done during a typical installation and asked respondents to check off the tasks that they performed. A large majority of residential (95%) and small commercial (93%) installation contractors reported installing a properly matched indoor coil and outdoor unit (AC

[53] Online contractor survey of 245 contractors conducted during May and June of 2012
[54] Telephone surveys of 297 residential customers and 300 small commercial customers conducted between August and October 2012
[55] Online contractor survey of 245 contractors conducted during May and June of 2012

& heat pump only) and a programmable thermostat if one was not already in use (91% residential; 96% small commercial) during a typical installation. Nearly two-thirds of residential (64%) and about one-half of small commercial (49%) installation contractors also said they use Manual J to calculate the correct equipment size (Table 3-12). However, note again that the field assessments described in Section 3.6 found that technicians' actual practices in the field fell short of performing many tasks considered to be good practices (though that study examined maintenance rather than installation practices).

Table 3-12: Equipment Tasks Performed During a Typical Installation[56]

Tasks performed	Residential Installation Contractors	Small Commercial Installation Contractors
Sample Size (multiple response)	*116*	*114*
Install a properly matched indoor coil and outdoor unit (AC & heat pump only)	95%	93%
Install programmable thermostat (if not already in use)	91%	96%
Calculate correct sizing for equipment using Manual J	64%	49%
Test ductwork to determine maximum system size	53%	56%
Install new refrigerant lines (not reuse existing lines)	46%	54%
Setup programmable thermostat with customer (if not already in use)	86%	91%
Consider zoning, with separate temperature controls for different areas	59%	69%

Similarly, a large majority of residential and small commercial installation contractors reported that they make repairs to existing ductwork if necessary (94% residential; 95% small commercial) and inspect the integrity of all accessible ductwork (91% residential; 92% small commercial). More than three-quarters of residential (77%) and nearly two-thirds of small commercial (64%) installation contractors said they test to confirm that duct leakage does not exceed recommended levels (Table 3-13).

[56] Online contractor survey of 245 contractors conducted during May and June of 2012

Table 3-13: Duct Work Tasks Performed During a Typical Installation[57]

Tasks performed	Residential Installation Contractors	Small Commercial Installation Contractors
Sample Size (multiple response)	*116*	*114*
Make repairs to existing ductwork if necessary	94%	95%
Inspect the integrity of all accessible ductwork including: duct strapping, hangers, sections, joints, and seams	91%	92%
Inspect integrity of all accessible ductwork insulation	90%	95%
Inspect air filter housing integrity and air seal	85%	90%
If insulating ducts, seal all duct seams before insulating	83%	90%
Test to confirm that duct leakage does not exceed recommended levels	77%	64%
Inspect all accessible ductwork for areas of moisture accumulation or biological growth	64%	72%

The on-line survey of contractors provided a list of verification and maintenance work done during a typical installation and asked respondents to check off the tasks that they performed. The vast majority of residential (95%) and small commercial (92%) installation contractors reported that they inspect all electrical components for proper operation. Customer education consists of leaving them all the manuals (95% residential; 91% small commercial) and showing them how to replace air filters (95% residential; 82% small commercial). One-half of residential (50%) and two-fifths of small commercial (40%) installation contractors said they provide customers with documentation of installation procedures (Table 3-14).

[57] Online contractor survey of 245 contractors conducted during May and June of 2012

Table 3-14: Verification and Maintenance Tasks Performed During a Typical Installation[58]

Tasks performed	Residential Installation Contractors	Small Commercial Installation Contractors
Sample Size (multiple response)	*116*	*114*
Inspect all electrical components for proper operation	95%	92%
Leave all manuals with customer	95%	91%
Show customer how to replace air filter(s)	95%	82%
Inspect blower motors for proper operation	91%	93%
Measure refrigerant charge	91%	91%
Inspect condensate drains/traps for proper operation	90%	92%
Test system controls' modes of operation and control sequences	89%	90%
Inspect cabinet, cabinet fasteners, and cabinet panels	89%	88%
Confirm proper levels of refrigerant and airflow across the coil	87%	86%
Inspect condensate drains (and traps) for proper operation	86%	90%
Inspect accessible refrigerant lines, joints, and coils for oil leaks	85%	90%
Inspect economizers*	NA	79%
Measure airflow across heat exchanger/coil	65%	60%
Provide customer with documentation of installation procedures	50%	40%
Clean condenser coils	1%	--
Follow-up with customer to confirm satisfaction	1%	--
Customer education beyond filter	2%	--
HERS inspection	--	1%

*Only small commercial customers were asked if they inspected economizers

About three-fifths of residential (62%) and small commercial (63%) installation contractors said that their company has a formal policy or process for following up with residential customers after an installation. In an open-ended response, about one-fifth of residential (20%) and small commercial (17%) installation contractors said that they follow up after an installation with a phone call to customers. A minority of contractors also mentioned following up with maintenance agreements or general maintenance (Table 3-15).

[58] Online contractor survey of 245 contractors conducted during May and June of 2012

Table 3-15: Customer Follow-Up Procedures after an Installation Job [59]

Follow-up procedures	Residential Installation Contractors	Small Commercial Installation Contractors
Sample Size (multiple response)	*116*	*114*
Phone call	20%	17%
Maintenance agreement	8%	15%
Maintenance follow-up	9%	11%
Customer satisfaction check	9%	9%
Customer meeting/education	10%	4%
Other	21%	17%
Did not have a formal policy or guideline	36%	35%
Did not indicate whether they have a formal policy or guideline	2%	2%
No answer	14%	11%

Among the respondents who indicated installing new cooling equipment in the last two years, 10% of residential customers and the 15% of small commercial customers rated the quality of the installation quite highly (four or five on a five-point scale).[60] On average, residential respondents rated the quality of installation 4.7 and small commercial respondents rated the quality of installation 4.5. Note while these findings show high satisfaction with the work done, the customers are not likely to have an understanding of the elements of a quality installation and these ratings therefore cannot be considered indicators of the actual quality of the work performed by contractors.

3.5 California IOU Quality Installation Programs

The California IOU quality installation programs are described in detail in Appendix A, but generally require training to ACCA Standard 5 and/or ENERGY STAR® QI. The surveys examined awareness of and participation in QI programs among both contractors and customers addressing some of the secondary indicators identified in Table 1-2 (SIQI3, SIQI-4). This section concludes with an examination of contractor training and qualification, addressing SIQI5.

3.5.1 Program Awareness and Participation

After a brief description of the California IOU QI programs, about one-third of residential (35%) and nearly one-fifth of small commercial (19%) installation contractors reported that they had ever participated in such a program. However, only ten percent of residential and eight percent of small commercial installation contractors said that they are currently participating in an IOU QI

[59] Online contractor survey of 245 contractors conducted during May and June of 2012
[60] Telephone surveys of 297 residential customers and 300 small commercial customers conducted between August and October 2012

program (Table 3-16). These self-reported participation rates may be over-stated by the respondents confusing QI with other programs. As reported in Section 3.5.2, very few installation contractors have received IOU training and qualification for QI. Program, training generally to ACCA Standard 5 and/or ENERGY STAR® QI, is a prerequisite for participation.

Table 3-16: Contractors' Participation in a Quality Installation Program[61]

Participation	Residential Installation Contractors	Small Commercial Installation Contractors
Sample Size	*116*	*114*
Currently participating in an IOU QI program	10%	8%
Currently participating or have participated in the past in an IOU QI program	35%	19%
Have never participated in an IOU QI program	64%	75%
Did not know if they their company has participated in an IOU QI program	--	4%
Did not indicate whether their company participated in an IOU QI program	2%	1%

[1] One residential and one commercial case were recoded from yes to no as the respondents later indicated that they were not familiar with the programs.

Most residential customers (79%) said they were unaware of central AC system rebate programs. Almost all residential respondents who were aware of any equipment rebate programs were unable to name any. By contrast, nearly two-thirds of small commercial customers (64%) said they were aware equipment rebate programs existed, but, again, most (59%) were unable to name any specific programs.[62]

Residential respondents, even when prompted, were largely unaware of the specific QI programs offered by their IOUs. SDG&E residential customers were significantly more likely to have heard of SDG&E's Quality Care program than SCE or PG&E customers were to have heard of the programs offered by their IOUs. Likewise, small commercial respondents were largely unaware of the specific QI programs offered by the IOUs, even when prompted; again, SDG&E customers were significantly more likely to have heard of their IOU's program than customers of other IOUs (Table 3-17).

[61] Online contractor survey of 245 contractors conducted during May and June of 2012

[62] Telephone surveys of 297 residential customers and 300 small commercial customers conducted between August and October 2012

Table 3-17: Aided Customer Awareness of Quality Installation Programs*[63]

Aware of Program**	Residential Customers			Small Commercial Customers		
	Inland	Mild	Total	Inland	Mild	Total
Sample Size	*112*	*8*	*120*	*111*	*9*	*120*
SCE Installation	14%	1	14%	6%	1	8%
Sample Size	*81*	*36*	*117*	*80*	*40*	*120*
PG&E Quality Care	15%	6%	10%	16%	10%	13%
Sample Size	*43*	*17*	*60*	*44*	*16*	*60*
SDG&E Quality Care	14%	4	21%†	23%	2	16%†

*PG&E and SDG&E programs include QM as well as QI

**Results are reported as unweighted counts where sample size is less than 20.

†Significance testing compares the values within a single column as opposed to comparing values in a single row.

Given the small proportions of customers aware of QI programs offered by the IOUs, it is not surprising that very few respondents believe they have received any rebates for QI (Table 3-18).

Table 3-18: Customer Participation in Cooling Equipment Quality Installation Programs[64]

Percentage That Received Program Rebate*	Residential Customers			Small Commercial Customers		
	Inland	Mild	Total	Inland	Mild	Total
SCE Installation						
Sample Size	*112*	*8*	*120*	*111*	*9*	*120*
Installation Rebate	2%	1	4%	--	--	--
PG&E Quality Care						
Sample Size	*81*	*36*	*117*	*80*	*40*	*120*
Installation Rebate	2%	3%	3%	1%	--	1%
SDG&E Quality Care						
Sample Size	*43*	*17*	*60*	*44*	*16*	*60*
Installation Rebate	--	1	4%	--	--	--

*Results are reported as unweighted counts where sample size is less than 20.

3.5.2 Quality Installation Training and Qualification of Contractors

NMR conducted an analysis of contractors who have gone through the IOUs' training and qualification programs. First, NMR determined the number and percentage of residential and commercial survey respondents by job type and service territory. NMR then multiplied these numbers by the total number of active C-20 licensed contractors in order to determine the estimated number of contractors by contractor sector (residential or commercial), job type (maintenance or installation), and service territory. The analysis based the total number of

[63] Telephone surveys of 297 residential customers and 300 small commercial customers conducted between August and October 2012

[64] Ibid.

contractors on an extrapolation from calls to HVAC contractors, described in the EMI report,[65] which estimated that there are a total of 8,210 firms with C-20 licensed HVAC contractors.[66]

NMR then divided contractor quality installation qualification and training data that was provided by the IOUs by the estimated number of installation contractors in each service territory. Table 3-19 reports the estimated percentage of installation contractors that are qualified through an IOU program in each of the three electric IOU territories.

Table 3-19: Percent of Installation Contractors Qualified by the IOUs

IOU	Residential Installation Contractors	Commercial* Installation Contractors
Pacific Gas & Electric**	3%	>1%
San Diego Gas & Electric	1%	1%
Southern California Edison	3%	--

* Since the IOUs presented training and qualification data on commercial contractors, without distinguishing small and large contractors, this analysis is presented for commercial contractors in general.
**Pacific Gas & Electric did not distinguish between qualified and trained contractors

When asked about other certifications, more than one-half of installation contractors said their technicians were not certified by any organization. It is important to note that only two-fifths of residential and just over one-fourth of small commercial installation contractors hold NATE certifications which are promoted by the IOU programs (Table 3-20).

Table 3-20: Installation Contractors' Certifications[67]

Certification	Residential Installation Contractors	Small Commercial Installation Contractors
Sample Size (multiple response)	*116*	*114*
Our company has none of these certifications	53%	59%
NATE C3	40%	27%
Other certifications/organization memberships	20%	13%
No answer	3%	7%

[65] For complete details on the methodology of the study see the EMI report, "California HVAC Contractor & Technician Behavior Study."
[66] As indicated in the EMI report, the sample frame for the incidence study was developed from the list of contractors contained in the California Contractors State License Board (CSLB) active C-20 list, obtained on December 17, 2011. The EMI report focuses on the number of firms, rather than the number of contractors, "Because the research team wanted only one response per contractor firm, the list of 10,806 C-20 contractors was de-duplicated by both company address and phone number. This process resulted in 10,486 unique contractors with phone numbers…. Following phone calls to a random sample of contractors and asking questions about C-20 licenses, 8,210 of 10,486 firms were estimated to be currently working in the industry and to hold a C-20 license."
[67] Online contractor survey of 245 contractors conducted during May and June of 2012

In view of the low share of installation technicians with any training and the contractors citing technicians' lack of knowledge as a barrier to QI (Table 3-9), this study has identified an increase in the number of technicians with training as a secondary indicator of HVAC subprograms' progress. This training should improve their knowledge of the requirements of QI; it may be accomplished through NATE training and some of the IOU program training.

3.6 Quality Installation Field Assessments

DNV GL conducted the quality installation field assessments for this study as an auxiliary task to the WO 32 field assessment work. Attempts to recruit and field non-residential installations were unsuccessful and the field assessments therefore focused on residential systems. The team recruited "non-participants" from a group of customers who were identified in the residential customer survey as having as having recently installed an HVAC system, but did not participate in Quality Install programs. This sample of non-participants was further supplemented with customers identified as having recently installed an HVAC system in the CLASS study (WO 21). The team recruited program participants from the SCE service area and identical protocols were followed at 50 participant and 50 non-participant sites.

3.6.1 Overview of Findings

The overall objective of the field assessments was to ascertain the extent to which recent installations in the general market met Title 24 minimum standards[68] and were consistent with QI program assumptions.[69] The field assessments found a mixed record of compliance with Title 24 among installations in the overall HVAC replacement market. In general, system performance metrics in the overall market were not as poor as assumed by the QI program. However, there were significant proportions of the market that did meet the QI program assumptions regarding sub-optimal performance metrics, and these should be targeted for improvement. Specific noteworthy findings from the QI field assessments include the following.

- **Duct Leakage**. The Title 24 requirements specify less than 15% duct leakage. There were many non-participant systems with leakage greater than the Title 24 minimum and program efficient case assumption of 12%, but on average they were not as leaky as the QI program assumption of 24% and there were many systems measured during site visits that were equal to or less than the 15% minimum.
- **System Airflow**. The Title 24 minimum and program efficient case assumption specifies system airflow at 400 cubic feet per minute (CFM) per ton. System airflows measured during the program non-participant site visits were even lower than the 350 CFM/ton baseline assumed by the QI program. The team noted that Title 24 does not take into

[68] Both participants and non-participants should be meeting Title 24 mandatory rules for replacements which are more fully described in Appendix F.
[69] The QI program assumptions are laid out in a work paper described in Section 3.6.3.

account the higher static pressures for actual systems which may be the key driver of the low airflows.

- **System Sizing**. Title 24 specifies using Manual J. There is under and oversizing relative to Manual J, and the program non-participant site visits revealed that systems were oversized by an average of 13%. The QI work paper assumes 20% oversizing for non-participants and correct sizing for participants.
- **Refrigerant Charge**. Title 24 specifies the refrigerant charge at the factory level. This field assessment used Title 24 diagnostics to verify that the proper refrigerant charge was weighed into the system after installation. However, recent studies cited in section 4.6.5 have found that the Title 24 and other diagnostics to verify refrigerant charge are flawed. As a result, the results of this field assessment were considered to be indeterminate.

The field assessments provide a market baseline relative to both Title 24 requirements and the IOU work paper baseline assumptions for QI. Table 3-21 summarizes the key findings from the field assessments.

Table 3-21: Comparison of Code Requirements, Field Findings, and Baseline Assumptions

Code Requirement	Field Findings for QI Non-Participants	IOU QI Work Paper Baseline Assumption	Implications from Field Findings
Duct Leakage <15%	16.6% Leakage +/- 2.3% ; 52% of cases have leakage greater than 15%	24% Leakage	There are many systems with leakage greater than Title 24 threshold, but on average they are not as leaky as assumed in the QI baseline as there are systems meeting or beating the 15% code requirement.
System Airflow at 400 CFM/ton	300 CFM / ton +/- 20 CFM / ton	350 CFM / ton	System airflows are even lower than assumed. Title 24 does not take into account higher static pressures for actual systems, which may be the key driver of the low airflows.
System Sizing using ACCA Manual J	Only 30% of cases within a half ton of Manual J; Manual J / Installed = 0.87	20% Oversizing	There is under and oversizing relative to Manual J, the average sizing ratio is 13% oversized. QI program adds Manual S and as a result more systems are within half ton, but many are between 0.1 ton and 0.5 ton oversized
Refrigerant Charge at Factory recommended level	Indeterminate – See Appendix F	N/A	See section 4.6.5. The use of Title 24 diagnostics and other diagnostic options is problematic in verifying proper charge. The indirect diagnostics do not reliably verify that proper charge was weighed into the system after installation.

All of the research conducted may be used to inform future ex-ante impact estimates and future program designs.

As a precursor to discussing the field results, it is important to briefly review both the Title 24 energy code requirements for replacement HVAC systems and the assumptions made by the Quality Installation (QI) program work paper.

3.6.2 Testing required for Compliance with Title 24

If all residential HVAC installations complied with Title 24 then the required values could serve as the baseline. However, compliance is thought to be much less than 100% and therefore this this study investigated these testing requirements. Specifically, this study investigated the requirements regarding duct sealing and refrigerant charge testing.

Duct Sealing. The Title 24 duct sealing requirements (maximum 15% leakage for existing and 6% for new ducts) apply to all climate zones for new systems serving newly constructed homes or additions to existing homes. Duct sealing is also required in certain climate zones when ducts are extended or HVAC equipment is replaced.

Refrigerant Charge Testing. The Title 24 refrigerant charge testing requirements only apply to specific climate zones in all cases: new construction, additions, or system replacements.

3.6.3 IOU Work Paper Assumptions for Quality Installation

The IOU QI program work paper makes the following assumptions regarding current installation practices:

- HVAC units are typically over-sized by 20%. Participants are assumed to have correctly sized systems.
- Fan settings are typically incorrect, resulting in airflows of only 350 cfm/ton. Participants are assumed to have correct fan settings at the recommended 400 cfm/ton.
- Ducts are not properly sealed and are estimated to have total air handling unit flow leakage of 24%. Participant systems are assumed to have 12% leakage.

3.6.4 Field Findings on Duct Leakage

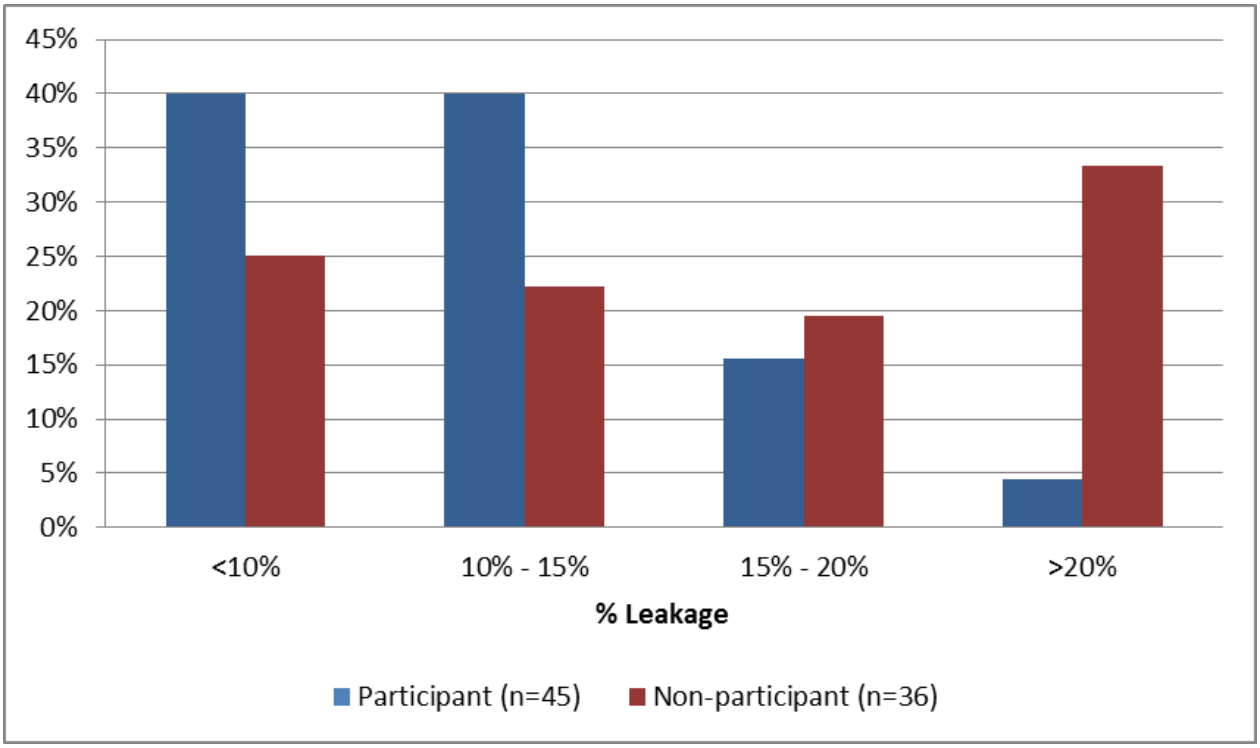
All participant and almost all of the non-participant systems assessed were located in climate zones requiring duct testing and sealing for system replacements. Both groups can be compared to Title 24 and to the work paper assumptions. As noted in the preceding section, the work paper assumption is for non-participants to have an average of 24% total leakage relative to nominal airflow and participants to have 12%. Table 3-22 and Figure 3-1 show the mean values and distributions for total duct leakage. For non-participants, slightly more than one-half of tested systems (52%) had duct leakage greater than 15%, but on average they were not as leaky as the QI program assumption of 24% and there were many systems that were equal to or less than the 15% minimum. The difference between participants and non-participants is statistically significant at the 90% confidence interval (CI).

Table 3-22: Total Duct Leakage for Recent Residential Installations

	Participants	Nonparticipants*
Sample Size	*45*	*36*
Mean Duct Leakage	11.5%	16.6%
Standard Deviation	0.045	0.085
90% CI Error Bound	+/- 0.011	+/- 0.023
Relative Precision	+/- 9%	+/- 14%

* Non-participant test results were limited to locations where Title 24 required duct leakage less than 15%.

Figure 3-1: Total Duct Leakage Distribution



3.6.5 Field Findings on Fan Airflow

The IOU work paper for Quality Installation assumes that non-participant units will have an air flow of 350 CFM per ton of installed cooling and that this will fall short of the Title 24 recommended 400 CFM per ton. The assumed difference between 350 CFM per ton for non-participants and 400 CFM per ton for participants results in the claimed savings.

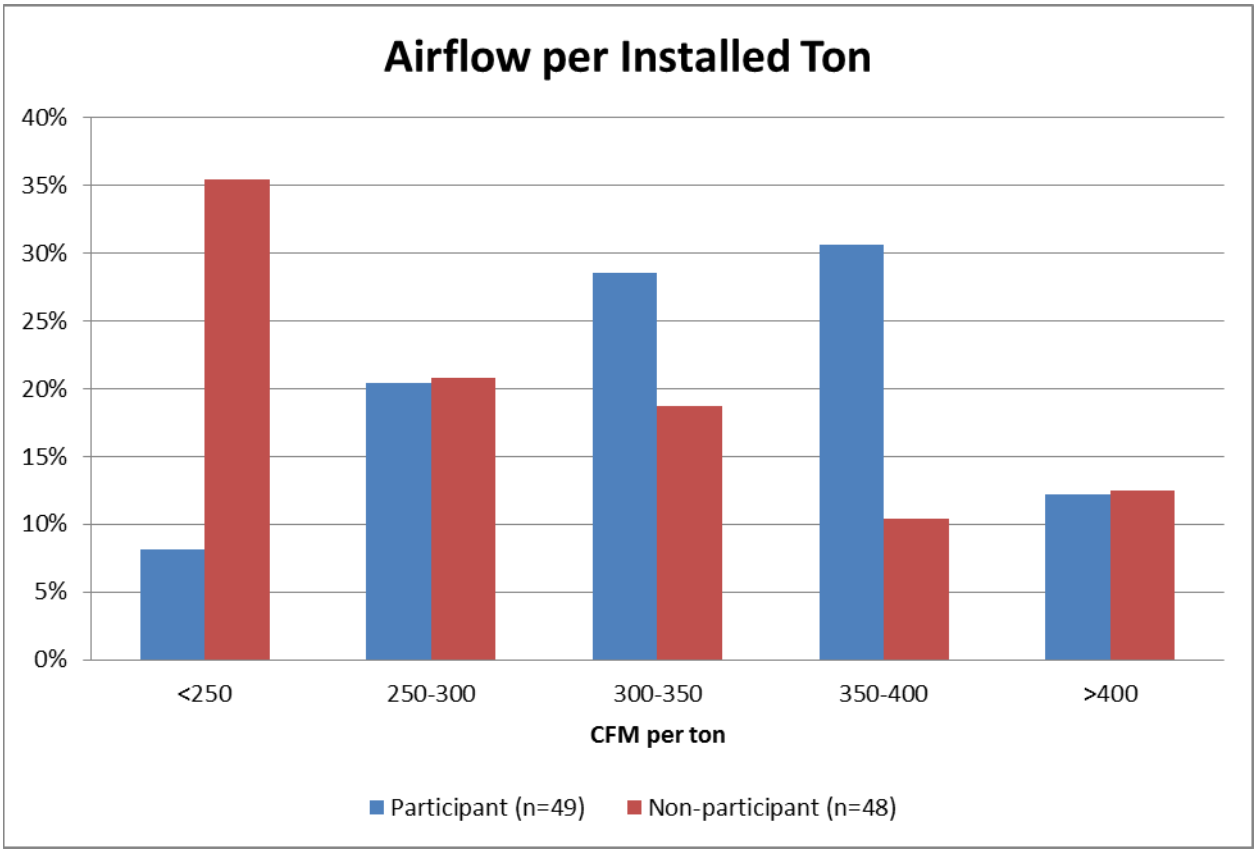
The field data collected estimated the averages were closer to 300 CFM per ton for non-participants and 338 CFM per ton for participants, but the assumed versus actual percentage

change between non-participants and participants remains about the same at slightly over 10%.[70] The difference is not statistically significant at the 90% confidence interval (Table 3-23 and Figure 3-2).

Table 3-23: Airflow per Installed Ton

	Participants	Nonparticipants
Sample Size	*49*	*48*
Average CFM per ton	337.5	299.7
Standard Deviation	68.37	85.74
90% CI Error Bound	+/- 16.07	+/- 20.36
Relative Precision	+/ -5%	+/- 7%

Figure 3-2: Airflow Distribution



3.6.6 Field Findings on System Sizing

The team used the data collected onsite to develop a system sizing model for all participants and non-participants. We compared the calculated load to the installed tonnage to determine the

[70] While flow rates in both participants and non-participants are lower than expected, this may not be solely due to fan settings, but to the combination of fan settings and static pressure in the actual systems.

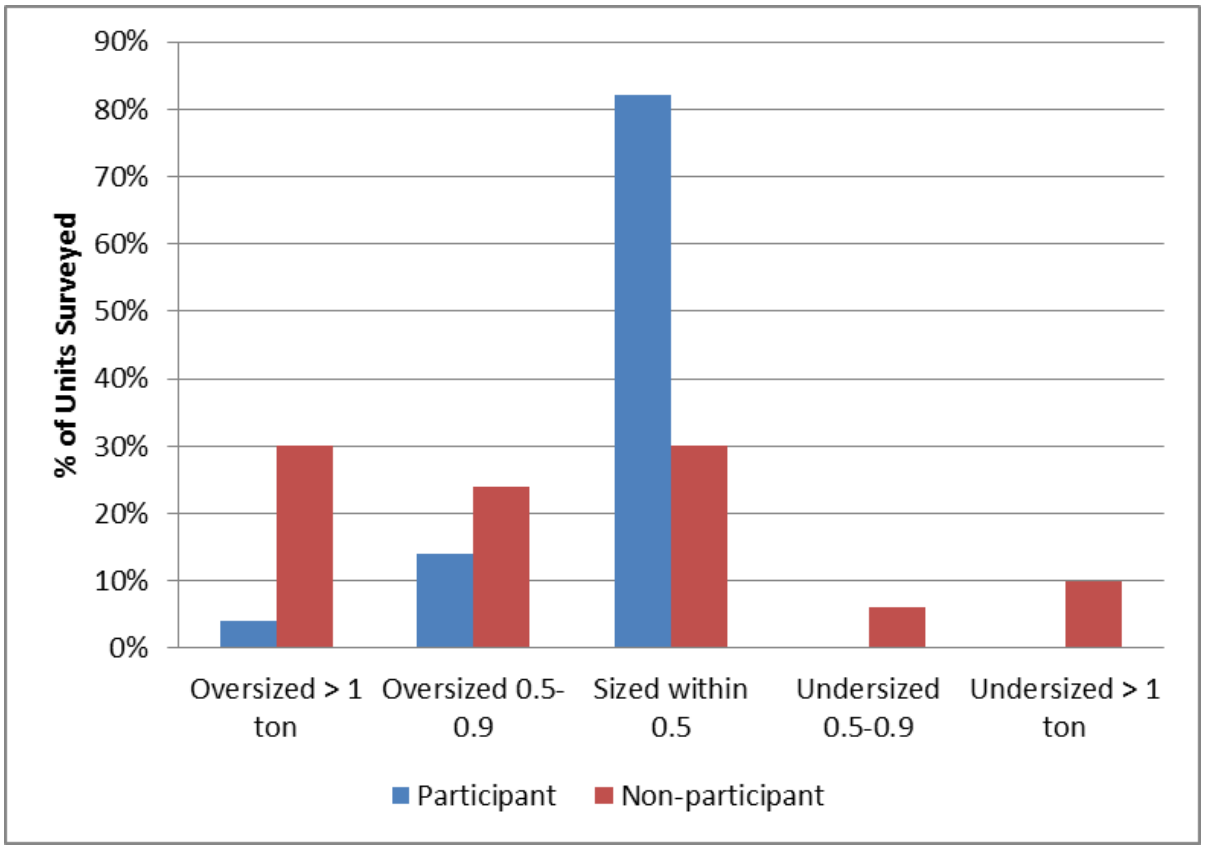
amount of over- and under-sizing. For participants, the ACCA Manual J loads were input into ACCA Manual S calculations to select systems with the proper sensible heat ratio.

After adjustments to include both Manual J model results and Manual S performance run estimates, 30% of non-participant systems were found to be oversized by one ton or more while 10% were undersized by one ton or more. While the undersized non-participants diminish the assumed savings, the assumption that oversizing is prevalent among non-participants is supported by the onsite findings. Among participants, in contrast, the large majority of units (82%) were within one-half ton of calculated load. The QI program thus appears to eliminate extreme cases of improper sizing, while non-participants are oversized in 54% of the cases (Table 3-24 and Figure 3-3).

Table 3-24: Final System Sizing based on Manual J and S Calculation

Bin	Participants	Non-participants
Oversized > 1 ton	4%	30%
Oversized 0.5-0.9 ton	14%	24%
Sized within 0.5 ton	82%	30%
Undersized 0.5-0.9 ton	0%	6%
Undersized > 1 ton	0%	10%
Average Target Size - Man S or Manual J, tons	3.28	3.09
Average Installed, tons	3.64	3.54
Average Man S / Installed	0.90	0.87

Figure 3-3: System Sizing Distribution based on Manual S



4 Quality Maintenance

Several aspects of Quality Maintenance (QM) are covered in this section: industry standards, contractor and customer awareness and attitudes, contractor and customer experiences and practices, the California IOU programs promoting QM, and field assessments of residential and commercial HVAC systems.

4.1 Overview of Findings

As with the case of QI, the baseline for Quality Maintenance (QM) in California is also low. A minority of contractors (45% residential; 34% small commercial) are aware of ACCA Standard 4 or ANSI/ASHRAE/ACCA Standard 180 and a small minority said they adhere to all of the appropriate specifications (10% of all residential contractors; 7% of all small commercial contractors). Thirty percent of residential contractors and 22% of small commercial contractors said they were currently participating or had ever participated in an IOU QM program. [71]

[71] Again, this figure may have been over-stated due to the respondents including any IOU program they had participated in, even though they were specifically asked about the Quality Maintenance program.

However, only 16% of residential contractors and 6% of small commercial contractors said they are currently participating in such a program. As in the case of QI, this self-reported participation rate is likely to be overstated by contractors responding to the survey since only a small percentage of maintenance contractors, ranging from 1% to 10%, depending on the IOU, have been trained and/or qualified by the IOUs. Program training, generally to the ANSI/ACCA Standard 4 (residential) or ANSI/ASHRAE/ACCA Standard 180-2008 (commercial), is a prerequisite for participation.

When asked about other certifications, more than one-half (55% residential; 56% small commercial) of maintenance contractors said their technicians were not certified by any organization. Note that about two-fifths (39%) of residential and three out of ten (30%) small commercial maintenance contractors hold NATE certifications, which are promoted by the IOU programs.

QM awareness among customers is also fairly low. Just over one-fifth of residential respondents (21%) and small commercial respondents (22%) had heard of the term quality maintenance. Even after it was described to them, fewer than one-half of all customers (40% residential; 36% small commercial) said they had heard of QM, and almost none of those customers could identify any QM guidelines or programs. When asked about specific QM programs, 10% to 21% of residential customers and 13% to 16% of small commercial customers said they had heard of the particular programs offered by their IOU (PG&E and SDG&E programs include both QI and QM). As in the case of QI, contractors reported that the greatest barrier to QM is customers not wanting to pay for it (52% residential; 64% small commercial).

Nearly one-half of residential customers (48%) and one-third (66%) of small commercial customers recalled that they had their central AC system serviced, for any reason, within the last year, but more than one-fifth (21%) of residential customers and 9% of small commercial customers said that they have never had it serviced. Reflecting customers' propensity to call HVAC contractors only when their systems need repairs, excluding once service calls for repairs are excluded, 24% of residential customers and 58% of small commercial customers said they have maintenance done on their HVAC systems every year. One-third (33%) of residential customers and one-quarter (25%) of small commercial customers said they never have maintenance done, except for repairs.[72]

The contractor surveys had a slightly different approach to estimating maintenance frequency. Sixty-four percent of residential maintenance contractors and 79% of small commercial maintenance contractors said they market maintenance contracts. Excluding the contractors who do not market contracts, 27% of residential and 41% of small commercial contractors have almost all of their maintenance customers renewing their contracts each year.

[72] These statistics are based on customer responses. It may be that customers are receiving some regular maintenance services when their systems are being repaired, but are not aware of this.

In general, the QM field assessments determined that the performance metrics among non-program systems were consistent with and validated the QM program assumptions of sub-optimal performance. The field assessments found that residential system total duct leakage relative to nominal flow (23% for heating and 20% for cooling) is fairly close to the QM program baseline assumption of 24%. Leakage to the outside relative to the measured airflow (27% for heating and 32% for cooling) is slightly higher than the baseline. The residential (330 CFM per ton for cooling) and commercial (359 CFM per ton for cooling) system airflows were not significantly different from the QM program baseline of 350 CFM per ton. These values are all well below the QM program requirements. Table 4-1summarizes these findings. As noted for the QI field assessments, verifications of the refrigerant charge are considered to be indeterminate.

Table 4-1: QM Field Observations and Assumptions for the Program Baseline and Efficient Case

Statistic	Field Observations (mean)	QM Program Baseline Assumptions	QM Efficient Case Assumptions
Total System Duct Leakage (using nominal heating airflow)	23%	24%	12%
Total System Duct Leakage (using nominal cooling airflow)	20%	24%	12%
Residential System Airflow in Cooling Mode (CFM per ton)	331	350	400
Commercial System Airflow (CFM per ton)	359	350	400

The California HVAC Contractor and Technician Behavior Study[73] included field observations to understand how contractors and technicians conduct diagnostics and remediation. Field observations of technicians conducting maintenance calls on a system with intentionally implemented faults yielded particularly important QM insights-- as well as a reminder that self-reports by contractors are not always accurate. Overall, the typical "maintenance" services provided were below the standards of ACCA 4 utility "quality maintenance" program goals and industry best practices as judged by the expert technician. Post-observation interviews indicated that observed technicians were not knowledgeable about ACCA Standard 4, and none of the 13 observed technicians stated that they use the standard in their regular work. During field observations, almost all of the technicians attempted some of basic maintenance tasks, but few performed the tasks correctly. Performance level was not related to the technician's certifications, training, years on the job, nor participation in utility programs. Some of the most

[73] Energy Market Innovations. California HVAC Contractor & Technician Behavior Study. CALMAC Study SCE0323.01.

important tasks for energy efficiency were frequently not even attempted. There was, in fact, a disconnect between contractors' stated practices and technicians' practices in the field.

4.2 Industry Standards for Quality Maintenance

In California, the same industry standards are used statewide as the guidelines for quality maintenance. All three IOUs utilize the American National Standards Institute ANSI/ACCA Standard 4 for residential QM and ANSI/ASHRAE[74]/ACCA Standard 180-2008 for commercial QM. ACCA Standard 4 provides checklists with inspection and corrective action maintenance tasks for different systems and components such as air distribution systems, furnaces, controls and safeties, evaporator coils, condenser units, fan coils, boilers, package units, geothermal and water source heat pumps, evaporative coolers, and accessories. HVAC contractors are required to inspect all HVAC equipment and components to identify the faults which violate manufacturer's instructions, manufacturer's warranty requirements, building codes, occupant safety or health standards, environmental regulations, and recognized industry good practices. They also need to inform customers of improper operation findings, corrective actions taken, corrective actions recommended, and the price to complete the recommended actions. Contractors should also interview homeowners regarding known home history and concerns/opinions about comfort, indoor air quality, utility costs, and equipment performance.[75]

4.3 Quality Maintenance Awareness and Attitudes

Both the contractor and customer surveys examined awareness of quality maintenance, focusing on ACCA and ASHRAE standards and guidelines as well as what role QM played in the selection of a contractor. These address some of the secondary indicators identified in Table 1-2 (SIQM-1 and SIQM-2). The surveys also examined the perceived benefits of QM from both the contractors' and customers' perspectives and the contractors' perceived barriers to implementing QM.

4.3.1 Awareness of Quality Maintenance and ACCA/ASHRAE Standards

Nearly one-half (45%) of residential maintenance contractors said they are aware of "ACCA Standard 4: Maintenance of Residential HVAC Systems." About one-third (34%) of small commercial maintenance contractors said they are aware of "ANSI/ASHRAE/ACCA Standard 180: Standard Practice for Inspection and Maintenance of Commercial Building HVAC Systems" (Table 4-2).

[74] American Society of Heating, Refrigerating, and Air Conditioning Engineers.
[75] Summarized from ACCA Standard 4, Maintenance of Residential HVAC Systems; full text is found in Appendix A.

Table 4-2: Awareness of ACCA/ASHRAE Standards among Maintenance Contractors[76]

Percent aware	Residential Maintenance Contractors	Small Commercial Maintenance Contractors
Sample Size	*109*	*110*
Yes	45%	34%
No	49	58
Don't know	6	8

When initially asked if they had heard of the term *quality maintenance*, less than one-quarter of residential (22%) customers and small commercial (21%) customers replied in the affirmative. When interviewers aided respondents by defining the term,[77] two-fifths of residential respondents (40%) and more than one-third of small commercial respondents (36%) recognized it. Table 4-3 shows Residential customers living in mild climates (46%) were somewhat more likely than Inland residential customers to recognize the term after being aided (35%). Similarly, Mild region small commercial customers (41%) were somewhat more likely than Inland small commercial customers to recognize the term after being aided (33%).

Table 4-3: Unaided and Aided Awareness of Quality Maintenance by Customers[78]

Aware of Quality Maintenance	Residential Customers			Small Commercial Customers		
	Inland	Mild	Total	Inland	Mild	Total
Sample Size	*236*	*61*	*297*	*235*	*65*	*300*
Unaided	22%	23%	22%	21%	22%	21%
Aided	35%	46%	40%	33%	41%	36%

As shown in Table 4-4, 8% of all residential customers were aware of any QM guidelines or programs for central AC systems, and 5% of all small commercial customers were aware of any QM guidelines or programs for small commercial cooling equipment. Note that the majority of customers (60% of residential customers and 64% of small commercial customers) had no awareness of QM and thus were not asked this question.

Residential respondents from the Mild region (39%) were significantly more likely than Inland region residential respondents (25%) to be unaware of QM guidelines; however, they (46%) were also somewhat more likely than Inland residential customers (35%) to report being aware of QM in the first place. Even the few customers with aided awareness of QM, however, were largely unaware of specific QM programs or guidelines. The majority of the 25 residential customers that were aware of QM guidelines (91%) were unable to name any specific guidelines.

[76] Online contractor survey of 245 contractors conducted during May and June of 2012

[77] Interviewers described how *quality maintenance* is a service that requires that the routine maintenance or tune-up of a central AC system/cooling equipment is done according to specific industry standards and guidelines so as to ensure that the equipment is operating efficiently.

[78] Telephone surveys of 297 residential customers and 300 small commercial customers conducted between August and October 2012

Most commonly, residential respondents aware of QM guidelines were able to name ENERGY STAR® guidelines (4%).

Of the 17 small commercial respondents indicating they were aware of QM guidelines and programs, most (15 of 17) were unfamiliar with any specific guidelines.

Table 4-4: Awareness of Quality Maintenance Guidelines and Programs by Customers[79]

Aware of Any Guidelines	Residential Customers			Small Commercial Customers		
	Inland	Mild	Total	Inland	Mild	Total
Sample Size	*236*	*61*	*297*	*235*	*65*	*300*
No	25%	39%†	31%	28%	37%	32%
Yes	9	7	8	5	4	5
Not aware of Quality Maintenance Ψ	65	54	60	67	59	64
Awareness of Specific Quality Maintenance Guidelines (Multiple Responses, Unweighted Counts)*						
Sample Size	*21*	*4*	*25*	*14*	*3*	*17*
ENERGY STAR	6%	--	4%	--	--	--
ACCA Standard 4	--	--	--	1	--	1
ACCA Standard 180	--	--	--	1	--	1
PG&E AC Quality Care Rebate Program	--	--	--	1	--	1
Other	9%	--	6%	--	--	--
Aware but unable to name specific guidelines and programs	86%	4	91%	12	3	15

† Significantly different from Inland or Mild customers at the 90% confidence level.

*Results are reported as unweighted counts where sample size is less than 20.

Ψ The survey design filtered the questions asked of respondents so that if respondents were not aware of a topic, they were not asked further questions pertaining to it. Thus the respondents reported here were not asked this question but their responses are included so as to provide percentages based on the total sample of customers.

Only 3% of all residential respondents and 2% of all small commercial respondents were certain that they had asked prospective contractors about their use of QM guidelines while in the process of selecting a contractor. Mild region residential customers (42%) were significantly more likely than Inland residential customers (30%) to confirm that they did not do so despite their greater awareness of QM guidelines. Similarly Mild region small commercial customers (40%) were significantly more likely than Inland small commercial customers (28%) to recall that they did not ask prospective contractors about their use of QM guidelines (Table 4-5). Note that the majority of customers (60% of residential customers and 64% of small commercial customers) had no awareness of QM and thus were not asked this question.

[79] Telephone surveys of 297 residential customers and 300 small commercial customers conducted between August and October 2012

Table 4-5: Customer Selection of HVAC Contractor and Quality Maintenance Guidelines[80]

Specifically Asked About Quality Maintenance Guidelines When Selecting Contractor	Residential Customers			Small Commercial Customers		
	Inland	Mild	Total	Inland	Mild	Total
Sample Size	*236*	*61*	*297*	*235*	*65*	*300*
No	30%	42%†	35%	28%	40%†	33%
Yes	2	3	3	2	1	2
Don't know/Refused	2	1	2	3†	--	2
Not aware of Quality Maintenance Ψ	65	54	60	67	59	64

† Significantly different from Inland or Mild customers at the 90% confidence level.

Ψ The survey design filtered the questions asked of respondents so that if respondents were not aware of a topic, they were not asked further questions pertaining to it. Thus the respondents reported here were not asked this question but their responses are included so as to provide percentages based on the total sample of customers.

As noted for QI, customer awareness of QM in general and specific programs and guidelines may not be necessary to ensure quality maintenance in a market where the baseline is already relatively high. However, the HVAC contractor responses and field observations reported throughout this study highlight the need for customers to be aware of and value QM, at least until progress toward market transformation is further along.

4.3.2 Meaning of Quality Maintenance

The surveys asked both installation contractors and customers for their definitions of quality maintenance; as would be expected, the contractors provided much more specific responses. About one in eight residential maintenance contractors (14%) defined quality maintenance to include air filters, followed by general mention of inspection or testing (13%) and checking refrigerant charge (13%). About one-fifth of small commercial contractors (21%) defined quality maintenance to include general mention of inspection and testing, followed by 14% who cited the complete, proper, or right way to do a job, and 11% who cited inspecting air filters (Table 4-6). It should also be noted that a sizable portion of contractors (39% of residential and 45% of small commercial and industrial) chose not to answer this question. Additionally, in view of the field assessments described in Section 4.6, there may be a disconnect between contractors' survey responses and their technicians' actual practices in the field.

[80] Telephone surveys of 297 residential customers and 300 small commercial customers conducted between August and October 2012

Table 4-6: Contractors' Definitions of Quality Maintenance[81]

Definitions	Residential Maintenance Contractors	Small Commercial Maintenance Contractors
Sample Size (multiple response)	*109*	*110*
Inspecting air filters	14%	11%
General mention of inspection/testing	13%	21%
Checking refrigerant charge	13%	5%
Inspecting other aspects of ductwork	10%	9%
Inspecting condensing coil	10%	7%
Inspecting electrical components	10%	6%
'Complete' or 'Proper' - doing the job the 'right way'	7%	14%
Standards-based (ACCA 4,180, BPI)	1%	--
Other	80%	61%
No answer	39%	45%

Customers who had heard of the term "quality maintenance" without any prompting by the interviewer then defined what they understood was meant by the term. Note that the great majority of customers (78% of residential customers and 79% of small commercial customers) had no unaided awareness of QM and thus were not asked this question. Among those who did respond, both residential (5% of total) and small commercial (7% of total) customers most commonly described QM as a regular inspection or cleaning of equipment. Residential customers (5% of total) also commonly defined it as an effort to make sure that equipment works efficiently and properly. [82]

4.3.3 Quality Maintenance Perceived Benefits and Barriers

Maintenance contractors were asked if they agreed or disagreed that proper HVAC maintenance provided specific benefits. The vast majority of residential (92%) and small commercial (91%) maintenance contractors agreed or strongly agreed that regular, proper maintenance of a customer's HVAC system increases energy savings and reduces electric bills. More than 90% of maintenance contractors also agreed or strongly agreed that it can prolong a system's operational lifespan and improve a system's reliability. More than 80% agreed or strongly agreed that it can prevent expensive repairs, increase customer comfort, and improve indoor air quality (Table 4-7).

[81] Online contractor survey of 245 contractors conducted during May and June of 2012

[82] Telephone surveys of 297 residential customers and 300 small commercial customers conducted between August and October 2012

Table 4-7: Maintenance Contractors' Perceived Benefits of Proper HVAC Maintenance[83]

(Percent that strongly agree benefit is provided)

Benefit	Residential Maintenance Contractors	Small Commercial Maintenance Contractors
Sample Size	*109*	*110*
Increase energy savings and reduce electric bills	92%	91%
Prolong a system's operational lifespan	91%	93%
Improve a system's reliability	91%	92%
Prevent expensive repairs	90%	87%
Increase customer comfort	86%	89%
Improve indoor air quality	83%	88%

The survey asked customers with unaided and aided awareness of QM to identify its benefits in an open-ended question. Only 40% of residential customers and 36% of small commercial customers were asked this question as the rest had no awareness of QM. Residential customers most commonly associated QM with improving a system's reliability (8% of all respondents), prolonging its operational lifespan (8% of all respondents), ensuring it operates safely (6% of all respondents), and increasing energy savings (5% of all respondents). Small commercial customers most commonly associated QM with prolonging equipment's operational lifespan (11% of all respondents), saving energy and reducing their energy bills (10% of all respondents), and improving a system's reliability (8% of all respondents).[84]

Thus, as in the case of QI, customers and contractors agreed that QM is expected to increase energy savings and reduce bills. Customers noted all benefits much less frequently than contractors. Customers also mentioned, unprompted, the remaining five benefits that contractors were asked to rate: improving a system's reliability, preventing expensive repairs, prolonging a system's lifespan, improving indoor air quality, and increasing comfort. Note, however, that three-fifths of residential customers and more than three-fifths of small commercial customers (64%) did not identify any QM benefits since they had no awareness of QM.

[83] Online contractor survey of 245 contractors conducted during May and June of 2012

[84] Telephone surveys of 297 residential customers and 300 small commercial customers conducted between August and October 2012

Table 4-8 presents the most important reasons why customers chose to have their cooling equipment professionally serviced. Residential (37%) and small commercial customers (45%) were most commonly motivated to have their equipment professionally serviced to ensure it kept working properly through regular maintenance. The second most frequently cited reason for professional maintenance was to repair system malfunctions (18% of residential customers and 26% of small commercial customers). Note that some customers (31% of residential customers and 17% of small commercial customers) had no or could not recall equipment service and thus were not asked this question.

Table 4-8: Customers' Most Important Reason for Servicing Cooling Equipment Professionally [85]

Most Important Reason	Residential Customers			Small Commercial Customers		
	Inland	Mild	Total	Inland	Mild	Total
Sample Size	*236*	*61*	*297*	*235*	*65*	*300*
Routine/Regular maintenance/To make sure it keeps working properly	40%	33%	37%	45%	46%	45%
System malfunction/Not working	17	19	18	27	25	26
To take advantage of incentive/rebate	2	--	1	1	--	<1
Other	9	12	11	5	5	5
Don't know/Refused	1	4	2	6	8	7
Have never had equipment serviced [Ψ]	20	22	21	9	8	9
Installed Central AC within last 2 years [Ψ]	9	7	8	n/a	n/a	n/a
Don't recall last time equipment was serviced [Ψ]	3	2	2	7	10	8

[Ψ] The survey design filtered the questions asked of respondents so that if respondents were not aware of a topic, they were not asked further questions pertaining to it. Thus the respondents reported here were not asked this question but their responses are included so as to provide percentages based on the total sample of customers.

[85] Telephone surveys of 297 residential customers and 300 small commercial customers conducted between August and October 2012

On average, residential customers aware of QM estimated that QM has the potential to reduce their electric bill by 12% while small commercial customers thought it has the potential to reduce their electric bill by 21% (Table 4-9). On average, Mild region residential customers (16% average decrease) thought they would achieve significantly greater savings than did Inland region residential customers (10% average decrease). Conversely, Inland small commercial customers (24% average decrease) suggested a notably, yet not significantly, higher average percentage decrease than Mild region small commercial customers (18% average decrease). Note that the majority of customers (60% of residential customers and 64% of small commercial customers) had no awareness of QM and thus were not asked this question.[86]

Table 4-9: Customers' Anticipated Savings on Electric Bills from Quality Maintenance[87]

Percentage Savings	Residential Customers			Small Commercial Customers		
	Inland	Mild	Total	Inland	Mild	Total
Sample Size	*236*	*61*	*297*	*235*	*65*	*300*
0%	7%	5%	6%	2%	1%	2%
1 to 10%	6	6	6	7	9	8
11 to 20%	2	4	3	5	7	6
21 to 30%	2†	--	1	3	2	3
31 to 40%	--	--	--	1	--	<1
41 to 50%	1	--	<1	1	3	2
More than 50%	<1	1	1	2†	--	1
Don't know/Refused	17	29	22	12	18	15
Not aware of Quality Maintenance Ψ	65	54	60	67	59	64
Average percentage savings	10%	16%†	12%	24%	18%	21%

† Significantly different from Inland or Mild customers at the 90% confidence level.

Ψ The survey design filtered the questions asked of respondents so that if respondents were not aware of a topic, they were not asked further questions pertaining to it. Thus the respondents reported here were not asked this question but their responses are included so as to provide percentages based on the total sample of customers.

The market for quality maintenance services is hindered by a lack of education or training about QM – among customers, a reluctance to pay for QM is indicative of a lack of understanding of its value; and, among contractors, a lack of technician or contractor sales and communications skills indicates a need for contractor training. Maintenance contractors reported that the top barriers to selling HVAC maintenance services is that customers do not want to pay for them even though they know about the benefits of QM; this was cited by over one-half (52%) of residential maintenance contractors and nearly two-thirds (64%) of small commercial maintenance contractors. Not surprisingly, cost was also most frequently cited as a barrier to QI

[86] Note that there is no estimate of actual bill reductions resulting from QM; these findings are simply meant to gauge customer expectations.

[87] Telephone surveys of 297 residential customers and 300 small commercial customers conducted between August and October 2012

(Table 3-9). Many contractors (58% residential; 52% small commercial and industrial), however, believe that customers may be willing to pay for maintenance services if they have evidence of how much money they will save. As in the case of QI, data showing tangible value from QM, such as bill savings, would be useful in educating customers and increasing their willingness to pay for it. The second most common barrier, cited by nearly two-fifths of contractors (39%) is that technicians need more soft skills training, such as communication skills, to be able to sell maintenance to customers. A sizable portion of contractors also noted that customers do not know that maintenance can improve the performance and longevity of their cooling system and reduce their electric bills (Table 4-10).

Table 4-10: Maintenance Contractors' Self-Reported Barriers to Selling HVAC Maintenance Services[88]

Barriers	Residential Maintenance Contractors	Small Commercial Maintenance Contractors
Sample Size (multiple response)	*109*	*110*
Customers know about the benefits of maintenance, but do not want to pay extra money for it unless someone can show them evidence of how much money they can save	58%	52%
Customers know about the benefits of maintenance, but do not want to pay extra money for it	52%	64%
Technicians need more soft skills training, such as communication skills, to be able to sell maintenance to customers	39%	39%
Customers do not know that maintenance can improve the performance and longevity of their cooling system	37%	37%
Customers do not know that maintenance can reduce their electric bills	36%	38%
Equipment warranties make certain customers less willing to have maintenance performed on their HVAC units	27%	18%
Technicians need more technical training to be able to perform maintenance	14%	17%
Customers cannot afford/do not want to pay for it	4%	3%
There are no barriers, all our customers have maintenance performed on their HVAC systems regularly	6%	11%
Other	6%	1%
Not applicable	1%	--
No answer	3%	--

[88] Online contractor survey of 245 contractors conducted during May and June of 2012

4.4 Quality Maintenance Experiences and Practices

Both the contractor and customer surveys examined quality maintenance experiences and practices, focusing on the use of maintenance service contracts, the maintenance services performed, and the frequency and duration of the maintenance visits. The maintenance services areas covered included contractor adherence to ACCA or ASHRAE standards and other formal policies and guidelines, the maintenance tasks performed, and the customers' rating of their HVAC maintenance. The contractors' self-reported adherence to ACCA and ASHRAE standards provides baseline values for MTI-4 (from Table 1-1) while the frequency of maintenance visits addresses SIQM-6 (from Table 1-2).

4.4.1 Maintenance Contracts and Recommendations

About two-fifths of residential (42%) and nearly two-thirds of small commercial (64%) maintenance contractors said their typical visits are part of the services they provide for customers under contract (Table 4-11).

Table 4-11: Contractors' Typical Maintenance Services: Contracts vs. Single Visits[89]

Maintenance visits	Residential Maintenance Contractors	Small Commercial Maintenance Contractors
Sample Size	*109*	*110*
Contracts	42%	64%
Single visits	19	14
Don't know	2	2
Do not market maintenance services	33	18
Did not indicate whether they market maintenance services	4	3

About one-fifth of residential (18%) and about one-third of small commercial (34%) maintenance contractors said that less than five percent of their customers fail to renew their maintenance contracts each year for any reason. Excluding the contractors who do not market maintenance contracts, 27% of residential and 41% of small commercial contractors have at least 95% of customers renewing their contracts each year (Table 4-12).

[89] Online contractor survey of 245 contractors conducted during May and June of 2012

Table 4-12: Contractors' Reported Percent of Maintenance Contracts That Fail to Renew Each Year[90]

Percent of existing contracts	Residential Maintenance Contractors	Small Commercial Maintenance Contractors
Sample Size	*109*	*110*
Less than 5 percent	18%	34%
5 to 9 percent	15	13
10 to 49 percent	20	20
50 percent or more	4	3
Prefer not to answer	2	6
Don't know	6	5
Do not market maintenance services	33	18
Did not indicate whether they market maintenance services	3	3

Nearly two-fifths of residential maintenance contractors (38%) said that their company structures their contracts for two maintenance visits per year. Over one-half of small commercial maintenance contractors (51%) structure their contacts for four or more visits per year (Table 4-13). Note, however, that only 42% of residential maintenance contractors and 64% of small commercial maintenance contractors said their typical visits are part of the services they provide for customers under contract, as shown in Table 4-11.

Table 4-13: Number of Visits per Year for Contractors' Maintenance Contracts[91]

Maintenance visits per year	Residential Maintenance Contractors	Small Commercial Maintenance Contractors
Sample Size	*109*	*110*
1 visit per year	6%	1%
2 visit per year	38	13
3 visit per year	2	10
4 visit or more per year	16	51
Number of visits varies	4	2
Don't know	--	--
Do not market maintenance services	33	18
Did not indicate whether they market maintenance services	4	3
No answer	1	2

Most residential maintenance contractors (59%) recommend that homeowners have maintenance check-ups for their HVAC systems at least twice a year; an additional 28% recommend check-ups once a year. Small commercial maintenance contractors recommended maintenance check-

[90] Online contractor survey of 245 contractors conducted during May and June of 2012
[91] Ibid.

ups more frequently. About one-half of small commercial maintenance contractors (49%) said that they recommend that customers have maintenance check-ups at least four times a year; 13% recommend three times a year and 28% recommend maintenance check-ups for small commercial customers twice a year (Table 4-14).

Table 4-14: How Often Contractors Recommend Customers Have HVAC Maintenance Check-Ups[92]

Recommended maintenance check-up frequency	Residential Maintenance Contractors	Small Commercial Maintenance Contractors
Sample Size (multiple response)	*109*	*110*
At least every other year	93%	96%
At least once a year	87%	96%
At least twice a year	59%	90%
At least three times a year	3%	62%
At least four times a year	1%	49%
Recommended frequency varies	4%	4%
Do not recommend that customers schedule maintenance appointments	3%	1%

4.4.2 Maintenance Services Frequency and Timing

In practice, customers appear to have HVAC maintenance check-ups less frequently than contractors recommend. Nearly one-fifth (17%) of residential and over two-fifths (45%) of small commercial maintenance contractors reported that over one-half of customers have at least one HVAC check-up per year (Table 4-15).

[92] Online contractor survey of 245 contractors conducted during May and June of 2012

Table 4-15: Maintenance Contractors' Reports of the Percentage of Customers Who Have at Least One HVAC Check-Up per Year[93]

Percent of customers	Residential Installation Contractors	Small Commercial Installation Contractors
Sample Size	*109*	*110*
Less than 10 percent	26%	19%
10 to 24 percent	37	19
25 to 49 percent	19	16
50 to 74 percent	11	10
75 to 100 percent	6	35
Don't know	--	2
No answer	1	--

Customers were asked about the last time they had their cooling systems serviced for any reason. Nearly one-half of residential customers (48%) recalled that they had their central AC system serviced within the last year; more than one-fifth (21%) said that they have never had it serviced. Small commercial customers appeared to have had their cooling equipment serviced more recently than residential respondents. One-half of small commercial customers (50%) recalled having had their cooling equipment serviced in the last six months and one-third (66%) said they had it serviced within the last year (Table 4-16).

Table 4-16: Customers' Report of Time of Last Cooling Equipment Service[94]

Timing	Residential Customers			Small Commercial Customers		
	Inland	Mild	Total	Inland	Mild	Total
Sample Size	*236*	*61*	*297*	*235*	*65*	*300*
In the last six months	29%	32%	31%	50%	50%	50%
Six months to one year ago	18	15	17	16	17	16
One to two years ago	12	12	12	10	8	9
Two to three years ago	7	3	5	4†	--	2
More than three years ago	11	13	12	4	9	6
Never	20	22	21	9	8	9
Don't know/Refused	3	2	2	7	10	8

† Significantly different from Inland or Mild customers at the 90% confidence level.

[93] Online contractor survey of 245 contractors conducted during May and June of 2012

[94] Telephone surveys of 297 residential customers and 300 small commercial customers conducted between August and October 2012

Reflecting customer propensity to call HVAC contractors only when their systems need repairs, when asked about the frequency of cooling equipment maintenance other than for repairs, customers indicated less frequent visits. One-third of residential customers said they never have their systems serviced while nearly one-quarter (24%) have their systems serviced at least once a year. Residential customers from the Inland region (39%) were significantly more likely to have their systems serviced at least every two years than were those from the Mild region (27%). Small commercial customers appeared to have their systems serviced more frequently than residential customers. Nearly three-fifths of small commercial customers (58%) reported having a contractor service or maintain their cooling equipment annually or more frequently. However, one-quarter of them (25%) reported never having their equipment serviced (Table 4-17).[95] Note that some customers (8% of residential customers) had installed their equipment within the last two years and thus were not asked this question.

Table 4-17: Customers' Reported Frequency of Cooling Equipment Maintenance[96]

Frequency	Residential Customers			Small Commercial Customers		
	Inland	Mild	Total	Inland	Mild	Total
Sample Size	*236*	*61*	*297*	*235*	*65*	*300*
Three or more times a year	1%	--	1%	19%	19%	19%
Two times a year	9	7%	8	14	17	16
Once a year or annually	19†	11	15	20	25	23
Once every two years	10	9	10	9†	3	6
Once every three years	7	14	10	1	4	2
Once every four years or less frequently	8	20†	13	5	5	5
Never	36	29	33	26	25	25
Don't know/Refused	1	3	2	5	2	4
Installed Central AC within last 2 years Ψ	9	7	8	n/a	n/a	n/a

† Significantly different from Inland or Mild customers at the 90% confidence level.

Ψ The survey design filtered the questions asked of respondents so that if respondents were not aware of a topic, they were not asked further questions pertaining to it. Thus the respondents reported here were not asked this question but their responses are included so as to provide percentages based on the total sample of customers.

[95] These statistics are based on customer responses. It may be that customers are receiving some regular maintenance services when their systems are being repaired, but are not aware of this.

[96] Telephone surveys of 297 residential customers and 300 small commercial customers conducted between August and October 2012

Most residential maintenance contractors (72%) and small commercial maintenance contractors (85%) reported that they spend at least an hour during a typical maintenance visit; most commonly between one-half of an hour to one hour working on each unit serviced (Table 4-18).

Table 4-18: Contractors' Reported Length of Time Technicians Spend During a Typical Maintenance Visit[97]

Length of typical maintenance visit	Residential Maintenance Contractors	Small Commercial Maintenance Contractors
Sample Size	*109*	*110*
½ hour or less	10%	24%
½ hour to one hour	62	61
1-2 hours	24	13
2 hours or more	1	1
Don't know	1	1
No answer	2	1

Small commercial customers[98] were asked about the length of their most recent service visit. As shown in Table 4-19, they were most likely to report that it lasted either one to three hours (31%) or 30 minutes to one hour (23%). On average, the service took 1.6 hours to perform. Inland small commercial customers (12%) were significantly more likely than Mild region small commercial customers (3%) to report having had their most recent service visit last less than 30 minutes. Note that some customers (17% of small commercial customers) had no or could not recall equipment service and thus were not asked this question.

[97] Online contractor survey of 245 contractors conducted during May and June of 2012

[98] Residential customers were also asked about the length of their last service; however, the shortest length option provided to them was "less than 4 hours". This option was chosen by nearly everyone who responded to the question. It is likely that without shorter duration options, the length of residential service visits would be overstated and is thus not reported.

Table 4-19: Small Commercial Customers: Length of Last Service Visit[99]

Length of last service visit	Inland	Mild	Total
Sample Size	*235*	*65*	*300*
Less than 30 minutes	12%†	3%	8%
Between 30 minutes and an hour	21	27	23
Between 1 and 3 hours	30	33	31
Between 3 and 4 hours	3	8	5
More than 4 hours	6	1	4
Don't know/Refused	12	10	11
Have never had equipment serviced Ψ	9	8	9
Don't recall last time equipment was serviced Ψ	7	10	8
Average Duration*	1.6	1.6	1.6

† Significantly different from Inland or Mild customers at the 90% confidence level.

*For the purposes of estimating the average service-visit duration, the team used the midpoint from each response category to represent the number of service-visit hours to allocate to each respondent. If respondents indicated that the service visit lasted "More than 4 hours," the team used values of 5 as proxies for their responses.

Ψ The survey design filtered the questions asked of respondents so that if respondents were not aware of a topic, they were not asked further questions pertaining to it. Thus the respondents reported here were not asked this question but their responses are included so as to provide percentages based on the total sample of customers.

4.4.3 Maintenance Services Performed

As noted in Section 4.3.1, only 45% of residential and 34% of small commercial maintenance contractors were aware of ACCA/ASHRAE Standards. About two-fifths of all residential (42%) and one-third of small commercial (32%) maintenance contractors reported that they adhere to all or some of the ACCA/ASHRAE standards' specifications on a job; these responses were given by the vast majority of residential and all the small commercial maintenance contractors who indicated awareness of ACCA/ASHRAE Standards. However, only a minority of contractors aware of ACCA/ASHRAE Standards said they adhere to all of their specifications; overall only 10% of residential and 7% of small commercial maintenance contractors provided this response (Table 4-20).

[99] Telephone surveys of 297 residential customers and 300 small commercial customers conducted between August and October 2012

Table 4-20: Maintenance Contractor Implementation of ACCA/ASHRAE Standards, Among Those Aware of the Standards[100]

Use of standards	Residential Maintenance Contractors	Small Commercial Maintenance Contractors
Sample Size	*109*	*110*
Adhere to all of the standard's specifications on a job	10%	7%
Adhere to some of the standard's specifications on a job	32	25
Aware of the standard but do not adhere to it on a job	2	--
Not aware of the standard	49	58
Don't know if aware of the standard	6	8
Did not indicate adherence to the standard	1	2

About three-fifths of residential (63%) and small commercial (58%) maintenance contractors said their companies have a formal policy or set of guidelines that technicians are required to follow for maintenance procedures (Table 4-21).

Table 4-21: Percent of Companies That Have Formal Policies or Guidelines that Technicians Are Required to Follow for Maintenance Procedures[101]

Percent with policies or guidelines	Residential Maintenance Contractors	Small Commercial Maintenance Contractors
Sample Size	*109*	*110*
Yes	63%	58%
No	31	39
Don't know	2	1
No answer	4	2

The on-line survey of contractors provided a list of tasks performed during a typical maintenance visit and asked respondents to check-off the tasks that they did. A large majority of residential (92%) and small commercial (92%) maintenance contractors said they inspect blower motors for proper operation. Large majorities also said they inspected condensing coils (91% residential; 95% small commercial), heat exchangers (91% for both residential and small commercial), all electric components (91% residential; 90% small commercial), and filters (90% residential; 96% small commercial) (Table 4-22). Note again that when assessing self-reported contractor practices, the field assessments described in Section 4.6 found that technicians' actual practices in the field fell short of performing many tasks considered to be good practices.

[100] Online contractor survey of 245 contractors conducted during May and June of 2012
[101] Ibid

Table 4-22: Tasks Performed During a Typical Maintenance Visit[102]

Tasks performed	Residential Maintenance Contractors	Small Commercial Maintenance Contractors
Sample Size	*109*	*110*
Inspect blower motors for proper operation	94%	92%
Inspect condensing coil and clean/adjust as needed	91	95
Visually inspect heat exchanger for signs of corrosion, fouling, structural problems	91	91
Inspect all electrical components for proper operation	91	90
Inspect filters for particulate accumulation and clean/replace as needed	90	96
Test system controls' modes of operation and control sequences	87	86
Inspect condensate drains for proper operation	86	94
Measure refrigerant charge	81	78
Inspect accessible refrigerant lines, joints, and coils for oil leaks	77	86
Inspect air filter housing integrity and air seal	76	78
Inspect cabinet, cabinet fasteners, and cabinet panels	73	73
Inspect evaporator coil and clean/adjust as needed	68	90
Inspect grilles, registers and diffusers for dirt accumulation	66	68
Inspect integrity of all accessible ductwork insulation	64	52
Inspect the integrity of all accessible ductwork including: duct strapping, hangers, sections, joints, and seams	57	50
Inspect all accessible ductwork for areas of moisture accumulation or biological growth	51	50
Measure airflow across heat exchanger/coil	51	41
Inspect economizers*	35	78
No answer	2	1

* Economizers generally are on 5 tons or more units and thus most residential units would not require an economizer.

[102] Online contractor survey of 245 contractors conducted during May and June of 2012

Customers listed the services contractors performed during their most recent cooling equipment service visit. Over one-half of residential (51%) and nearly two-thirds of small commercial customers (64%) said their most recent service visit included routine tune-ups and maintenance (Table 4-23). Three out of ten residential (30%) and about one-half of small commercial (46%) customers also had some repairs performed during their last service call. Note that some customers (31% of residential customers and 17% of small commercial customers) had no or could not recall equipment service and thus were not asked this question.

Table 4-23: Services Performed during Most Recent Cooling Equipment Service Visit [103]

Services Performed	Residential Customers			Small Commercial Customers		
	Inland	Mild	Total	Inland	Mild	Total
Sample Size (multiple response)	*236*	*61*	*297*	*235*	*65*	*300*
Routine tune up and maintenance	53%	48%	51%	66%	61%	64%
Repairs that were identified during the service call	16	16	16	28	22	25
Repairs that were identified before the service call	12	17	14	19	23	21
Have never had equipment serviced [Ψ]	20	22	21	9	8	9
Installed Central AC within last 2 years [Ψ]	9	7	8	n/a	n/a	n/a
Don't recall last time equipment was serviced [Ψ]	3	2	2	7	10	8

[Ψ] The survey design filtered the questions asked of respondents so that if respondents were not aware of a topic, they were not asked further questions pertaining to it. Thus the respondents reported here were not asked this question but their responses are included so as to provide percentages based on the total sample of customers.

Among the respondents who had a recent maintenance visit, 59% of residential customers and 75% of small commercial customers rated the quality of the maintenance quite highly (four or five on a five-point scale). On average, both residential and small commercial respondents gave the quality of maintenance a rating of 4.5.[104]

[103] Telephone surveys of 297 residential customers and 300 small commercial customers conducted between August and October 2012
[104] Ibid.

4.5 California IOU Quality Maintenance Programs

The California IOU quality maintenance programs are described in detail in Appendix A, but generally require training to ACCA Standard 4. The surveys examined awareness and participation in QM programs on the part of both contractors and customers addressing secondary indicators identified in Table 1-2 (SIQM-3 and SIQM-4). This section concludes with an examination of contractor training and qualification, addressing SIQM-5.

4.5.1 Program Awareness and Participation

After a brief description of the California IOU QM programs, nearly one-third of residential maintenance contractors (30%) and over one-fifth of small commercial maintenance contractors (22%) reported that they had ever participated in such a program. However, only 16 percent of residential and six percent of small commercial maintenance contractors said that they are currently participating in an IOU QM program (Table 4-24). These self-reported participation rates may be over-stated by the respondents confusing QM with other programs. As shown in Section 4.5.2, far fewer maintenance contractors have gone through IOU training and qualification. Program training, generally to the ANSI/ACCA Standard 4 (residential) or ANSI/ASHRAE/ACCA Standard 180-2008 (commercial), is a prerequisite for participation.

Table 4-24: Contractors' Participation in a Quality Maintenance Program[105]

Participation	Residential Maintenance Contractors	Small Commercial Maintenance Contractors
Sample Size	*109*	*110*
Currently participating in an IOU QM program	16%	6%
Currently participating or have participated in the past in an IOU QM program	30	22
Have never participated in an IOU QM program	66	76
Did not know if they their company has participated in an IOU QM program	2	2
Did not indicate whether their company participated in an IOU QM program	2	1

[105] Online contractor survey of 245 contractors conducted during May and June of 2012

Residential respondents, even when prompted, were largely unaware of the specific QM programs offered by their IOUs. SDG&E residential customers were significantly more likely to have heard of SDG&E's Quality Care program than SCE or PG&E customers were to have heard of the programs offered by their IOUs. Likewise, small commercial respondents were largely unaware of the specific QM programs offered by the IOUs, even when prompted (Table 4-25).

Table 4-25: Aided Customer Awareness of Quality Maintenance Programs[*106]

Aware of Program[**]	Residential Customers			Small Commercial Customers		
	Inland	**Mild**	**Total**	**Inland**	**Mild**	**Total**
Sample Size	*112*	*8*	*120*	*111*	*9*	*120*
SCE Maintenance and Repair	13%	--	11%	14%	2	16%†
Sample Size	*81*	*36*	*117*	*80*	*40*	*120*
PG&E Quality Care	15%	6%	10%	16%	10%	13%
Sample Size	*43*	*17*	*60*	*44*	*16*	*60*
SDG&E Quality Care	14%	4	21%†	23%	2	16%†

[*]PG&E and SDG&E programs include QM as well as QI

[**]Results are reported as unweighted counts where sample size is less than 20.

†Significance testing compares the values within a single column as opposed to comparing values in a single row.

[106] Telephone surveys of 297 residential customers and 300 small commercial customers conducted between August and October 2012

Given the small proportions of customers aware of QM programs offered by the IOUs, it is not surprising that very few respondents believe they have received or been passed along any rebates for QM (Table 4-26).

Table 4-26: Cooling Equipment Quality Maintenance and Installation Program Participation[107]

Percentage That Received Program Rebate*	Residential Customers			Small Commercial Customers		
	Inland	Mild	Total	Inland	Mild	Total
SCE Maintenance and Repair						
Sample Size	*112*	*8*	*120*	*111*	*9*	*120*
Maintenance Rebate	2%	--	1%	--	--	--
PG&E Quality Care						
Sample Size	*81*	*36*	*117*	*80*	*40*	*120*
Maintenance Rebate	4%	3%	3%	3%	--	1%
SDG&E Quality Care						
Sample Size	*43*	*17*	*60*	*44*	*16*	*60*
Maintenance Rebate	--	--	--	2%	--	1%

*Results are reported as unweighted counts where sample size is less than 20.

4.5.2 Quality Maintenance Training and Qualification of Contractors

NMR conducted an analysis of the percentages of all contractors who have gone through the IOUs' training and qualification programs as described in Section 3.5.2. NMR divided contractor quality maintenance qualification and training data that were provided by the IOUs by the estimated number of maintenance contractors in each service territory. Table 4-27 reports the percentage of maintenance contractors that are qualified through an IOU program in each of the three electric IOU territories.

Table 4-27: Percent of Maintenance Contractors Qualified by the IOUs

IOU	Residential Maintenance Contractors	Commercial* Maintenance Contractors
Pacific Gas & Electric**	10%	7%
San Diego Gas & Electric	2%	3%
Southern California Edison	1%	2%

* Since the IOUs presented training and qualification data on commercial contractors, without distinguishing small and large contractors, this analysis is presented for commercial contractors in general.
**Pacific Gas & Electric did not distinguish between qualified and trained contractors

When asked about other certifications, more than one-half of maintenance contractors said their technicians were not certified by any organization. It is important to note that about two-fifths of

[107] Telephone surveys of 297 residential customers and 300 small commercial customers conducted between August and October 2012

residential and three out of ten small commercial maintenance contractors hold NATE certifications, which are promoted by the IOU programs (Table 4-28).

Table 4-28: Maintenance Contractors' Certifications[108]

	Residential Maintenance Contractors	Small Commercial Maintenance Contractors
Sample Size (multiple response)	*109*	*110*
Our company has none of these certifications	55%	56%
NATE C3	39%	30%
Other	21%	13%
No answer	2%	7%

As noted for QI, in view of the low share of maintenance technicians with any training and the contractors citing technicians' lack of selling skills and knowledge as a barrier to QM (Table 4-10), this study has identified an increase in the number of technicians with training as a secondary indicator of HVAC subprograms' progress. As in the case of QI, this training should improve their knowledge of the requirements of QM; it may be accomplished through NATE training and some of the IOU program training.

4.6 Quality Maintenance Field Assessments

DNV GL completed field assessments on 50 residential and 30 commercial systems that had recently had maintenance performed. The team recruited participants for on-site visits from customers who were identified in the residential customer survey as having maintenance recently performed on their HVAC system. This sample was further supplemented with customers identified as having recently serviced an HVAC system in the CLASS (WO 21) and CSS (WO 24) studies. While the preferred approach to assess maintenance savings is pre-post measurement, DNV GL performed these field assessments to establish the current state of units in the field after receiving non-program maintenance.

4.6.1 Overview of Findings

The overall objective of the field assessments was to ascertain the extent to which performance metrics for recently maintained systems in the general market were consistent with QM program assumptions.[109] In general, the field assessment determined that the performance metrics among non-program systems were consistent with and validated the QM program assumptions of sub-optimal performance. Specific noteworthy findings from the QM field assessments include the following.

[108] Online contractor survey of 245 contractors conducted during May and June of 2012

[109] The QM program assumptions are laid out in a work paper described in Appendix F. The work paper describes the assumptions that are made about non-participant systems.

- **Residential Duct Leakage.**[110] The DEER and QM baseline assumption for existing ducts is 24% leakage. System total leakage relative to nominal flow was measured at 23% for heating and 20% for cooling which are close to the values assumed by the DEER and QM program.
- **Residential System Airflow**. Based on Title 24 and an HVAC technician rule of thumb, the working assumption for proper system airflow is 400 CFM/ton. System airflow measured during the site visits averaged 332 CFM per ton for cooling which was not significantly different than the baseline of 350 CFM/ton assumed by the QM program
- **Commercial System Airflow**. System airflow measured during the site visits averaged 359 CFM per ton for cooling which was not significantly different than the baseline of 350 CFM/ton assumed by the QM program.
- **Commercial System Economizers**. The field assessments found 55% of units with dampers open from 10% to 30%, and 9% of units with dampers fully-open. Field measurements and simulations from other studies indicate fully open dampers increase cooling and heating energy by 50% compared to closed dampers.
- **Refrigerant Charge**. Charge diagnostics are used to determine if the refrigerant charge is at the factory level. The field assessments used Title 24 and manufacturer diagnostics to verify that proper refrigerant charge was present in the system. However, recent studies cited in the Appendix have found that the Title 24 and other diagnostics used to verify refrigerant charge are flawed. As a result, the results of this field assessment are considered to be indeterminate.

[110] The scope of residential QM appears to include unit and system level measures. In the past, refrigerant charge and duct sealing were addressed by separate programs, but they are both part of the new Residential QM concept.

The field assessments of non-participant sites provide a market baseline relative to IOU work paper baseline assumptions for QM. Table 4-29 summarizes the key findings from the field assessments.

Table 4-29: Comparison of Baseline Assumptions and Field Findings

IOU QM Work Paper Baseline Assumption	Field Findings for QM Non-Participants	Implications from Field Findings
Residential Duct Leakage: 24% Leakage	23% ± 3.5%for heating 20% ± 2 % for cooling Over 50% of cases have leakage greater than 15%	On average, leakage relative to nominal flow was close to the values assumed by the DEER and QM program.
System Airflow at 350 CFM / ton	Residential Systems: 332 CFM / ton +/- 42 CFM / ton Commercial Systems: 359 CFM / ton +/- 26 CFM / ton	On average, airflow was close to the values assumed by the DEER and QM program.
Commercial System Economizers N/A	55% of units with dampers open from 10% to 30%, and 9% of units with dampers fully-open	Field measurements and simulations from other studies indicate fully open dampers increase cooling and heating energy by 50% compared to closed dampers.
Refrigerant Charge N/A	Indeterminate – See Appendix F	See section 4.6.5. The use of Title 24 diagnostics and other diagnostic options is problematic in verifying proper charge. The indirect diagnostics do not reliably verify that proper charge was weighed into the system after installation.

4.6.2 IOU Work Paper Assumptions for Quality Maintenance

Paralleling the QI program assumptions, the IOU QM program work paper makes the following assumptions regarding current post-maintenance system performance.

- Ducts are not properly sealed and are estimated to have total air handling unit flow leakage of 24% relative to nominal airflow. Participant systems are assumed to have 12% leakage.
- Fan settings are typically incorrect, resulting in only 350 cfm/ton of airflow. Participants are assumed to have correct fan settings at the recommended 400 cfm/ton.

Since there is no energy code standard for maintenance, there is no established Title 24 benchmark.

4.6.3 Residential Site Findings

4.6.3.1 Field Findings on Duct Leakage

The current DEER and QM work paper assumption is that existing systems have an average of 24% total leakage relative to nominal airflow. It was unknown if any of the sampled systems

were installed according to the Title 24 minimums applicable at the time they were installed. All systems were 5 years old or older. The average total leakages were close to 24%: 23% for heating and 20% for cooling (Table 4-30 and Figure 4-1).

Table 4-30: Total Duct Leakage for Recently Maintained Residential Systems

	% Duct Leakage	
Statistic	**Using nominal heating airflow (kBtu heating output x 21.7)**	**Using nominal cooling airflow (Cooling capacity tons x 400)**
Sample Size	*11*	*18*
Average	23%	20%
Standard Deviation	15%	10%
90% CI Error Bound	+/- 7%	+/- 4%
Relative Precision	+/- 32%	+/- 20%

Figure 4-1: Total Duct Leakage for Recently Maintained Residential Systems

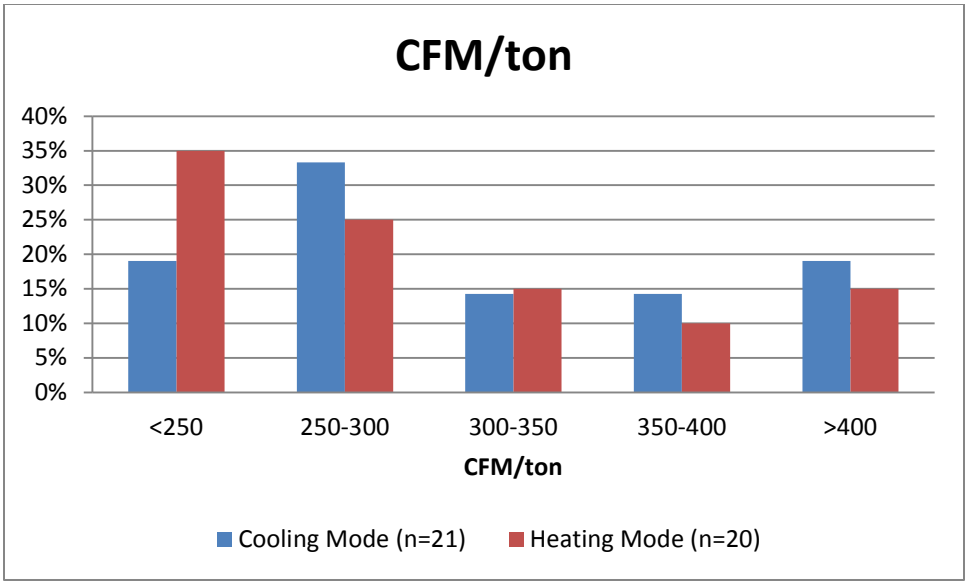
4.6.3.2 Field Findings on Fan Airflow

The QM work paper assumption of 350 CFM/ton has non-participant units falling short of the Title 24 recommended 400 CFM/ton of installed cooling. The assumption of 400 CFM/ton is a general rule of thumb for HVAC technicians as well. The field data collection estimated the averages were closer to 332 CFM/ton in the cooling mode (Table 4-31 and Figure 4-2).

Table 4-31: Measured Airflow

	CFM / ton	
Statistic	**Cooling**	**Heating**
Sample Size	*21*	*20*
Average	331.5	302.5
Standard Deviation	116.0	120.8
90% CI Error Bound	41.6	44.4
Relative Precision	13%	15%

Figure 4-2: Measured Airflow per Ton



4.6.4 Commercial Sites

4.6.4.1 Field Findings on Fan Airflow

The QM work paper assumption of 350 CFM/ton has non-participant units falling short of the Title 24 recommended 400 CFM/ton of installed cooling. The assumption of 400 CFM/ton is a general rule of thumb for HVAC technicians as well. The field data collection estimated the averages were closer to 359 CFM/ton in the cooling mode (Table 4-32).

Table 4-32: Measured Airflow

Statistic	Cooling (CFM/ton)
Sample Size (includes multiple units per site)	*42*
Average	359.1
Standard Deviation	101.1
90% CI Error Bound	25.8
Relative Precision	7%

4.6.4.2 Field Findings on Economizers

The field assessment found 55% of units with dampers open from 10% to 30%, and 9% of units with dampers fully-open. Field measurements and simulations from other studies indicate fully open dampers increase cooling and heating energy by 50% compared to closed dampers. Virtually all the units with economizers were in need of repair due to sensor faults, broken linkages, or other issues causing the economizers to fail functional tests. Smaller units did not have economizers and simply had fixed position outside air intake dampers.

4.6.5 Refrigerant Charge – Issues Identified in Literature that Apply to Both Installations and Maintenance

While measurements to assess refrigerant charge were performed in accordance with Title 24, the results may be considered misleading based on recent laboratory studies by the Purdue University[111] and the CPUC, conducted under Work Order 32 (WO32). The key takeaway for the market assessment is that while there are protocols being widely used to diagnose and remediate HVAC system faults, there is no single best practice or most-accurate method. Many systems have been misdiagnosed over the past decade and these practices are continuing today. See Appendix F for additional details.

4.6.6 Field Observations from the California HVAC Contractor & Technician Behavior Study[112]

The California HVAC Contractor and Technician Behavior Study included field observations to understand how contractors and technicians conduct diagnostics and remediation. This section summarizes the methodology and results of these field observations.

[111] David P. Yuill and James E. Braun. "Evaluating Fault Detection and Diagnostics Protocols Applied to Air-Cooled Vapor Compression Air-Conditioners," paper presented at the International Refrigeration and Air Conditioning Conference. West Lafayette, IN. 2012.
James E. Braun and David P. Yuill. Evaluation of the Effectiveness of Currently Utilized Diagnostic Protocols. Purdue University. West Lafayette, IN. 2014.

[112] Energy Market Innovations. California HVAC Contractor & Technician Behavior Study. CALMAC Study SCE0323.01.

4.6.6.1 Methodology

The field observations consisted of two main components: (1) the observation of technicians conducting a service or maintenance call on a system with intentionally implemented faults where technicians were unaware that researchers were observing them; and (2) a semi-structured interview with the observed technicians. A total of 16 field observations were conducted, but only 13 technicians provided permission to use their observations in this study and only nine of these consented to follow-up interviews.

EMI conducted the field observations at the home of a research ally in Corona, CA, over the course of three weeks in May 2012. A master HVAC technician tuned up and conducted in-depth diagnostics of the HVAC system so that its performance was well understood both before the study as well as between technician visits. The master technician then imposed two controlled faults so that the unit's performance was degraded in a known way. Both faults (three closed air-supply registers, and fan control wires switched to be set on low speed instead of high speed) had the effect of decreasing evaporator airflow, which has a dramatic effect on the system's capacity and energy efficiency. The artificially introduced faults gave the research team the opportunity to see how technicians diagnosed a problem with the system and how they used their diagnosis to offer repairs, offer maintenance services, and explain their work to customers. The intent of the study was not to have the flaw actually repaired, and the researchers halted the technicians before this occurred.

4.6.6.2 Findings

Overall, the technical performance of the field-observed technicians providing typical "maintenance" services was below the standards of ACCA 4, utility "quality maintenance" program goals, and industry best practices as judged by the expert technician. Post-observation interviews indicated that technicians were not knowledgeable about ACCA Standard 4, and none of the 13 observed technicians stated that they use the standard in their regular work. During field observations, almost all of the technicians attempted some of basic maintenance tasks, such as checking the thermostat, inspecting filters, inspecting the metering device, and inspecting refrigerant line insulation, but few performed the tasks correctly.

Results of the field observations suggest that the requirements of conducting "quality maintenance" often conflict with other demands that technicians face. Technicians face demands from both their company (or their own monetary goals if sole practitioners) and from their customers. These include time constraints placed on each visit, and the perception that customers have two primary priorities: making sure their system is functioning (however inefficiently) and spending as little money as possible.

A number of noteworthy tasks were left off the contractors' lists when they reported what their technicians perform during a typical installation or maintenance visit. The most infrequently reported installation tasks included calculating correct sizing for equipment using Manual J, testing ductwork to determine maximum system size, installing new refrigerant lines, and

providing the customer with documentation of installation procedures. These field observations serve as a reminder that self-reports by contractors are not always accurate.

Some of the most important tasks for energy efficiency; such as ensuring that registers are open, measuring static pressure and temperature differences across the evaporator coil, and checking refrigerant charge, were frequently not attempted. Interestingly, no technician observed in the field study attempted evaporator cleaning, although 68% of surveyed contractors stated that the evaporator coil is inspected and cleaned/adjusted as necessary during a typical residential maintenance visit. This provides evidence of a disconnect between contractors' stated practices and technicians' practices in the field. Data gathered from the field observations also suggests that quality maintenance is not a concept with a generally agreed-upon meaning.

5 Market Share Tracking System

The system described in this section is intended to help develop a systematic process for periodic reporting of market share and sales in the future. NMR interviewed eight HVAC equipment distributors in order to assess the level of consolidation in the market for HVAC distribution in California and identify the firms with the largest market shares. NMR also coordinated with WO32 on interviews with twenty distributors, including eighteen companies that participated in the HVAC Distributor Incentive Program in 2011 and 2012 and two companies that did not participate. NMR also researched the processes and procedures of the Energy Center of Wisconsin's (ECW) Furnace and Air Conditioning Tracking System (FACTS), which obtained quarterly data from twelve distributors from 1997 until the discontinuation of the program in 2011. The system proposed in this section is largely modeled along the lines of that successful program.

5.1 Distributor Reaction to a Market Share Tracking System

The initial interviews with eight distributors identified six to ten companies that hold a large share (75% to 90%) of the statewide market. The interviews identified four additional companies as having significant shares of local markets such as Los Angeles and the Bay Area, though they did not operate statewide.

The WO32 interviews with twenty distributors included six distributors that had been identified as accounting for large shares of the statewide market and one distributor identified as having a significant share of a local market. The interviews described a potential sales tracking system in which the distributors would supply the CPUC quarterly data on the sales of HVAC packaged and split-system units. Distributors, in turn, would receive aggregated quarterly industry benchmark information so they could measure individual sales performance against that of the California industry as a whole. The interviews stressed that information provided by individual distributors would remain completely confidential and be aggregated with information from other distributors to provide an overall picture of the market. The interviewees were asked if such information would be useful to their companies and if they would be willing to participate in the data collection effort.

Of the six distributors identified as accounting for large shares of the statewide market, two were fairly certain that the information would be useful to their companies and they would provide the data requested. One additional interviewee would probably participate but noted that the data that would be most useful to his company would be on the brands of HVAC system. The fourth interviewee was unsure about whether his company would participate and the last two statewide sales interviewees did not believe their companies would participate. The interviewee with a significant share of a local market was unsure if his manager would be willing to participate.

5.2 Process and Procedures

The proposed market share tracking system for California would track residential and commercial sales as follows:

- Number of all packaged and split equipment units sold
- Number of air-cooled three-phase packaged and split units sold by efficiency level[113]
- Number of single-phase air-cooled packaged and split equipment units sold by efficiency level
- Number of water source heat pumps and/or water/evaporative cooled air conditioners sold by efficiency level
- Number of ductless mini-split equipment units sold by efficiency level
- Number of ductless multi-split equipment units sold by efficiency level

Distributors would provide data quarterly. The data provided would include the product number of the units sold, the number of units for each product code, and the zip code where the units were shipped. The distributor data could then be aggregated to regions of interest. FACTS aggregated data to the county level, but, in California, it may make more sense to have five regions aggregated with aggregated climate zones, as follows:

- Region 1 comprised of Climate Zones 1, 2, 3, 4, and 5
- Region 2 comprised of Climate Zones 6 and 7
- Region 3 comprised of Climate Zones 8, 9, and 10
- Region 4 comprised of Climate Zones 11, 12, and 13
- Region 5 comprised of Climate Zones 14, 15, and 16

The distributors' reaction to providing sales data, described in Section 5.1, points to the need for carefully recruiting participants and clearly demonstrating the benefits of a market share tracking system. Following ECW's approach, the most effective course of action may be to personally visit the distributors' offices and meet with the person responsible for approving the data collection, ideally accompanied by their contact at the IOU program. The distributors need to be reassured that their data will be kept confidential and data identifying their individual market shares will not be made public or released to competitors.

The project should attempt to recruit the fourteen distributors who have been identified as having significant statewide or local market shares. An effective strategy would be to focus on the largest distributors first and, after recruiting one or two of them, use that fact to recruit the others.

[113] In all cases, efficiency level is broken down into the four tiers qualifying for the HVAC Distributor Incentive Program and non-qualifying equipment. This information can be developed from product model numbers provided by the distributors.

5.3 Materials

Several key materials need to be prepared before the distributors are approached. The first is a confidentiality agreement, in which the CPUC acknowledges that the relevant data provided by the distributor will contain confidential and proprietary sales information; and that information will be held in strict confidence and not disclosed to any third party without distributor's written permission. Furthermore, the information will not be used for any purpose other than the analyses described without an explicit agreement, access will be limited to employees directly involved in conducting the analyses, and copies of the information provided will be destroyed upon completion of the research.

Other materials to be developed include a data collection form, which can be very simple, containing fields for the product model number, the number of units shipped, the date, and the zip code where the units are shipped. Distributors can submit forms on-line; it will be necessary to have a secure File Transfer Protocol (FTP) site if they choose to use it.

Finally, it is important to have a mock package of graphs and reports to illustrate to distributors what this project will provide to them in the form of quarterly reports. This package can be individualized to each company; it would show total sales for the state or a particular region[114] and their own sales or market share. It should be noted that several distributor interviewees said they already get some sales data through the Air Conditioning, Heating, and Refrigeration Institute (AHRI), but there are no data on sales by efficiency levels. Such data would be quite useful to these companies and could provide a strong selling point for the market share tracking system. Mock-ups of data that could be provided are found in Appendix J.

[114] Regional data will be provided to the participants only if it does not compromise confidentiality by revealing their competitors' market shares

6 Conclusions and Recommendations

The HVAC Market Baseline Characterization Study examined the market shares of HVAC systems at varying levels of efficiency and the current installation and maintenance practices for these systems in California based on recently completed studies from several work orders collecting information from on-sites, as well as interviews with contractors, customers, program managers, and others involved in the California HVAC market. With a particular focus on residential and small commercial customers, this study sought to establish a baseline for a range of current maintenance and installation practices and the market shares of highly efficient systems that have been recently installed. This data will assist the CPUC in assessing the market effects attributable to these programs in the future. Additional studies will be needed to establish causality as shown in Table 6-4 and Section 6.5.2.

6.1 Market Shares of Energy-Efficient Equipment

Market shares of energy-efficient HVAC equipment sold in the residential and small commercial markets in 2011 and 2012 in California were significant especially for single-phase air cooled systems which was the dominant HVAC type. Overall nearly one-half (46%) of the units sold were single-phase air-cooled and four out of every ten of these (40%) met Tier 1[115] or better efficiency standards. The next largest market share (23%) was for air-cooled three-phase packaged and split equipment; more than one-half of these units (56%) met Tier 1 or better efficiency standards. Just over eight out of ten (81%) of the remaining unit types met Tier 1 or better efficiency standards.

The California Energy Efficiency Strategic Plan calls for 15% of HVAC equipment shipments optimized for California's climate by 2015 and 70% by 2020. The market transformation indicator of progress toward this goal is annual sales of climate-appropriate air conditioning. Using Tier 1 or better as a proxy for climate appropriate AC, this study estimates that 57% of HVAC units sold to residential and small commercial customers in 2011 and 2012 met the criterion. Thus, based on a Tier 1 standard, the current estimate of sales exceeds the goal set by the California Energy Efficiency Strategic Plan for 2015 and approaches the more ambitious goal for 2020. Only 13.5% of HVAC units sold in 2011 and 2012 would meet a higher climate-appropriate standard of Tier 2 or better.

[115] Performance tiers were defined using the 2010-2012 SCE Qualifying Minimum Equipment Efficiencies & Incentive Levels for Commercial Air Conditioners (see Appendix A). The number of tiers and tier standards, defined based on minimum unit SEER, EER, or IEER ratings, vary by HVAC unit type and capacity.

6.2 Quality Installation Findings

The baseline for Quality Installation (QI) in California is relatively low. Only a minority of contractors (42% residential; 36% small commercial) were aware of ACCA Standard 5 and a small minority said they adhere to all of its specifications (14% of all residential contractors; 8% of all small commercial contractors). Thirty-five percent of residential contractors and 19% of small commercial contractors said they were currently participating or had ever participated in an IOU QI program.[116] However, only 10% of residential contractors and 8% of small commercial contractors said they were currently participating in such a program. This self-reported participation rate is likely to be overstated by contractors responding to the survey since only a very small percentage of installation contractors, ranging from 1% to 3%, depending on the IOU, have been trained and/or qualified by the IOUs. Program training, generally to ACCA Standard 5 (residential) and 9 (commercial) and/or ENERGY STAR® QI, is a prerequisite for participation.

When asked about other certifications, more than one-half (53% residential; 59% small commercial) of installation contractors said their technicians were not certified by any organization. Note that only two-fifths (40%) of residential installation contractors and just over one-fourth (27%) of small commercial installation contractors hold NATE certifications, which are promoted by the IOU programs.

QI awareness among customers is fairly low. Fewer than one-fifth of residential respondents (16%) and small commercial respondents (17%) had heard of the term quality installation. Even after it was described to them, only about a quarter of all customers (25% residential; 28% small commercial) said they had heard of QI, and almost none of those customers could identify any QI guidelines or programs. When asked about the specific QI and rebate programs offered by their IOU, 10% to 21% of residential customers and 8% to 16% of small commercial customers said they had heard of particular IOU programs. Not surprisingly, contractors report that the greatest barrier to QI is customers not wanting to pay for it (63% residential; 66% small commercial).

Another potential barrier to QI (which also applies to QM) is the presence of unlicensed HVAC contractors. According to the California Contractors State License Board (CLSB), there are between 12,000 and 16,000 HVAC contractors who have C-20 licenses.[117] However, the CLSB estimates that there may be about 3,000 unlicensed HVAC contractors operating in California.[118] The presence of these unlicensed contractors who do not pull the necessary building permits for HVAC installations or who perform shoddy, low-cost maintenance jobs may be placing additional cost pressure on contractors, potentially weakening adherence to QI and QM.

[116] This figure was likely overstated as a result of respondents including any IOU program they had participated in, even though they were specifically asked about the Quality Installation program.
[117] The CSLB C-20 license is for Warm-Air Heating, Ventilating and Air-Conditioning Contractors.
[118] The CSLB staff member noted that this estimate is of contractors and not technicians.

The QI field assessments found a mixed record of compliance with Title 24 among installations in the overall HVAC replacement market. However, system performance metrics in the overall market were generally not as poor as assumed by the QI program.[119] The field assessments found that many systems have duct leakage greater than the Title 24 specification of <15% and the program efficient case assumption of 12%, but the average of 17% shows they were not as leaky as the baseline 24% duct leakage assumed by the QI program. The Title 24 minimum and efficient case assumption specifies system airflow at 400 CFM/ton. System airflows of 300 CFM/ton measured during the program non-participant site visits were even lower than the 350 CFM/ton baseline assumed by the QI program. While there was undersizing and oversizing relative to Manual J, systems not participating in the program were oversized by an average of 13%, which is lower than the baseline assumption of 20%. Table 6-1 summarizes these findings. The field assessments used Title 24 and manufacturer diagnostics to verify that proper refrigerant charge was present in all the systems tested. However, recent studies have found that the Title 24 and other diagnostics used to verify refrigerant charge are flawed; thus the results of this field assessment are considered to be indeterminate.

Table 6-1 QI Field Observations and Assumptions for the Program Baseline and Efficient Case

Statistic	Field Observations (mean)	QI Program Baseline Assumptions	QI Efficient Case Assumptions
Total System Duct Leakage	17%	24%	12%
System Airflow (CFM per ton)	300	350	400
System Oversizing	13%	20%	0%

6.3 Quality Maintenance Findings

As in the case of QI, the baseline for Quality Maintenance (QM) in California is also relatively low. A minority of contractors (45% residential; 34% small commercial) are aware of ACCA Standard 4 or ANSI/ASHRAE/ACCA Standard 180 and a small minority said they adhere to all of the appropriate specifications (10% of all residential contractors; 7% of all small commercial contractors). Thirty percent of residential contractors and 22% of small commercial contractors said they were currently participating or had ever participated in an IOU QM program.[120] However, only 16% of residential contractors and 6% of small commercial contractors said they were currently participating in such a program. As in the case of QI, this self-reported participation rate is likely to be overstated by contractors responding to the survey since only a small percentage of maintenance contractors, ranging from 1% to 10%, depending on the IOU,

[119] WO32 is developing savings estimates based on field findings, but these were not available for inclusion in this report.

[120] Again, this figure was likely over-stated due to the respondents including any IOU program they had participated in, even though they were specifically asked about the Quality Maintenance program.

have been trained and/or qualified by the IOUs. Program training, generally to the ANSI/ACCA Standard 4 (residential) or ANSI/ASHRAE/ACCA Standard 180-2008 (commercial), is a prerequisite for participation.

When asked about other certifications, more than one-half (55% residential; 56% small commercial) of maintenance contractors said their technicians were not certified by any organization. Note that about two-fifths (39%) of residential maintenance contractors and three out of ten (30%) small commercial maintenance contractors said they hold NATE certifications, which are promoted by the IOU programs.

QM awareness among customers is also fairly low. Just over one-fifth of residential respondents (21%) and small commercial respondents (22%) had heard of the term quality maintenance. Even after it was described to them, fewer than one-half of all customers (40% residential; 36% small commercial) said they had heard of QM, and almost none of those customers could identify any QM guidelines or programs. When asked about specific QM programs, 10% to 21% of residential customers and 13% to 16% of small commercial customers said they had heard of the particular programs offered by their IOU (PG&E and SDG&E programs include both QI and QM). As was the case for QI, contractors reported that the greatest barrier to QM is customers not wanting to pay for it (52% residential; 64% small commercial).

Nearly one-half of residential customers (48%) and one-third (66%) of small commercial customers recalled that they had their central AC system serviced, for any reason, within the last year, but more than one-fifth (21%) of residential customers and 9% of small commercial customers said that they have never had it serviced. Reflecting customers' propensity to call HVAC contractors only when their systems need repairs, once service calls for repairs are excluded, 24% of residential customers and 58% of small commercial customers said they have maintenance done on their HVAC systems every year. One-third (33%) of residential customers and one-quarter (25%) of small commercial customers said they never have maintenance done, except for repairs.[121]

The contractor surveys had a slightly different approach to estimating maintenance frequency. Sixty-four percent of residential maintenance contractors and 79% of small commercial maintenance contractors said they market maintenance contracts. Excluding the contractors who do not market contracts, 27% of residential contractors and 41% of small commercial contractors said that almost all of their maintenance customers renew their contracts each year.

In general, the QM field assessments determined that the performance metrics among non-program systems were consistent with and validated the QM program assumptions of sub-optimal performance. The field assessments found that residential system total duct leakage relative to nominal flow (23% for heating and 20% for cooling) is fairly close to the QM

[121] These statistics are based on customer responses. It may be that customers are receiving some regular maintenance services when their systems are being repaired, but are not aware of this.

program baseline assumption of 24%. Leakage to the outside relative to the measured airflow (27% for heating and 32% for cooling) is slightly higher than the baseline. The residential (331 CFM per ton for cooling) and commercial (359 CFM per ton for cooling) system airflows were not significantly different from the QM program baseline of 350 CFM per ton. These values are all well below the QM program requirements. Table 6-2 summarizes these findings. As noted for the QI field assessments, verifications of the refrigerant charge are considered to be indeterminate.

Table 6-2 QM Field Observations and Assumptions for the Program Baseline and Efficient Case

Statistic	Field Observations (mean)	QM Program Baseline Assumptions	QM Efficient Case Assumptions
Total System Duct Leakage (using nominal heating airflow)	23%	24%	12%
Total System Duct Leakage (using nominal cooling airflow)	20%	24%	12%
Residential System Airflow in Cooling Mode (CFM per ton)	331	350	400
Commercial System Airflow (CFM per ton)	359	350	400

Field observations of technicians conducting maintenance calls on a system with intentionally implemented faults yielded particularly important QM insights, and also served as a reminder that self-reports by contractors are not always accurate. Overall, the typical "maintenance" services provided were below the standards of ACCA 4 utility "quality maintenance" program goals and industry best practices as judged by the expert technician. Post-observation interviews indicated that observed technicians were not knowledgeable about ACCA Standard 4, and none of the 13 observed technicians stated that they use the standard in their regular work. During field observations, almost all of the technicians attempted some of basic maintenance tasks, but few performed the tasks correctly. Performance level was not related to the technician's certifications, training, years on the job, or participation in utility programs. Some of the most important tasks for energy efficiency were frequently not even attempted. There was, in fact, a disconnect between contractors' stated practices and technicians' practices in the field. This is a key reason for recommending periodic field assessments as well as surveys in Table 6-4 below.

6.4 Proposed Market Share Tracking System

The study developed a proposed market share tracking system that would recruit distributors to provide quarterly data. The proposed system was modeled largely along the lines of the Energy Center of Wisconsin's (ECW) successful Furnace and Air Conditioning Tracking System (FACTS). Our proposed approach would provide systematic process for periodic reporting of market share by efficiency level and sales.

6.5 Baseline Summary

6.5.1 Summary of Market Progress Indicators

Table 6-3 summarizes the baseline values and suggested tracking for the Market Transformation Indicators (MTIs) established for CPUC HVAC programs.

Table 6-3: Market Transformation Indicator Baseline Values and Suggested Tracking to Assess HVAC Subprograms Progress

Market Transformation Indicator	Baseline Value	Comments and Suggested Tracking
Market share of climate appropriate HVAC equipment (MTI-1)	40% of single-phase air cooled units and 56% of air cooled three-phase packaged and split equipment sold in 2011 and 2012 meet a Tier 1 or better performance standard. (Single-phase air cooled equipment was predominantly residential and three-phase equipment was almost exclusively commercial. Performance tiers were defined using the 2010-2012 SCE Qualifying Minimum Equipment Efficiencies & Incentive Levels for Commercial Air Conditioners (see Appendix A). The number of tiers and tier standards, defined based on minimum unit SEER, EER, or IEER ratings, vary by HVAC unit type and capacity.)	Explicit criteria for HVAC units qualifying as "climate-appropriate" have not been defined. Proposed market share tracking system would collect data by efficiency level from distributors four times each year
Percentage change in the use of Quality Installation guidelines among all California Residential HVAC installation contractors (MTI-2)	14% of residential contractors say they adhere to all ACCA* Standard 5 requirements Indirect evidence of extent of adherence to QI from the field assessment indicated that system performance metrics in the overall market were not as poor as assumed by the QI program: mean total system duct leakage of 16% versus efficient case assumption of 12%; mean system airflow at 300 CFM per ton versus efficient case assumption of 400 CFM per ton; mean oversizing of 13% versus efficient case assumption of 0%	Contractor surveys every two years; field assessments every four years
Percentage change in the use of Quality Installation guidelines among all California Commercial HVAC installation contractors (MTI-3)	8% of small commercial contractors say they adhere to all ACCA Standard 5 requirements; no field assessments available	Contractor surveys every two years; field assessments every four years
Percent change in the employment of Quality Maintenance practices among all California HVAC contractors and technicians (MTI-4)	10% of residential and 7% of small commercial contractors say they adhere to all applicable ACCA/ASHRAE standards Indirect evidence of extent of adherence to QM from the field assessment indicated that the performance metrics among non-program systems validated the QM program assumptions of sub-optimal performance: mean total system duct leakage of 23% versus efficient case assumption of 12%; mean total system duct leakage of 20% versus efficient case assumption of 12%; mean residential system airflow at 331 CFM per ton versus efficient case assumption of 400 CFM per ton; mean commercial system airflow at 359 CFM per ton versus efficient case assumption of 400 CFM per ton. The HVAC Contractor and Technician Behavior Study conducted observations of 13 technicians on a maintenance call. The study found that the typical maintenance service was below the standards of ACCA 4, utility quality maintenance program goals. The technicians were not knowledgeable about ACCA Standard 4, and none of them indicated using the standard.	Contractor surveys every two years; field assessments every four years

This study proposed several secondary indicators for MTI-2, MTI-3, and MTI-4. Table 6-4 summarizes the current baseline values and suggested tracking frequency for the secondary indicators.

Table 6-4: Baseline Values and Suggested Tracking of Secondary Indicators Assessing HVAC Subprograms Progress

Secondary Indicator	Baseline Value	Comments and Suggested Tracking
Quality Installation: ***percent change***		
Contractor awareness of ACCA standards (SIQI-1)	42% residential; 36% small commercial	Contractor surveys every two years; field assessments every four years
Customer awareness of the concept of QI (SIQI-2)	Unaided: 16% residential; 17% small commercial. Aided: 25% residential; 28% small commercial.	Unaided and aided customer awareness reported; Customer surveys every two years
Contractors currently participating in QI programs (SIQI-3)	10% residential; 8% small commercial	Contractor surveys every two years; check against IOU reporting
Customer awareness of rebate and QI programs (SIQI-4)	10% to 21% residential; 8% to 16% small commercial	Awareness varies by IOU; Customer surveys every two years
Technicians with training in QI (SIQI-5)	1% to 3% of all contractors	IOU qualification analyses every year
Portion of contractors who obtain building permits for HVAC installations (SIQI-6)	NA	Although tracking this indicator was outside the scope of this study, interviews revealed it to be a significant issue that could inhibit QI.
Quality Maintenance: ***percent change***		
Contractor awareness of ACCA/ASHRAE standards (SIQM-1)	Awareness: 45% residential; 34% small commercial; adherence to all: 10% residential; 7% small commercial	Contractor surveys every two years; field assessments every four years
Customer awareness of the concept of QM (SIQM-2)	Unaided: 22% residential; 21% small commercial. Aided: 40% residential; 36% small commercial	Unaided and aided customer awareness reported; Customer surveys every two years
Contractors currently participating in QM programs (SIQM-3)	16% residential; 6% small commercial	Contractor surveys every two years; check against IOU reporting
Customer awareness of QM programs (SIQM-4)	10% to 21% residential; 13% to 16% small commercial	Awareness varies by IOU; Customer surveys every two years
Technicians with training in QM (SIQM-5)	1% to 10% of all contractors	IOU qualification analyses every year
Customers who have regular maintenance of their HVAC systems (SIQM-6)	24% residential; 58% small commercial	Percent who have annual maintenance excluding repairs reported; Contractor and customer surveys every two years

[*] Awareness of the SCE Installation Program is 14% for residential customers and 8% for small commercial customers; awareness of the SCE Maintenance and Repair Program is 11% for residential customers and 16% for small commercial customers. Awareness of the PG&E Quality Care Program covering QI and QM is 10% for residential customers and 13% for small commercial customers. Awareness of the SDG&E Quality Care Program covering QI and QM is 21% for residential customers and 16% for small commercial customers.

6.5.2 Attribution of Market Effects

Following completion of the field assessments every four years as suggested in Table 6-4, we recommend assessing what portion of changes in practices may be attributed to the IOU programs. Delphi panels are increasingly being used to estimate attribution for efforts such as the HVAC subprograms, which operate in markets with complex interrelated factors, over time. The Delphi panel of industry experts would examine the observed changes in the market indicators along with self-reports from contractors and customers on the reasons for changing practices. The panelists would also examine the program theory models as to how the observed changes relate to the primary and secondary indicators, and records of program activities such as training, number of qualifying contractors, and customer education. Attribution of market effects would thus be based on the data collected in surveys, interviews, and field assessments conducted by the suggested tracking shown in Table 6-4.

6.6 Recommendations

6.6.1 Program Design and Operation

The findings from this study led to the following recommendations pertaining to the design and operation of the HVAC subprograms:

- Focus on educating customers about the value of QI and QM. "Quality" is a generic term; many contractors will claim that they provide "quality" services. Customers need to be educated about the specifics (in lay terms) of QI and QM and the resulting energy savings. Customer education may also encourage the scheduling of regular maintenance visits, and also target those who are changing out HVAC systems such as through major renovations, and also those who are building or buying new homes.
- Collaborate with industry leaders to train contractors so that they have their NATE certifications in place. Industry leaders may also help promote IOU program qualification requiring more stringent ACCA/ASHRAE/ENERGY STAR standards to contractors and educate customers about the value of QI and QM program-qualified contractors.
- Step up efforts to have contractors participate in the IOU training programs. Agreeing on a common definition across IOUs of qualification requirements is a first step. Without this, it will be difficult to sell the value of "program-qualified contractors" to contractors and consumers.
- Seek to increase the market share of more efficient systems by educating customers about the energy savings and other benefits associated with more efficient HVAC systems and the rebates available. As with the first recommendation above, effective strategies and messages should be explored with customer focus groups or surveys prior to launch.

- Specific recommendations from the field assessments include the following:
  - Continue to promote the use of software to perform system sizing calculations to reduce oversizing.
  - Research approaches to measuring refrigerant charge and develop diagnostics that are more reliable for maintenance.
  - Perform duct sealing as the primary residential maintenance measure.
  - Research approaches to repairing or replacing commercial economizers, reducing rooftop unit leakage (unit and economizers), and optimizing fan efficiency.

6.6.2 Research and Tracking

The following recommendations pertain to research and tracking of program indicators:

- Implement a market share tracking system based on the model developed by this study so that a systematic process for periodic reporting of market shares by efficiency level and sales is in place going forward.
- Periodically assess the market transformation indicators and secondary indicators suggested by this study through contractor and customer interviews and on-site assessments of HVAC installations and maintenance, as suggested in Table 6-3 and Table 6-4.
- Create more secondary indicators that can be measured through field assessments. Examples are increasing the number of systems properly sized within one-half ton of design load, increasing fan airflow (CFM per ton) and efficiency (Watts per CFM), reducing duct leakage to the outside in existing ducts, and reducing the number of new ducts in conditioned space. These indicators could be assessed through on-site assessments every four years.
- The on-site observations of maintenance work on a system with intentionally implemented faults provided invaluable information about the state of maintenance services available to most customers and should be repeated regularly.
- Further focus group research may be required to assess the extent to which customers (and contractors) are able to differentiate "Quality Installation" and "Quality Maintenance" from the generic term "quality" to which all contractors would lay claim. This research could explore alternative terms and messaging to identify those to which customers are most responsive.
- Continue to study differences in the performance of installed or maintained HVAC units between HVAC contractors who participate in IOU programs and/or are NATE certified, and HVAC contractors who do not participate in IOU programs and/or are not NATE certified. These differences are likely to get smaller as the HVAC market is being transformed, but are likely to significant for at leastthe next several years.