Final Report: 2014-2016 HVAC Permit and Code Compliance Market Assessment (Work Order 6) Volume II - Appendices

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Report Glossary

Provided are definitions of key words used in this report. Several definitions are direct citations from the California Energy Commission (CEC) California Building Energy Efficiency Standards or "Standards."[1]

Additional duct insulation refers to a supplemental threshold—required in some climate zones—of increasing the R-value of the duct insulation beyond the typical minimum of R-4.2. Depending on the climate zone, the Standards require that duct insulation must be increased to a minimum of R-6 or R-8.

Additions are changes to an existing building that increase both conditioned floor area and volume. These were excluded from the study. Installations that involved additions at the same time as the HVAC changeout were also excluded from this study.

Airflow is the volume of air per minute that central, forced-air system fans maintain across the return air intake; it is measured in cubic feet per minute (cfm). When entirely when new or replacement HVAC system changeouts (including new/replacement duct systems) are installed in CZs 10-15, the system must be tested and field-verified to have an airflow greater than 350 cfm per nominal ton of cooling capacity to comply with the Standards. This requirement does not apply, however, when only some of the HVAC components are new/replaced—a more common occurrence than changeouts. Additionally, a separate protocol dictates that the airflow must be greater than 300 cfm when measuring and verifying refrigerant charge. Therefore, at projects with new/replacement components that have less than 300 cfm of airflow, the project is—by definition—out of compliance with the refrigerant charge requirement.

Alterations are not additions, but rather changes to a building's envelope, space conditioning system, water heating system or lighting system. This building modification category was the focus of this study.

Building permit is an electrical, plumbing, mechanical, building, or other permit or approval issued by an enforcement agency and that authorizes any construction that is subject to Title 24, Part 6 Building Energy Standards (Standards).

California Building Energy Efficiency Standards, also referred to as the Standards, are the regulations and requirements contained in Title 24, Part 6 Building Energy Standards (Standards).

Changeout is a HVAC replacement of an existing component or system or installation of a new central system when a central system was not previously installed. These system types are the focus of the study. The study excludes HVAC installations that are part of a building alteration and portable space heating or cooling installations.

Climate region is a region made up of combined California climate zones (defined below) for the purpose of this study. Each region is made up of groups of climate zones that have relatively similar characteristics related to heating and cooling needs. For the top-down permit rate estimation, we used five climate regions: North Coast (zones 1, 2, and 5), North Inland (zones 2, 11, and 16), Central Inland (4, 12, and 13), South coast (6 and 7), and South Inland (8, 9, 10, 14, and 15). To evaluate the smaller on-site sample, we futher consolidated the zones into two regions comprised of similar climate characteristics: a Coastal region (zones 1, 3, 5, 6, and 7) and an Inland region (zones 2, 4, and 8-16).

Climate zone (CZ) is one of the 16 geographic areas of California for which the CEC has established for use with the California Building Energy Efficiency Standards. Typical weather data, prescriptive requirements,

[1] CEC, 2012.

and energy budgets are established for each climate zone. Climate zones are defined by ZIP code: http://www.energy.ca.gov/maps/renewable/building_climate_zones.html.

Codes and Standards Enhancement (Case) Initiative Reports are detailed studies used to inform CEC rulemaking.

Compliance forms (CFs) are any of the documents specified in Section 10-103(a) of the Standards that demonstrates compliance with Title 24, Part 6 Building Energy Standards (Standards). Examples include a certificate of compliance, certificate of installation, certificate of acceptance, and certificate of verification.

Database for Energy Efficient Resources (DEER) is a CEC and California Public Utilities Commission (CPUC) sponsored database designed to provide a source of well-documented estimates of energy and peak demand savings values, measure costs, and effective useful life (EUL).

Duct insulation is wrapped around or integral with all ductwork in located in unconditioned spaces. Unless ducts are installed entirely within conditioned spaces, the minimum duct insulation allowed by the Standards is R-4.2.

Duct leakage is the air leaked from the duct system when it is tested as required by the Standards. When a HVAC system is altered by the installation or replacement of components (including replacement of the air handler, outdoor condensing unit of a split system air conditioner or heat pump, cooling or heating coil, or the furnace heat exchanger), or if at least 40 feet of ductwork in unconditioned space is replaced, or if the entire duct system is new/replaced, the duct system must be tested and confirmed through field verification to have no more air leakage than is allowed by the Standards. Compliance requirements for the 2008 building code cycle include: either ≤6% total leakage (for new ducts), ≤15% total leakage (for existing ducts), ≤10% leakage to outside, ≥60% measured improvement compared with existing leakage conditions, or demonstration—confirmed through a smoke test—that all accessible leaks have been sealed. See Section 152(b)E (CZs 2 and 9-16) for the 2008 Standards.

Enforcement agency is the city, county, or state agency responsible for issuing a building permit.

Fan power index is the measure of the wattage drawn by the central system air handler fans divided by the airflow at the return air intake, in W/cfm. To comply with the Standards at entirely new or replacement duct systems, the system must be tested and field-verified to have an air-handler fan power index of less than 0.58 W/cfm for CZs 10-15. The requirement does not apply to the much more common occurrence of replacement of the entire duct system.

Field verification and diagnostic testing (FV/DT) is a term used to describe the actions taken HERS Raters when performing inspections.

Final permit is used to describe an installation with documentation of a mechanical permit having been both issued and finalized—or signed off on—by an enforcement agency. Throughout the report, we sometimes refer to final permits as “permitted” or “closed permit.”

HERS is the California Home Energy Rating System (HERS) as described in California Code of Regulations Title 20, Chapter 4, Article 8, Sections 1670 – 1675.

HERS Provider is business entity that administers a home energy rating in compliance with the HERS regulations.

HERS Registry is a registry maintained by a HERS Provider that contains field diagnostic test results performed by HERS Raters. HERS inspections primarily apply to residential installations, but some commercial equipment types—such as split systems—require HERS testing. Registries process the HERS Rater rating, store the documents, and issue the certification. The registry (by project level) is accessible to HERS Raters, building department officials, and HVAC contractors.

HERS Rater is a person who has been trained, tested, and certified by and is subject to the oversight of a HERS Provider to perform field verification and diagnostic testing required for demonstrating compliance with Title 24, Part 6 Building Energy Standards (Standards). Raters are typically independent contractors. Raters charge customers a service fee to rate the contractor's HVAC inspection and a portion of this fee is paid to Registry. HERS rater inspections are not limited to HVAC changeouts.

HVAC installation efficacy (HIE) is a weighted average of the requirement-level compliance (see definition) results for each energy efficiency requirements at a given site. DNV GL developed this metric for the purpose of this study. We established the weights for each requirement based on their relative influence on the energy impacts attributable to the HVAC alteration. Each requirement has its own set of weights that vary by climate zone and the building code in effect at the time of the alteration.

Load calculations are used for estimating building cooling and heating loads and, ultimately, for equipment sizing. According to the Standards, load calculations must be calculated in accordance with a method based on any one of the following: American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) Handbook, Sheet Metal & Air Conditioning Contractors' National Association (SMACNA) Residential Sheet Metal Manual, or Air Conditioning Contractors of America (ACCA) Residential Load Calculation: Manual J.

Mandatory measures are requirements that are mandatory and apply to any installed HVAC equipment.

Measurement access is a measure of access to the refrigerant charge port and to the supply and/or return plenums. Access to the refrigerant charge port is necessary to measure the amount of refrigerant in the system and to adjust as necessary. Measurement access holes are required to facilitate insertion of temperature or pressure probes into the supply or return plenums. There are three options: temperature measurement access holes (TMAH), saturation temperature measurement sensor (STMS), or permanent install static pressure probe (PSPP). Access must be in the plenum on either side of the evaporator coil to allow non-intrusive measurement of supply and return air temperature and humidity. This requirement applies in CZs 10-15.

No permit is an installation where there is no documentation of a mechanical HVAC by an enforcement agency permit from the local jurisdiction. Throughout this report we refer to unpermitted changeouts as "no permit" or "non-permitted".

Performance standard describes a compliance path whereby the energy budget calculated for the Proposed Design Building under Subsection 2 is no greater than the energy budget calculated for the Standard Building under Subsection 1. Installations that followed the performance path were excluded from the on-site sample fram for this study.

Prescriptive measures are those that are used in lieu of performance standards to comply with the Standards. It should be noted that different prescriptive requirements apply to 1) alterations that install/replace specific components of HVAC systems and 2) alterations that install/replace entire HVAC systems, including all components and ducts.

Refrigerant charge is the amount of refrigerant gas that a cooling system must contain. For a cooling system to perform properly, the correct refrigerant charge is required. To comply with the Standards, proper refrigerant charge must be tested and field-verified (home energy rating system or HERS) and diagnostic testing using procedures in the Reference Residential Appendix SA3.2 or the cooling unit must have a charge indicator display. HERS verification of refrigerant charge is required only in CZ 2, and CZs 8-15. The refrigerant charge verification includes requirement for verification of minimum system airflow rate. For alterations, a 300 cfm/ton minimum is required and 350 cfm/ton is required for entirely new or complete replacement systems.

Refrigerant line insulation is required around refrigerant lines in HVAC systems. The Standards require cooling system line insulation of a minimum thickness determined using Equation 150-A from the Standards.

Requirement-level compliance is scored by using a scale from zero to 100%. Some of the requirements used in this study are pass/fail and, hence, the requirement-level compliance receives a score of 100% or zero, respectively. The remainder of the requirement-level compliances each use a scale, from zero to 100%, to gauge the extent to which the installation falls short of the threshold dictated by the Standards. Meeting the threshold for a given requirement yields a compliance rate of 100%; no bonus is given for conditions that exceed a given threshold. To establish appropriate ranges for these scales, lower limits were selected to be represented by a zero on the scale (e.g., 150 cfm/ton for airflow and 60% for total duct leakage). This was done to account for the fact that no installation could reasonably be expected to have conditions below those lower limits.

Title 24, Part 6 Building Energy Standards (Standards) are the California Code of Regulations that dictate energy efficiency standards for buildings: http://www.bsc.ca.gov/Codes.aspx.

Un-final permit is used to describe an alteration where documentation exists of a mechanical permit issued by an enforcement agency, but the permit was either allowed to expire or remain open without sign-off from a building department. Throughout this report, we refer to un-final permits as "open."

APPENDIX A. TOP-DOWN PERMIT RATE METHODOLOGY

Top-down permit rate analysis

Researchers used a top-down method to "analyze the big picture." The analysis involved an estimate for the total number of units permitted and total number of units installed. For the permit estimate we used permit data from building departments and HERS certificate data from the largest HERS provider. We then compared those values to the estimated number of units that were sold for replacements during the same period using overall household population data. The development of total units sold took into consideration the average life cycle of equipment and how life cycles vary by the 16 California climate zones. This top-down approach resulted in a coarse permitting rate estimate that had the advantage of not being subject to response bias.

The top-down analysis breaks down into three primary analytical steps:

1. Estimate the total number of residential HVAC changeouts.
2. Estimate the number of permitted changeouts.
3. Calculate the permit rate.

The first and second of these steps consists of multiple analytical steps, which we discuss in detail below.

Estimating the number of residential HVAC changeouts—the denominator

We used a HVAC equipment stock accounting model to estimate the total number of residential HVAC changeouts. The concept of the approach is to begin with annual estimates of residential HVAC units currently installed within the state (stock), then use information about average equipment lifetimes, changes to equipment saturations, and changes to housing stocks to approximate the number of new HVAC units installed annually in both existing and new homes. We pulled data from the following sources:

- HVAC equipment saturations from the 2003 and 2009 California Residential Appliance Saturation Surveys (RASS)
- The number of California households by county in 2010 and 2014 and total California households from 2000 to 2014, both from US Census Data
- Estimated useful lifetimes (EUL) of HVAC equipment from the California Database for Energy Efficiency Resources (DEER) and the Department of Energy
- U.S. historic HVAC shipments by type from the Air-Conditioning, Heating, and Refrigeration Institute (AHRI) from 1995 to 2014

The approach gets us from those four key inputs to having shipments of HVAC equipment over time by type and climate region, broken out by new construction, replacement units, and new units in existing buildings (the latter two categories comprising changeouts). The process involves four key steps, which we discuss in detail below:

1. Develop estimates of equipment stocks over time by climate region.

2. Estimate equipment shipments over time by climate region and equipment type using EUL estimates and assuming that equipment survival rates follow a Weibull distribution.

3. Use national-level shipment data to cyclically adjust shipments estimates.

4. Disaggregate 2014 shipments into replacement HVAC, HVAC additions to existing construction, and HVAC shipments to new construction.

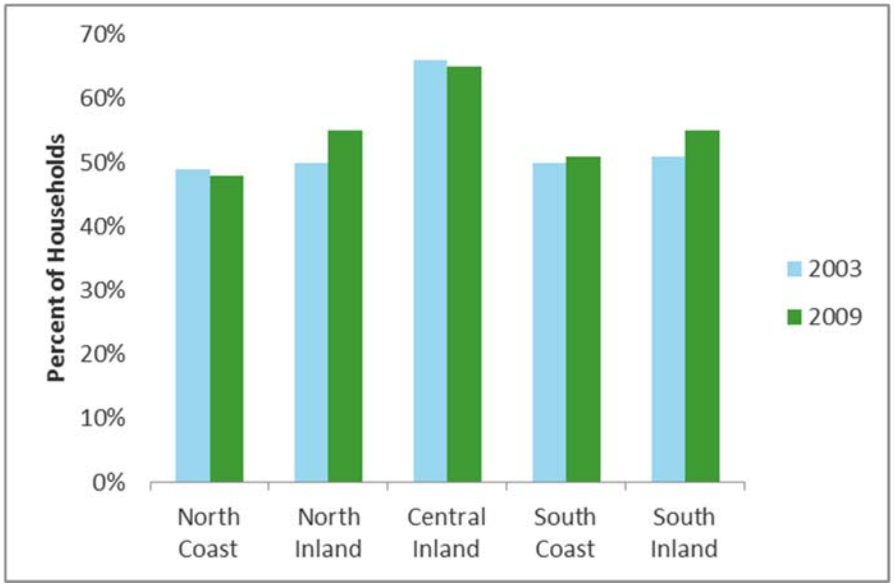
Estimating equipment stocks over time

The RASS studies were an ideal starting point for estimating equipment saturations over time. The large sample size (25,000) provided statistically reliable estimates by climate region and equipment type. Having two comparable studies at different points in time let us estimate the change in the saturations of each equipment type over time. The two RASS studies cover most, but not all, of California. They include the service territories of California's four investor-owned utilities and the Los Angeles Department of Water and Power (LADWP). These utilities represented 86 percent of California households in 2008 (when the sample for the 2009 RASS was drawn). Lacking an alternative data source for the remainder of the state, we extrapolated the equipment ownership patterns from the RASS study to the rest of the state by climate region.

The 2009 RASS sample included 24,225 individually-metered households, representing 11,093,798 households in the service territories of California's investor-owned utilities and LADWP. The 2003 RASS sample included 21,153 individually-metered households, representing 9,399,793 households. The covered territory represented 86 percent of California for the 2009 survey, and 77 percent for the 2003 survey. For this study, we assumed that the RASS saturations for each climate region were representative of all households in the region.

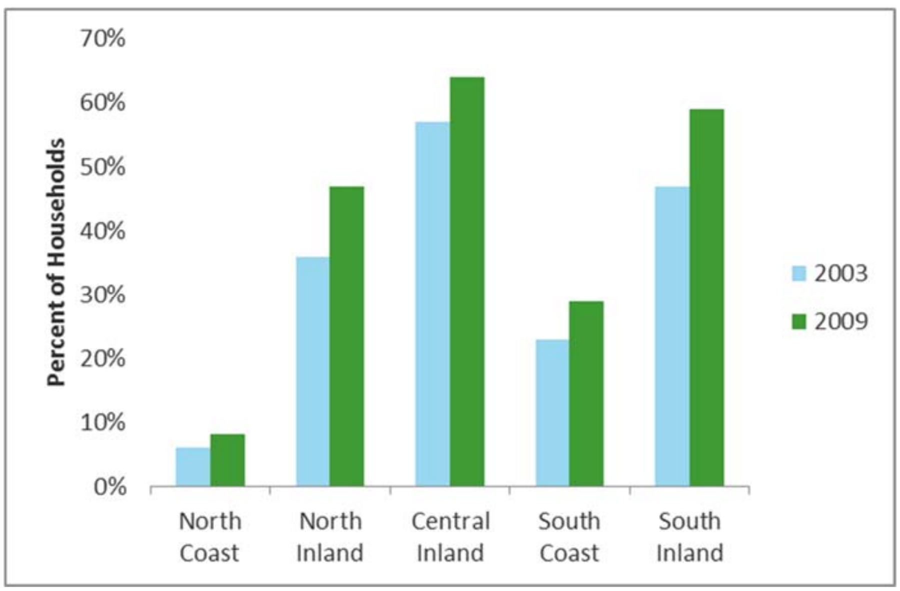
From the RASS data, we estimated the saturation of four key equipment types in 2003 and 2009. Because our primary source of permit data was HERS duct testing, we felt that focusing on ducted systems would provide the appropriate population for comparison. Figure 1 through Figure 4 next show the saturations for gas central forced-air heating (bottled and natural gas combined), central cooling, heat pumps (for cooling), and electric central forced-air heating, respectively. The saturations represent the percent of homes with that equipment as their primary heating or cooling system, as a percent of the RASS household population for the region. The charts compare the saturation in 2003 with the saturation in 2009, broken out by climate region.

Figure 1. Saturation data for central forced air, gas heating units



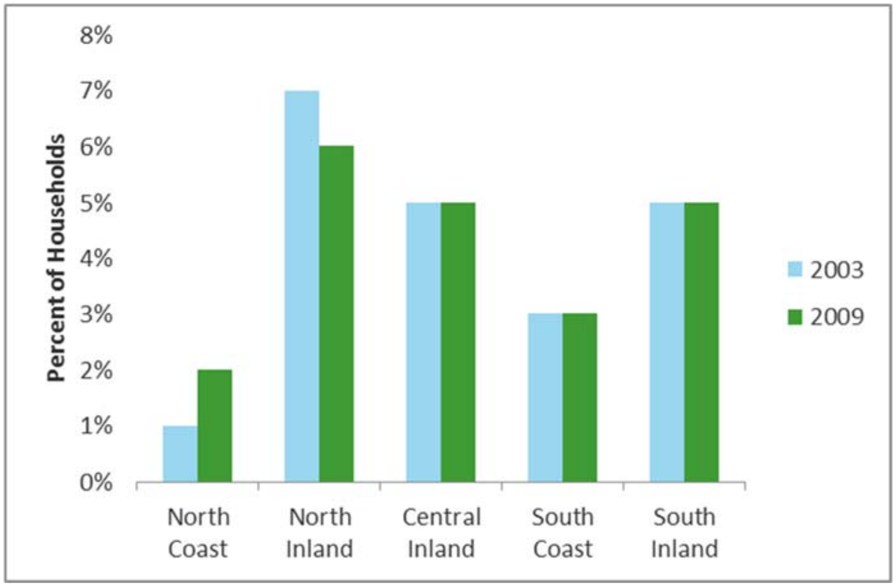
Based on 24,225 RASS responses for 2009 (2,752 North Coast, 2,384 North Inland, 4,066 Central Inland, 5,092 South Coast, and 9,931 South Inland) and 21,153 responses for 2003 (3,297 North Coast, 2,164 North Inland, 4,423 Central Inland, 3,650 South Coast, and 7,619 South Inland).

Figure 2. Saturation data for central cooling system units



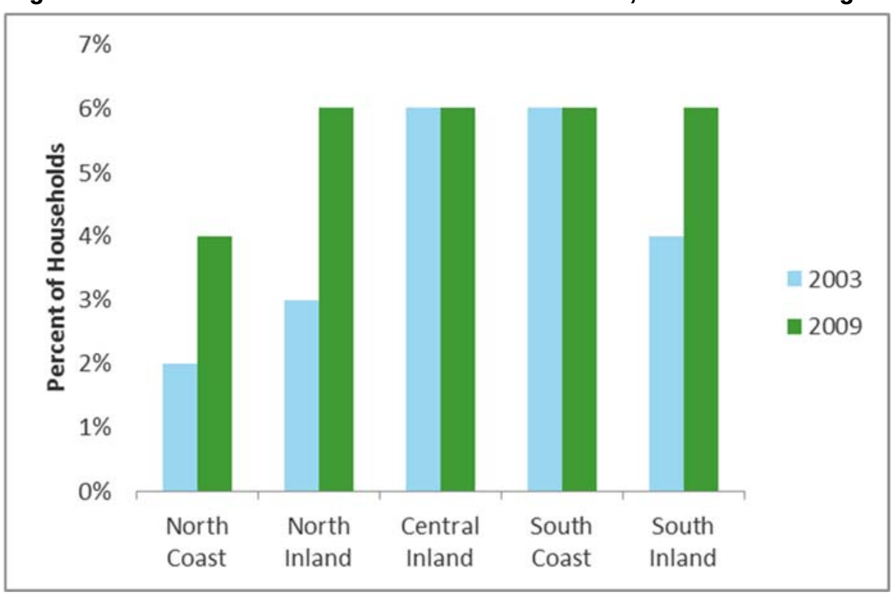
Based on 24,225 RASS responses for 2009 (2,752 North Coast, 2,384 North Inland, 4,066 Central Inland, 5,092 South Coast, and 9,931 South Inland) and 21,153 responses for 2003 (3,297 North Coast, 2,164 North Inland, 4,423 Central Inland, 3,650 South Coast, and 7,619 South Inland).

Figure 3. Saturation data for heat pump units



Based on 24,225 RASS responses for 2009 (2,752 North Coast, 2,384 North Inland, 4,066 Central Inland, 5,092 South Coast, and 9,931 South Inland) and 21,153 responses for 2003 (3,297 North Coast, 2,164 North Inland, 4,423 Central Inland, 3,650 South Coast, and 7,619 South Inland).

Figure 4. Saturation data for central forced air, electric heating units

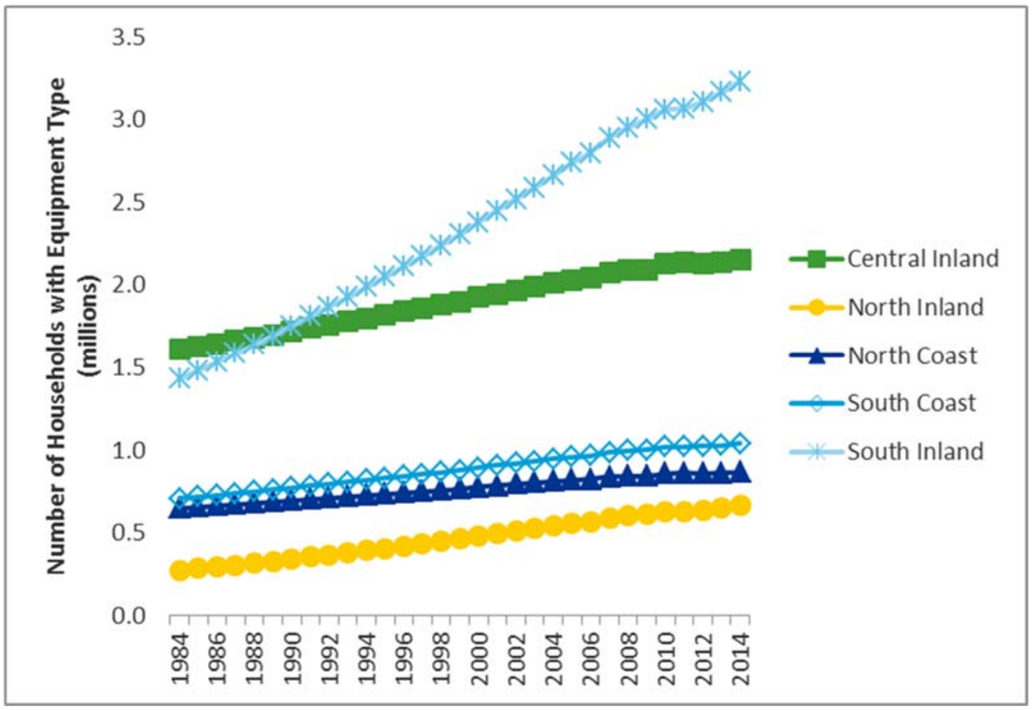


Based on 24,225 RASS responses for 2009 (2,752 North Coast, 2,384 North Inland, 4,066 Central Inland, 5,092 South Coast, and 9,931 South Inland) and 21,153 responses for 2003 (3,297 North Coast, 2,164 North Inland, 4,423 Central Inland, 3,650 South Coast, and 7,619 South Inland).

Taking into account the change in equipment saturations between 2003 and 2009, we interpolated and extrapolated equipment saturations backward to 1984 and forward to 2014. The time series needed to extend so far back in time to accurately represent the mix of vintages present in 2014. A unit sold in 1984 that survived 30 years (a possibility in real life and in the model under the assumption of a Weibull survival function) would still be present in the stock in 2014.

To get from saturation to the number of units, we brought in data on the number of California households from the US Census. County-level data was available for 2010 and 2014, [2] and overall state-level household counts from 2000 to 2014. We aggregated the county-level data up to climate regions, then interpolated to estimate housing stocks between 2010 and 2014 and extrapolated backward to 1984. We combined these estimates with the corresponding saturation estimates to estimate the number of households, by climate region, having each type of equipment of interest from 1984 to 2014. We used this estimate of the number of households as a proxy for the number of equipment units (assuming one unit per household) for the remainder of the top-down total changeout analysis. The resulting trends are shown in Figure 5 through Figure 8.

Figure 5. Number of households with central forced-air gas heating



2 http://www.census.gov/quickfacts/table/HSG010214/00

Figure 6. Number of households with central cooling

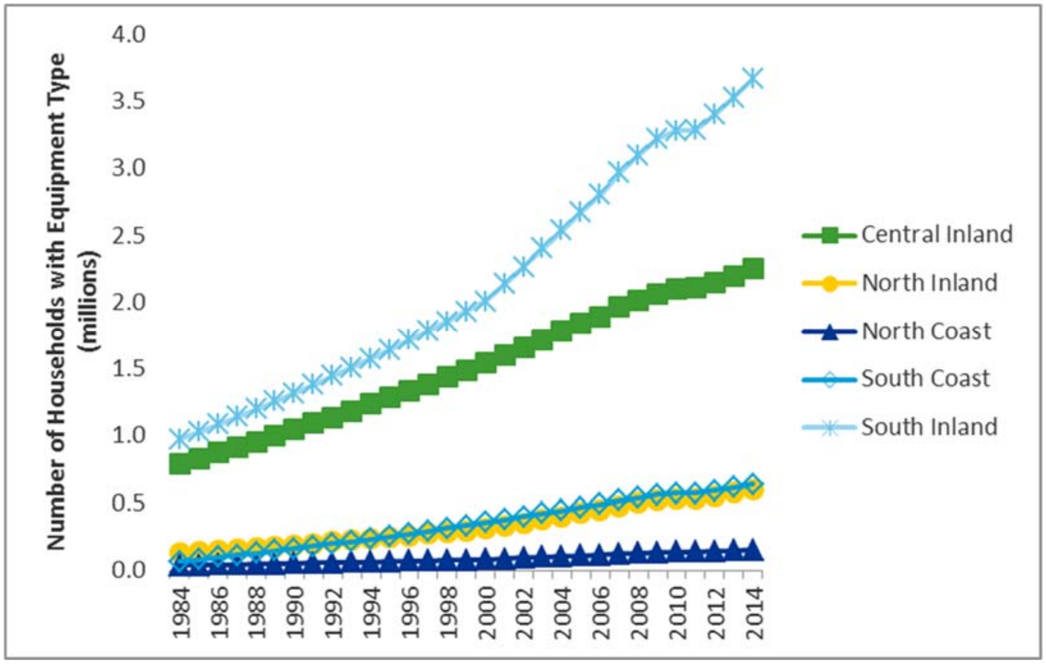


Figure 7. Number of households with heat pumps

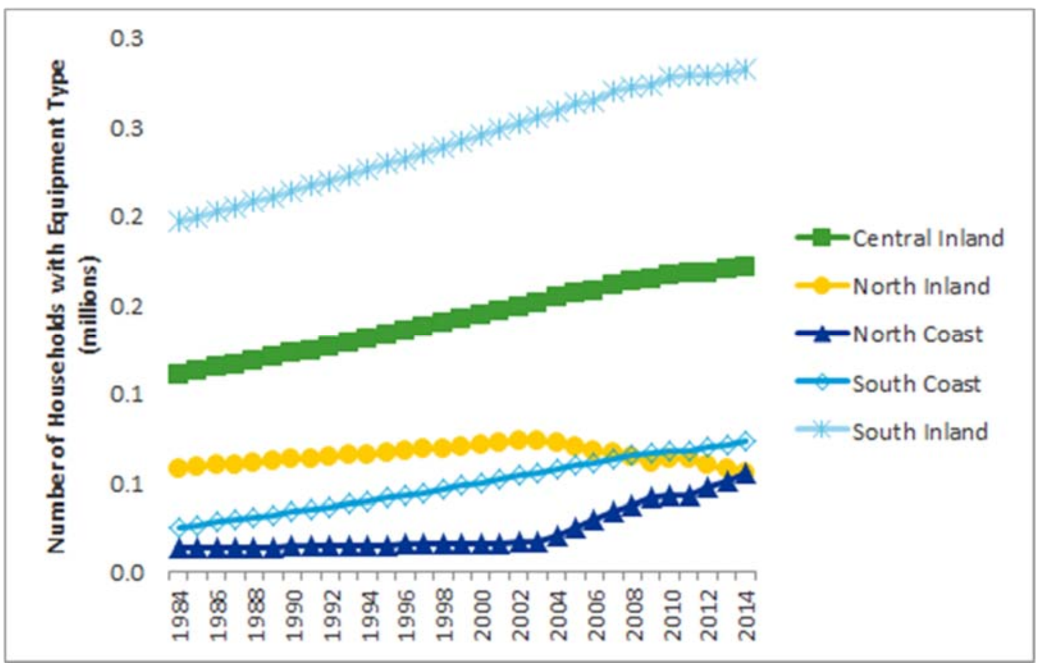
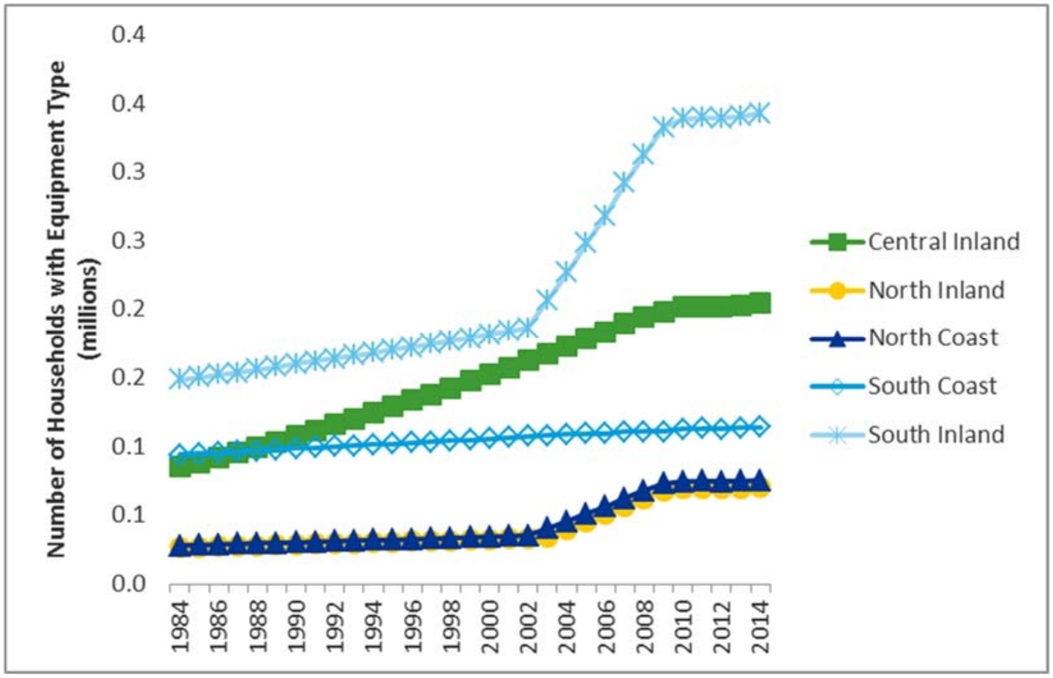


Figure 8. Number of households with central forced-air electric heating



Estimating equipment shipments based on equipment stocks

Given historic equipment stocks, we can infer shipments give sufficient information about equipment lifetimes and survival distributions. In this step of the analysis, we first estimated median equipment lifetimes by equipment and climate regions, then used them to develop probability distribution functions of time to equipment failure. Using these, we broke out each year's equipment stock by vintage.

Estimating HVAC lifetimes

Available data on equipment lifetimes provides a rough estimate of median equipment lifetime (EULs represent the age at which half of units are expected to have failed). We conducted a literature review looking for recent retention studies, utility work papers, and related literature to obtain the necessary lifetime values, but generally found that the DEER captured the best available estimates for most equipment types. The exceptions, gas central furnaces, have particularly long lifetimes, and we learned that DEER caps equipment lifetimes at 20 years. For gas furnaces only, we used a national-level EUL estimate of 22 years from the Department of Energy. Figure 9 presents the starting (statewide) effective useful lifetimes (EUL) used in the study.

Figure 9. Equipment EULs

Equipment type	State Average EUL	Reference Source
Central Air Conditioner	15	DEER
Central Heat Pump	15	DEER

Equipment type	State Average EUL	Reference Source
Central Natural Gas Furnace	22	DOE 2015. TSD. Energy Efficiency Program for Consumer Products and Commercial and Industrial Equipment: Residential Furnaces
Central Electric Furnace	20	DEER

HVAC usage, however, varies significantly across California's diverse climate zones, which would suggest that HVAC lifetimes (in years) should vary as well. To vary EULs by climate region, we used estimates of full-load hours by climate zone developed using DEER building simulations that were calibrated to previous RASS estimates.

Beginning with estimates of heating and cooling full load hours for California's 16 climate zones derived from building simulations, we weighted up to the climate-region level based on number of households by climate zone. We then took the ratio of statewide full load hours to regional full load hours to develop multipliers for each region. While this is only an approximation, we believe it results in more accurate turnover estimates at the climate region level. Figure 10 shows the multipliers we applied to the statewide EULs to adjust them for each region.

Figure 10. Climate region adjustment factors for EULs

Climate regions	Cooling	Heating
North Coast: CZ 1, 3, 5	5.7	0.77
North Inland: CZ 2, 11, 16	1.1	0.78
Central Inland: CZ 4, 12, 13	0.9	1.05
South Coast: CZ 6, 7	1.4	0.84
South Inland: CZ 8, 9, 10, 14, 15	0.7	1.23

The extremely high multiplier for the North Coast cooling is the result of very low full load hours in that region. Applying the raw multiplier would have resulted in an EUL of 85 years, which is not plausible due to factors unrelated to usage (e.g., parts corrode, homes are remodeled). We therefore capped the equipment lifetime at 30 years. Figure 11 shows the regionally adjusted EUL used for the stock accounting.

Figure 11. Climate region specific EULs

Climate regions	Central Air Conditioner	Central Heat Pump	Central Natural Gas Furnace	Central Electric Furnace
North Coast: CZ 1, 3, 5	30	30	17	15
North Inland: CZ 2, 11, 16	16	16	17	16
Central Inland: CZ 4, 12, 13	14	14	23	21
South Coast: CZ 6, 7	21	21	19	17
South Inland: CZ 8, 9, 10, 14, 15	11	11	27	25

The EULs were only a starting place for equipment lifetimes in the analysis. In real life, the lifetime of individual equipment units varies widely, with some units failing soon after installation while others keep operating for decades. This distribution tends to be skewed, with the mean lifetime being higher than the median lifetime. Rather than assume a simplified point estimate for equipment life, we assumed that equipment lifetimes followed a probability distribution.

The Weibull distributions used in the analysis have two parameters, a shape parameter and a scale parameter. For all equipment types and climate regions, we set the shape parameter to 2 for a distribution showing few failures initially, increasing to higher levels near the EUL, and then declining. The distribution is skewed, with the mean higher than the median. The scale parameter determines how stretched out the distribution is over time. We set the scale parameter for each equipment type and climate region so that the median of the distribution matched the equipment lifetime in that region. Figure 12 through Figure 14 show the probability distributions used for each equipment type, by region. Because the EULs for central air conditioners and heat pumps were the same, they have the same distributions, shown in Figure 12.

Figure 12. Probability distribution of lifetimes for central forced air gas heating

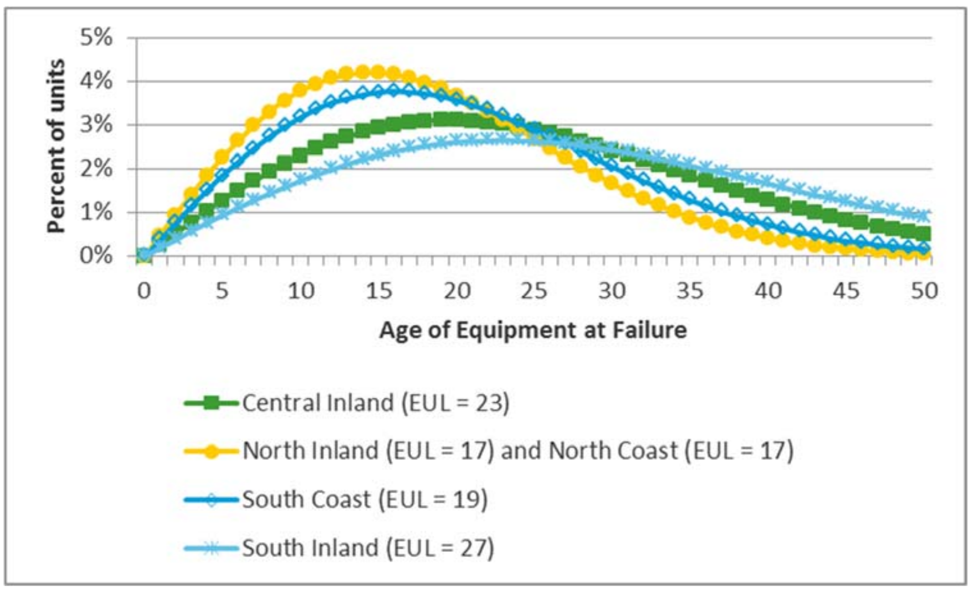


Figure 13. Probability distribution of lifetimes for central air conditioners and heat pumps

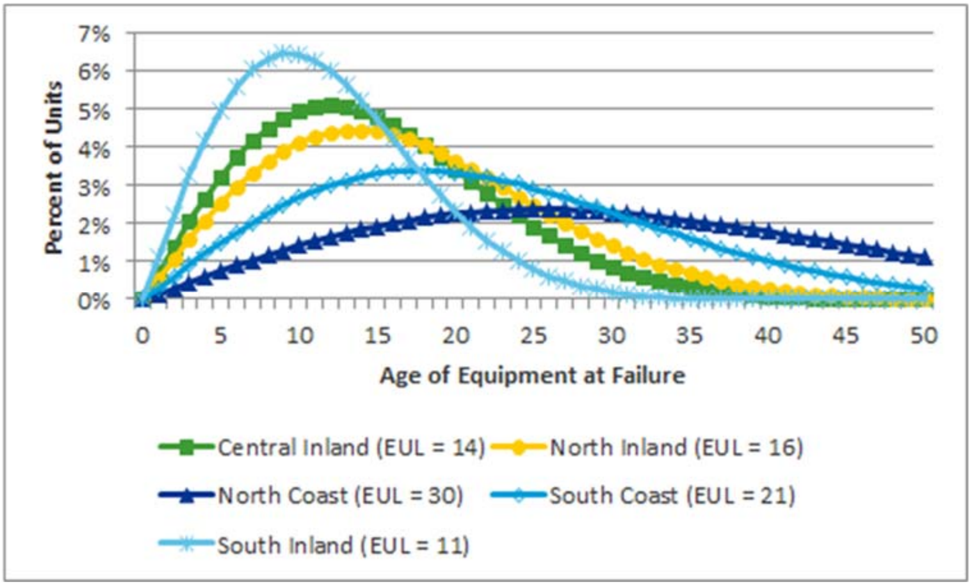
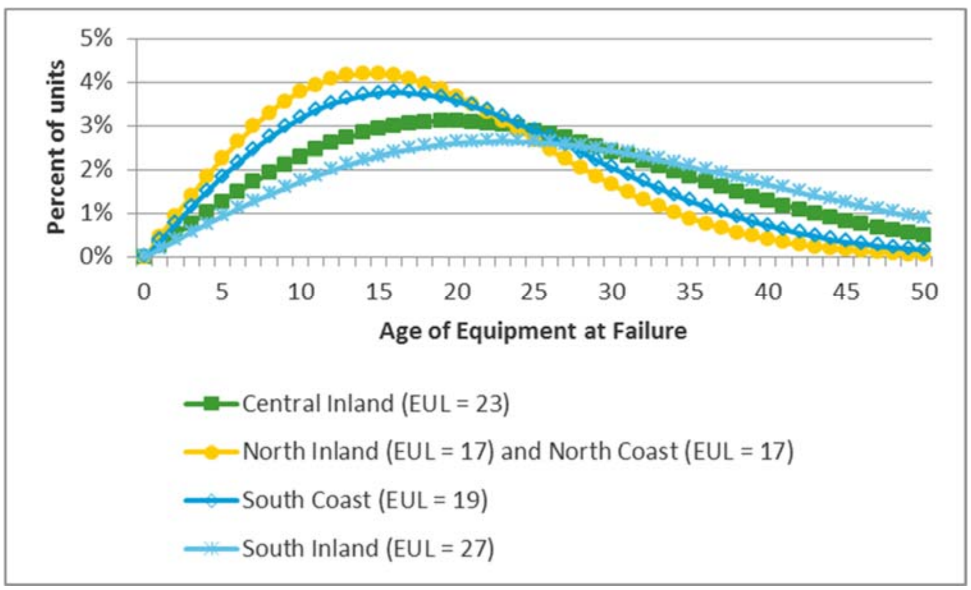


Figure 14. Probability distribution of lifetimes for central forced air electric heating



If the HVAC population were in equilibrium, then the expected number of changeouts for a given year would be estimated by multiplying the stock by the average failure rate. However, the number of HVAC units within California is growing, due to both increases in the housing stock and in equipment saturations (especially cooling) in existing homes. Therefore, the analysis needed to take into account the mix of equipment ages in the current stock to accurately assess the expected failure rate in 2014. Fortunately, the two RASS surveys provide the data necessary to estimate the change in saturations over time. This, combined with changes to the overall housing stock over time, allowed us to extrapolate both the equipment stocks (by type) and mix of equipment vintages in 2014.

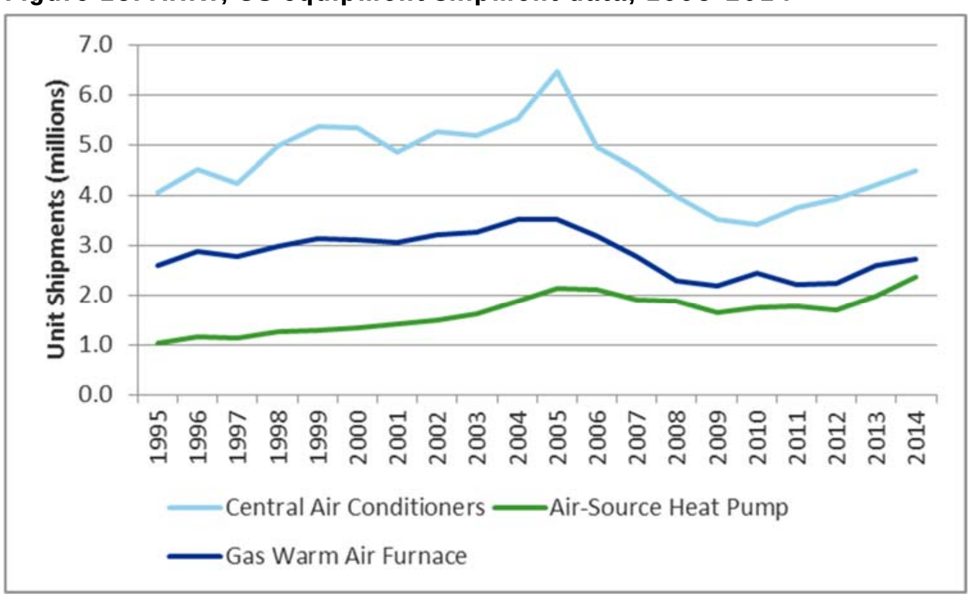
The first year of our stock accounting was 1984, beyond the highest median equipment lifetime used in the analysis. For 1984, we estimated a mix of equipment vintages to be consistent with our assumed Weibull distribution. From that point forward, the model tracked the equipment stocks by vintage, replacements, and new equipment. Equipment that was new in 1984 became 1985's one-year-old equipment, after subtracting out the (very few) failures of that new equipment predicted by the Weibull distribution. The stock accounting tracked each cohort over time, reducing the number of surviving units each year according to the Weibull distribution. We calculated the number of new units (shipments) each year as the estimated stock in that year, less the total of the surviving units.

Accounting for cyclical sales of HVAC equipment

Like other durable goods, HVAC equipment sales tend to be cyclical. During bad economic times, people often choose to repair rather than replace large equipment such as HVAC when there is an equipment failure. Also, in economic downturns, homeowners are less likely to make major renovations or additions to their homes. Conversely, in good economic times, the decision might be to replace rather than repair. The result is that sales of HVAC equipment can vary widely from the peak of a sales cycle to the trough.

Figure 15 shows US shipments for central air conditioners, air-source heat pumps, and gas warm-air furnaces from 1995 to 2014 AHRI.[3] For all equipment types, you can see the impacts of the real-estate crash and subsequent 2008 recession. From the peak in 2005 to the trough in 2010, shipments of central air conditioners fell by almost half; 2014 shipments are approximately midway between the most recent peak and trough.

Figure 15. AHRI, US equipment shipment data, 1995-2014



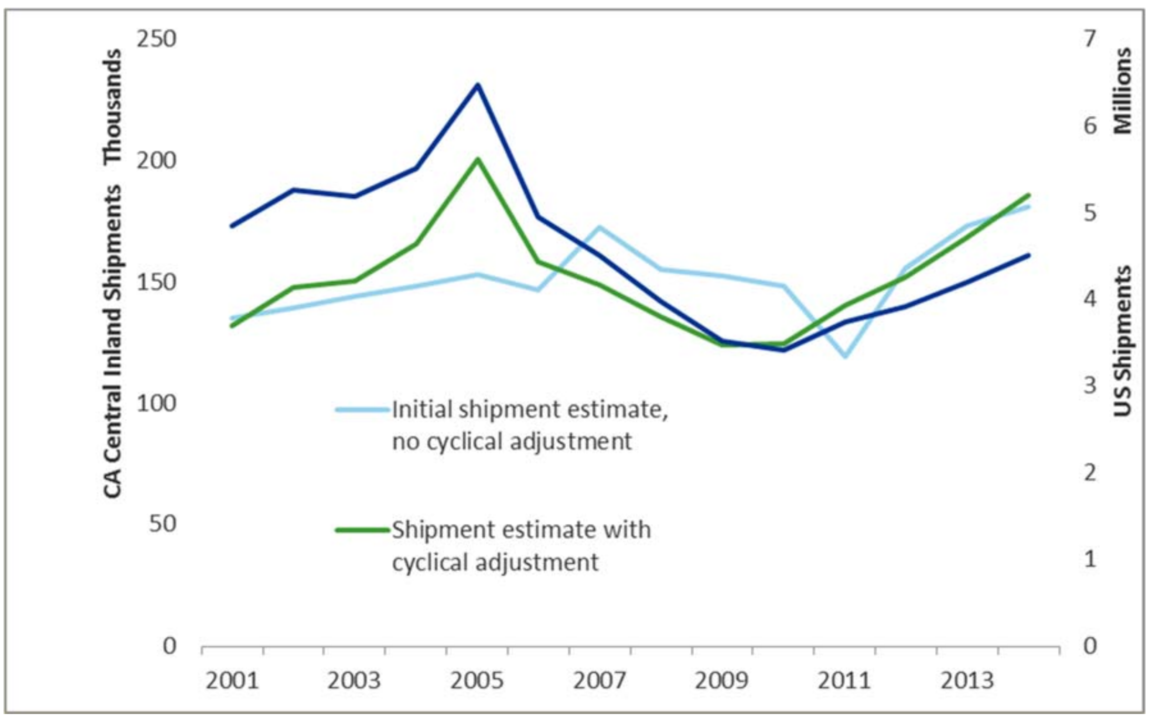
[3] This data is available to the public and represents shipments from 300 US manufacturers for central air conditioners and air-source heat pumps. The total number of US HVAC shipments is available per month and per year by rated capacity ranges (Btuh bins, e.g., 22–26.9 Btuh). AHRI data does not represent all manufacturer shipments; according to AHRI's statisticians, approximately 93% of their 300 members report shipments and membership is limited to manufacturers that produce of a certain volume of equipment. Small manufacturers are not eligible, although the threshold for AHRI acceptance is not publicly available.

The stock turnover approach discussed above produced annual estimates of total changeouts that are based on a typical distribution of equipment lifetimes. These estimates show some cyclicality because they are based on historic housing stocks, which reflect the effects of past business cycles. But the year-to-year variation in changeouts predicted by the stock accounting model were out of sync with real-world business cycles, because they are based on an algorithm that ignores economic factors.

In contrast, the numerator of the permit rate equation is specific to 2014, and does include the effect of real-world business cycles. Without some adjustment to the total changeout estimate to account for sales cycles, there will be a mismatch between the two numbers.

We used the AHRI shipment data illustrated in Figure 16 to capture cyclicality in HVAC shipments by developing statistical models to bring the out-of-sync cycles of the stock accounting shipment estimates in line with the real-world cycles represented by the AHRI data. We began by using simple linear regressions to estimate trend lines for both the AHRI data and our initial shipments estimate by equipment type. Using the AHRI shipments and trend lines, we calculated an adjustment factor in each year relating the actual shipments to the predicted shipments. We applied these adjustments to the trend-predicted shipments. If the AHRI shipments were above their trend line by 10 percent in a particular year, then we adjusted our shipments estimate by 10 percent above our trend line for that year. Figure 16 shows the result of this process for central air conditioning in the South Inland climate region.

Figure 16. Cyclical shipment adjustment, central air conditioning in the South Inland climate region



Categorizing changeouts: replacements vs. additions

We evaluated different approaches to distinguish HVAC changeouts from HVAC installed in new construction. The Freedonia Group produced a report that broke out the market for replacements versus additions.

However, those data were at the national level and do not capture the variation in equipment life that we incorporated into stock accounting. Therefore, the report could overstate new construction in regions where usage is low, and understate it where usage is high.

The US Department of Energy (DOE) issues technical support documents (TSDs) for their appliance and equipment standards-setting process. The TSDs include detailed analyses on equipment shipments broken out into new construction, existing owners (replacements), and new owners (existing buildings that acquire HVAC equipment for the first time). However, this data suffered from the same problem as the Freedonia data.

In the end, we realized that our stock accounting provided the means to create credible estimates of replacements in existing homes, new equipment in existing homes (since the model incorporates changing equipment saturations over time), and equipment installed in new construction. We used this approach disaggregate estimates of equipment that was installed in new homes, replacement units in existing homes, and added (including altered space) units installed in existing homes.

Total changeouts results

Total changeouts include replacement units, new units to existing space, and altered space HVAC systems. While our analysis did not distinguish altered space units from units added to existing spaces, we capture both in our estimate of added units to existing homes. To get total changeouts, we simply added our estimate of replacement shipment to our estimate of units added to existing homes (excluding only shipments to new construction). Figure 17 through Figure 20 show the breakdown of 2014 shipments resulting from the stock accounting, for gas central forced-air heating, central cooling, heat pumps, and electric central forced-air heating, respectively.

Figure 17. Central forced air, gas heating - shipments by installation type for 2014

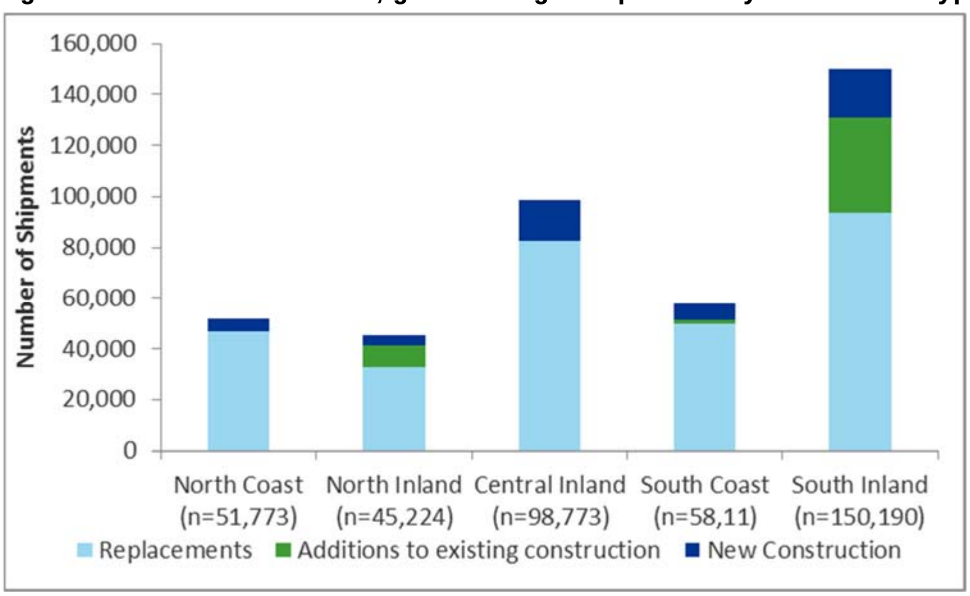


Figure 18. Central cooling - shipments by installation type for 2014

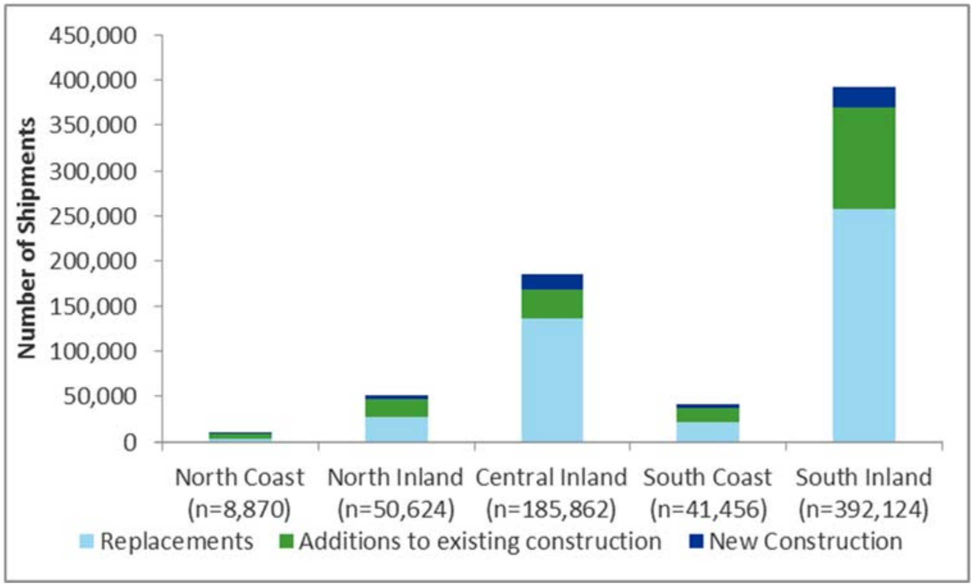


Figure 19. Heat pump - shipments by installation type for 2014

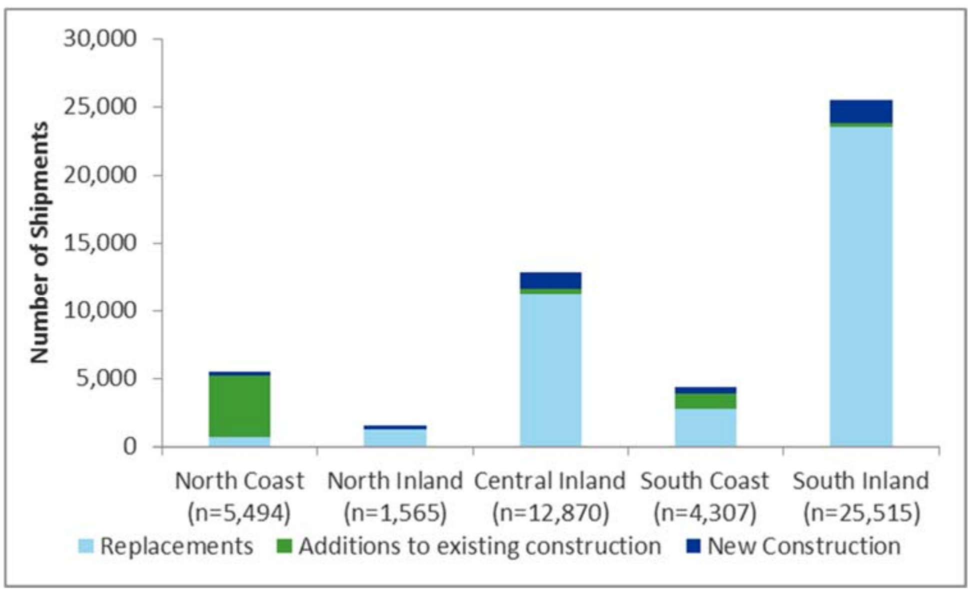


Figure 20. Central forced air electric heating – shipments by installations type for 2014

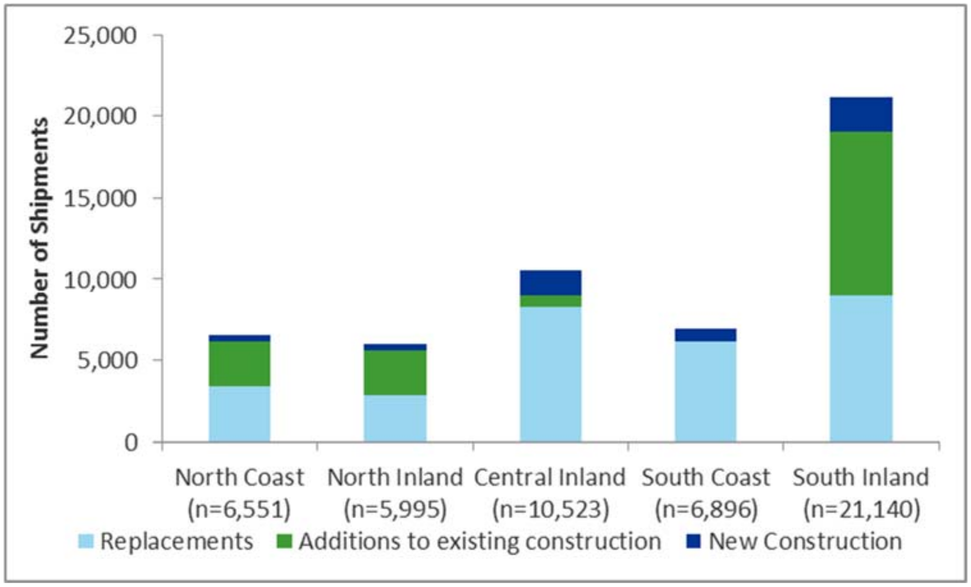


Figure 21 summarizes total changeouts by system type and climate region. Central cooling in the South Inland region accounts for the largest share of equipment changeouts, at 34 percent of the total. This is not surprising: Not only does South Inland represent the largest share of households of all the climate regions, at 40 percent, but it is also the hottest of the five climate regions. It represents 59 percent of all central cooling changeouts in the state.

Because furnaces have longer lives than central cooling or heat pumps, they represent a smaller share of changeouts (37 percent of total changeouts statewide) than of total equipment (about 52% percent of total equipment).

Figure 21. Summary of total changeouts by system type and climate region for 2014

Climate regions	Central Air Conditioner	Central Heat Pump	Central Natural Gas Furnace	Central Electric Furnace	All System Types
North Coast: CZ 1, 3, 5	8,001	5,180	46,872	6,124	**66,177**
North Inland: CZ 2, 11, 16	47,043	1,240	41,266	5,578	**95,126**
Central Inland: CZ 4, 12, 13	168,823	11,578	82,557	8,979	**271,937**
South Coast: CZ 6, 7	37,386	3,844	51,392	6,167	**98,790**
South Inland: CZ 8, 9, 10, 14, 15	370,024	23,813	130,748	19,074	**543,659**
Total	**631,277**	**45,655**	**352,835**	**45,922**	**1,075,689**

Although we present total changeouts at the climate region level, we were ultimately only able to calculate a permit rate at the state level. This was due to limitations in the granularity of the permit data, discussed in the next section. The disaggregated analysis of total changeouts, however, was valuable in creating a more accurate statewide total.

Estimating the number of permits issued—the numerator

We used two primary data source for estimating permitted HVAC changeouts: data on HVAC alteration certificates from the primary Home Energy Raters System (HERS) Provider[4] and HVAC permit changeout data from the Construction Industry Resource Board (CIRB) Reports.[5]

The CIRB Reports produces an organized data set of HVAC changeout permit counts (including counts of equipment units installed) sourced from building departments throughout the state, but it has some key limitations. The annual permit changeout report does not distinguish residential from commercial permits or replacements from building additions. In some cases, building departments, HVAC permits, were not provided to CIRB separately from other types of mechanical permits, these are characterized as "mechanical only."

The HERS certificate data, in contrast, focuses on precisely the subset of HVAC installations that we are interested in: residential changeouts. Like the CIRB data, it provides counts of both permits and HVAC systems. However, the HERS data has its own limitation: it covers only part of the state for the first half of 2014. And not every HERS certificate for the 2014 year was provided to the study. Figure 22 summarizes the advantages and disadvantages of the two datasets.

4 https://www.calcerts.com/ CalCERTS, Inc was the HERS Provider sourced for this study. This same data was requested from USERA but due to lack of cooperation this information was not obtained.

5 http://www.mychf.org/about-cirb.html The CIRB Report, a research service provided by the California Homebuilding Foundation (CHF), produces and distributes current and historical statewide building permit data by city, county and metropolitan statistical area.

Figure 22. Overview of CIRB and HERS data sources

	CIRB (Permit) Report Data	HERS HVAC Certificate Data
Source	California Home Building Foundation-Construction Industry Research Board (Reports)	HERS Providers (Residential HVAC Alteration Certificate Counts for 2014)
Description	Annual permit statistics, for 2014, reported by city and county building departments to CIRB	HERS Certificate counts, for 2014, from the HERS Registry collected from field inspections (HERS Raters) as required under Standards
Advantages	• Substantial coverage of the state building departments • Provided affordable and efficiently organized data • Active engagement by CIRB staff • Permit data directly from building departments without the cost of direct collection • Systematically collected and organized permit records non-standard formats	• Inspection data is specific to the residential sector • Data only includes changeouts, not new construction
Disadvantages	• Permit statistics were not available for all building departments • Permit statistics not consistently reported • Reported data may not identify residential vs. non-residential or HVAC permits vs. mechanical permits more generally • Permit activity cannot be isolated to a specific type of HVAC replacement (e.g., due to an addition vs. a one-for-one replacement)	• Data is for inspections, not permits • Incomplete coverage for the first half of the year • Limited accessibility, only one of two HERS Providers supplied Registry data • Certificates are not required for all installation types. *

*HERS inspections are required for ducted systems (all climate zones under the 2013 code; zones 2 and 9 to 16 only under the 2008 code). Inspections were required for split systems (refrigerant charge in zone 2 and 8 to 15; minimum airflow and maximum fan wattage inspections were required only in zones 8 to 15 under the 2008 code, but that was expanded to all zones under the 2013 code). Inspections are not required for non-ducted systems: wall furnaces, ductless split-systems, room air, boilers, etc.

Due to the mix of advantages and disadvantages to each dataset, we opted to use a combination of data from both HERS Providers and CIRB. The HERS data became our primary data source for the climate zones and time frames where it offers complete coverage. We filled in the gaps using the CIRB data.

APPENDIX B and APPENDIX C present the HERS and CIRB data, respectively, along with some additional information about the nature and coverage of the data.

The next two sections provide more detail on the two data sets and how we used them. Then we discuss in detail how we combined the data from the two sets to estimate total permits for 2014.

Permit rate estimates using HERS HVAC certificate data

A HERS certificate is a good proxy for a finalized permit and, unlike CIRB data, HERS data focus on residential dwellings. However, due the timeframe of the study and a change in the Title 24 code, HERS data for the first half of 2014 only covers part of the state.

We purchased data from the HERS Provider. The data represented the total number of HVAC alteration certificates by building department for the entire 2014 year separately for the first half and second half of the year. Of the two providers, only CalCERTS, Inc. agreed to fulfill the data request. Fortunately for the study, we estimate that CalCERTS represents 95 percent of HERS inspections performed in the state. To extrapolate to the entire state by climate region, we first estimated the number of omitted inspections (CalCERTS inspections divided by 0.95 minus the number of CalCERTS inspections). We then distributed those permits proportionately to building departments in climate zones 10, 12, 13, and 15 based on the number of households. USERA, which holds the remaining market share, is most active in those four climate zones.

We believe that the HERS data provides a good estimate of permits (and corresponding equipment unit counts) for the full year for climate zones 2 and 9 through 16, and for the second half of the year in the remaining climate zones. To fill in the missing data, we turned to the CIRB data, discussed in the next section.

Permit rate estimates using CIRB permit report data

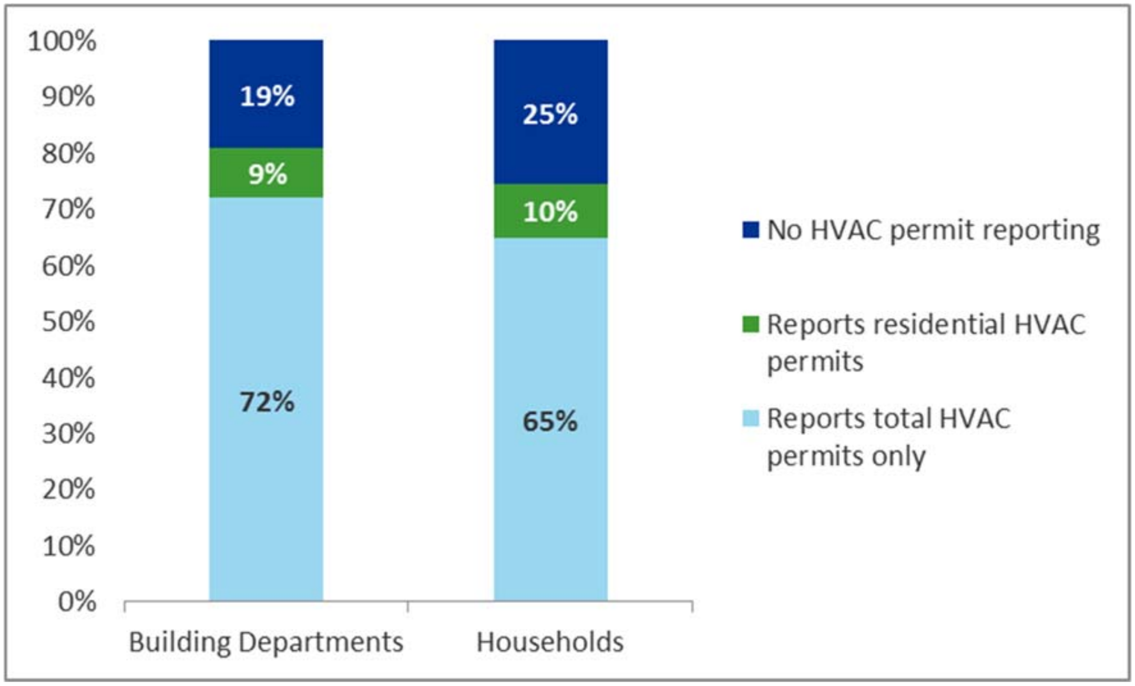
CIRB report data contains HVAC changeout permit statistics for a significant volume of city and county building departments. The initial CIRB dataset included data for 69 percent of the building departments in California, representing 72 percent of households.

To address the limited coverage of the CIRB data, we provided funding for a CIRB staff member to follow up with a prioritized list (based on number of households) of building departments to expand the coverage of the data. The final data covered 81 percent of building departments and 75 percent of households.

The level of detail provided by the reporting building departments was mixed. Some provided only permits for new construction or for undifferentiated mechanical permits. We considered trying to apply some assumption to break out the mechanical permits into HVAC and other, but ultimately decided that process would add complexity without adding any real improvements to the overall estimates. The two groups are combined in Figure 23 as "No HVAC permit reporting." The remaining building departments reported either residential or commercial HVAC permits separately or only total HVAC permits.

Only 48 of the total 538 building departments reported residential permits separately. For the 387 building departments that only reported total HVAC permits, we needed to break out residential permits. For each of the 48 building departments that provided residential and commercial HVAC permits, we calculated the percent of combined HVAC permits that were residential. We calculated the simple average of these values, and applied that to total HVAC changeouts for the remaining building departments.

Figure 23. Building departments reporting to CIRB by type of permit data



Because we used the HERS data as our primary source, the missing CIRB data only became a problem if it coincided with a gap in the HERS data. We will discuss the combined coverage of the two datasets in the next section.

Combining the HERS certificate and CIRB permit data

Using the CIRB and HERS datasets, we developed five sets of overlapping estimates of permitted equipment units at the building department level and combined them into a final estimate. We used the data on the number of permitted units, rather than number of permits, for consistency with the denominator.[6] The estimates were:

1. **CIRB-based permitted unit count for the full year:** Reliable counts of residential permitted equipment for 48 building departments and estimates of residential permits for another 387 building departments
2. **HERS-based permitted unit count for the first half of the year:** Reliable estimates for climate zones 2 and 9 through 16
3. **CIRB-based permitted unit estimate for the first half of the year:** Same as the full year data, but estimating the share of permits issued in the first 6 months of the year (to use in combination with half-year HERS data)
4. **HERS-based permitted unit count for the second half of the year:** Reliable estimates for all climate zones
5. **CIRB-based permitted unit estimates** for the full year based on mechanical permits

[6] There can be multiple units per permit in cases where cooling systems and heating systems are replaced simultaneously, or when a permit covers work in multiple units of a multifamily building. State wide, there were 1.09 units installed per permit,

Each of the five estimates provided only a partial picture of total permitted units. Some cover only part of the year while others have gaps and omissions. HERS might report zero inspections for a building department, while CIRB reports that permits were issued, while that situation might be reversed for another building department. APPENDIX D shows the values for each of the five components for each building department. We used a combination of all these estimates to create the most comprehensive estimates possible.

Components 1, 2, and 4 above were discussed in the CIRB and HERS sections, above. In order to estimate component 3, partial-year permitted units using the CIRB data, we leveraged the data from the many building departments for which we had HERS data for both the first and second half of the year. For each building department with a full year of HERS data, we calculated the percent of permitted units that were issued in the first half of the year. We aggregated from building departments to climate zones and climate regions. Because the HERS requirements are by climate zone, we were not able to calculate a ratio for climate zones 1 and 3 through 8, or for the North Coast or South Coast climate regions. For climate zones 4 and 8, we assigned those zones the average value for their regions (Central Inland and South Inland). For the remaining climate zones, we assigned the average value for an adjacent climate region (North Inland for North Coast, and South Inland for South Coast). We then assigned each building department a "first half of the year share" based on its climate zone.

We applied these shares to our estimates of 2014 residential HVAC changeouts from CIRB to get an estimate of residential permitted units in the first half of the year.

The fifth estimation approach was used only for a small subset of building departments where the other estimation approaches yielded an estimate of zero residential HVAC permitted units. Two building departments showed no permitted units issued using the other four approaches, but still reported unspecified mechanical permits. In the case of Goleta (in the South Coast climate region), CIRB reported that it issued 106 unspecified mechanical permits. To estimate the share of those unspecified mechanical permits that were residential HVAC changeouts, we looked at the residential changeout share of total HVAC and mechanical permits, for building departments where that data was available. We averaged these values by climate region, and applied the resulting ratio to mechanical permits from building departments with missing data.

Once all of the five components were calculated, we were able to combine them into what we believe are reliable estimates for each building department.

Our initial estimate of full year permitted units combined the HERS data for the second half of the year with the HERS permitted unit estimate for the first half of the year for climate zones 2 and 9 through 16, and with CIRB permitted unit estimates for the first half of the year for climate zones 1 and 3 through 9.

However, this initial estimate left 35 building departments with zero permitted units for the year. While it is possible for building departments in sparsely populated areas to issue no permits in a year, 15 of these reported HVAC permits to CIRB and four of those specifically reported residential HVAC permits. Due to this discrepancy, for building departments for which our initial estimate resulted in zero permitted units for the year we instead used the full year CIRB estimate.

This process left 20 building departments with an estimate of zero permits issued in 2014. For these, we turned to our fifth estimation approach, breaking out total mechanical permits. Of the 20 building departments, only Goleta and Solvang indicated that they had issued unspecified mechanical permits, and we filled in a residential HVAC permitted unit estimate for these using method 5 above.

That left 18 building departments with zero estimated permits. These were Alturas, Avalon, Biggs, Del Rey Oaks, Dorris, Etna, Fort Jones, Industry, La Habra Heights, Loyalton, Maricopa, Montague, Point Arena, San Juan Bautista, Tehama, Trinidad, Tulelake, and Weed. Most of these are small, or have small residential housing stock (the City of Industry), and could plausibly have actually issued no permits in a year. Together these building departments represent less 0.2 percent of households in California.

Total permit results

Figure 24 shows the estimated number of residential HVAC changeout permits in 2014 by climate region.

Figure 24. Estimated 2014 residential HVAC changeout permits by climate region

Climate region	2014 Permits
North Coast: CZ 1, 3, 5	2,986
North Inland: CZ 2, 11, 16	10,606
Central Inland: CZ 4, 12, 13	33,369
South Coast: CZ 6, 7	7,554
South Inland: CZ 8, 9, 10, 14, 15	31,082
Statewide	**83,241**

APPENDIX B. COUNT OF CHANGEOUTS BY BUILDING DEPARTMENTS (DATA SOURCE: HERS REGISTRY)

A key issue with the HERS data was that full-year data was only available for a subset of building departments. Among the building departments in climate zones where HERS inspections were not required under the 2008 code, some inspections were reported, but these may only represent a subset of changeouts. When we developed our estimate of first-half permits, we used these as a floor on the estimates.

Figure 25 shows the breakdown of HERS data based on whether the building department reported full-year data (based on code requirements), and for the remaining building departments, whether they reported any inspections during the first half of the year.

Figure 25. Distribution of HERS data by part-year / full-year data

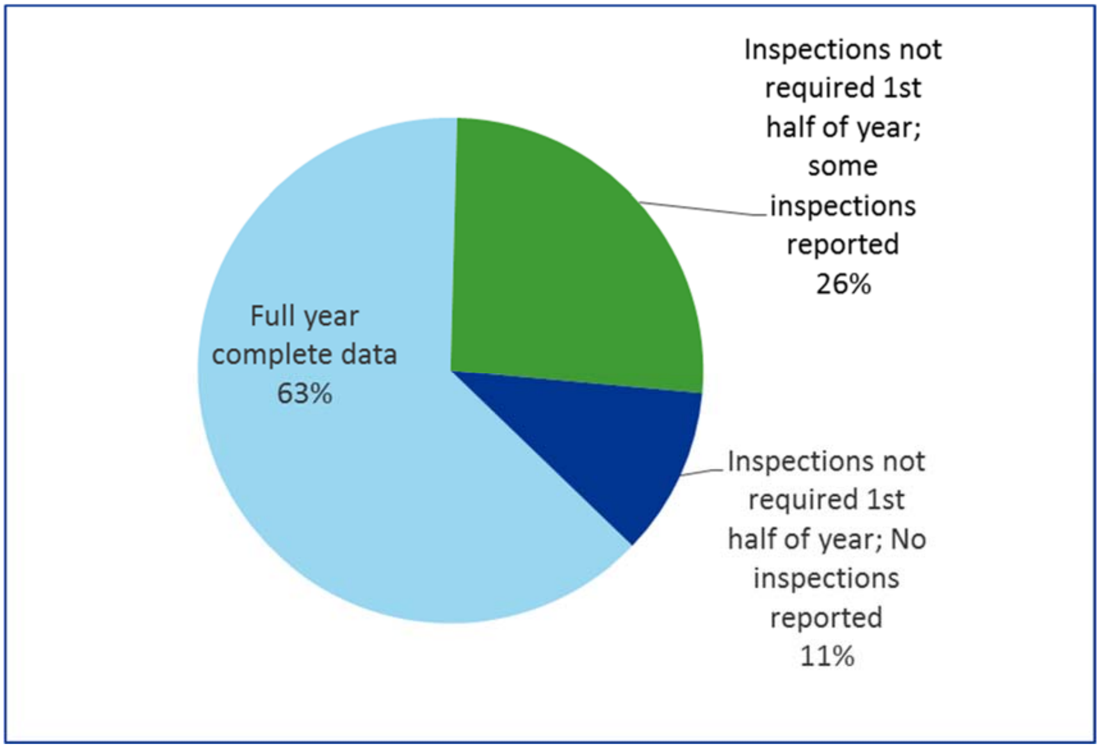


Figure 26 shows the number of CalCERTS HVAC inspections performed in 2014 under the 2008 code and the 2013 code. Since CalCERTS only represents 95% of inspections in California, we the data extrapolated to the entire state by climate region. First we estimated the number of omitted inspections (CalCERTS inspections divided by 0.95 minus the number of CalCERTS inspections). We then distributed those permits proportionately to building departments in climate zones 10, 12, 13, and 15 based on the number of households. USERA, which holds the remaining market share, is most active in those four climate zones. Figure 26 also includes the extrapolated number of inspections.

Figure 26. Total HVAC systems inspected in 2014—CalCERTS reported and total estimated

Building Department City	HERS Registry Reported		All HERS Raters (Estimated)	
	2008 Code	2013 Code	2008 Code	2013 Code
Alameda	16	101	16	101
Alameda County Unincorporated	28	57	31	63
Albany	2	5	2	5
Berkeley	40	71	40	71
Dublin	64	49	70	54
Emeryville	NULL	NULL	0	0
Fremont	38	94	38	94
Hayward	19	37	19	37
Livermore	207	137	226	151
Newark	10	16	10	16
Oakland	51	103	51	103
Piedmont	3	7	3	7
Pleasanton	215	136	235	150
San Leandro	9	23	9	23
Union City	8	19	8	19
Alpine County Unincorporated	3	3	3	3
Amador City	NULL	NULL	0	0
Amador County Unincorporated	78	40	85	44
Ione	24	10	26	11
Jackson	21	5	23	5
Plymouth	3	2	3	2
Sutter Creek	14	5	15	5
Biggs	NULL	NULL	0	0
Butte County Unincorporated	135	95	135	95
Chico	176	82	176	82
Gridley	14	7	14	7
Oroville	41	33	41	33
Paradise	91	30	91	30
Angels Camp	9	11	10	12
Calaveras County Unincorporated	86	63	94	69
Colusa	16	10	16	10
Colusa County Unincorporated	17	8	17	8
Williams	6	5	6	5
Antioch	129	114	141	125
Brentwood	64	62	70	68
Clayton	17	28	19	31
Concord	292	178	319	196
Contra Costa County Unincorporated	408	286	446	314
Danville	201	137	220	151
El Cerrito	8	30	8	30
Hercules	7	10	7	10

Building Department City	HERS Registry Reported		All HERS Raters (Estimated)	
	2008 Code	2013 Code	2008 Code	2013 Code
Lafayette	50	36	55	40
Martinez	113	71	124	78
Moraga	23	21	25	23
Oakley	50	35	55	38
Orinda	21	22	23	24
Pinole	10	9	10	9
Pittsburg	67	48	73	53
Pleasant Hill	68	55	74	60
Richmond	14	26	14	26
San Pablo	NULL	2	0	2
San Ramon	157	93	172	102
Walnut Creek	257	186	281	205
Crescent City	NULL	NULL	0	0
Del Norte County Unincorporated	NULL	NULL	0	0
El Dorado County Unincorporated	808	566	808	566
Placerville	64	33	70	36
South Lake Tahoe	77	34	77	34
Clovis	276	135	302	148
Coalinga	38	11	42	12
Firebaugh	4	1	4	1
Fowler	13	9	14	10
Fresno	867	568	948	625
Fresno County Unincorporated	254	177	278	195
Huron	NULL	1	0	1
Kerman	7	8	8	9
Kingsburg	34	12	37	13
Mendota	2	5	2	5
Orange Cove	4	NULL	4	0
Parlier	43	3	47	3
Reedley	29	16	32	18
San Joaquin	2	2	2	2
Sanger	23	17	25	19
Selma	22	17	24	19
Glenn County Unincorporated	16	2	16	2
Orland	22	3	22	3
Willows	25	6	25	6
Arcata	NULL	NULL	0	0
Blue Lake	NULL	NULL	0	0
Eureka	NULL	NULL	0	0
Ferndale	NULL	NULL	0	0
Fortuna	NULL	NULL	0	0
Humboldt County Unincorporated	NULL	NULL	0	0
Rio Dell	NULL	NULL	0	0

Building Department City	HERS Registry Reported		All HERS Raters (Estimated)	
	2008 Code	2013 Code	2008 Code	2013 Code
Trinidad	NULL	NULL	0	0
Brawley	30	6	33	7
Calexico	22	2	24	2
Calipatria	NULL	NULL	0	0
El Centro	58	7	63	8
Holtville	NULL	NULL	0	0
Imperial	12	7	13	8
Imperial County Unincorporated	17	2	19	2
Westmorland	NULL	NULL	0	0
Bishop	NULL	NULL	0	0
Inyo County Unincorporated	1	NULL	1	0
Arvin	5	15	5	16
Bakersfield	594	456	650	501
California City	10	7	10	7
Delano	29	16	32	18
Kern County Unincorporated	475	205	519	225
Maricopa	NULL	NULL	0	0
McFarland	2	1	2	1
Ridgecrest	21	23	21	23
Shafter	104	10	114	11
Taft	9	7	10	8
Tehachapi	9	10	9	10
Wasco	21	7	23	8
Avenal	2	7	2	8
Corcoran	8	4	9	4
Hanford	146	99	160	109
Kings County Unincorporated	35	6	38	7
Lemoore	47	30	51	33
Clearlake	2	1	2	1
Lake County Unincorporated	15	5	15	5
Lakeport	NULL	NULL	0	0
Lassen County Unincorporated	4	3	4	3
Susanville	NULL	NULL	0	0
Agoura Hills	76	108	76	108
Alhambra	115	42	115	42
Arcadia	66	26	66	26
Artesia	9	5	9	5
Avalon	NULL	NULL	0	0
Azusa	59	26	59	26
Baldwin Park	28	15	28	15
Bell	NULL	1	0	1
Bell Gardens	NULL	2	0	2
Bellflower	25	21	25	21

Building Department City	HERS Registry Reported		All HERS Raters (Estimated)	
	2008 Code	2013 Code	2008 Code	2013 Code
Beverly Hills	182	25	182	25
Bradbury	NULL	NULL	0	0
Burbank	105	42	105	42
Calabasas	131	25	131	25
Carson	31	36	31	36
Cerritos	97	52	97	52
Claremont	73	51	73	51
Commerce	3	1	3	1
Compton	15	6	15	6
Covina	54	32	54	32
Cudahy	1	NULL	1	0
Culver City	69	52	69	52
Diamond Bar	65	33	65	33
Downey	91	49	91	49
Duarte	45	17	45	17
El Monte	12	10	12	10
El Segundo	NULL	8	0	8
Gardena	27	34	27	34
Glendale	200	95	200	95
Glendora	64	29	64	29
Hawaiian Gardens	1	NULL	1	0
Hawthorne	12	19	12	19
Hermosa Beach	NULL	1	0	1
Hidden Hills	5	2	5	2
Huntington Park	3	4	3	4
Industry	NULL	NULL	0	0
Inglewood	239	37	239	37
Irwindale	NULL	NULL	0	0
La Canada Flintridge	30	13	30	13
La Habra Heights	NULL	NULL	0	0
La Mirada	64	48	64	48
La Puente	42	19	42	19
La Verne	45	39	45	39
Lakewood	94	65	94	65
Lancaster	283	197	283	197
Lawndale	2	4	2	4
Lomita	NULL	NULL	0	0
Long Beach	58	134	58	134
Los Angeles	2147	1064	2147	1064
Los Angeles County Unincorporated	753	451	753	451
Lynwood	3	1	3	1
Malibu	4	13	4	13
Manhattan Beach	10	27	10	27

Building Department City	HERS Registry Reported		All HERS Raters (Estimated)	
	2008 Code	2013 Code	2008 Code	2013 Code
Maywood	NULL	1	0	1
Monrovia	41	39	41	39
Montebello	24	12	24	12
Monterey Park	43	31	43	31
Norwalk	88	36	88	36
Palmdale	349	223	349	223
Palos Verdes Estates	3	14	3	14
Paramount	7	8	7	8
Pasadena	303	152	303	152
Pico Rivera	19	17	19	17
Pomona	98	56	98	56
Rancho Palos Verdes	4	27	4	27
Redondo Beach	1	24	1	24
Rolling Hills	NULL	NULL	0	0
Rolling Hills Estates	NULL	NULL	0	0
Rosemead	19	11	19	11
San Dimas	42	22	42	22
San Fernando	5	3	5	3
San Gabriel	64	28	64	28
San Marino	70	20	70	20
Santa Clarita	115	68	115	68
Santa Fe Springs	9	3	9	3
Santa Monica	12	43	12	43
Sierra Madre	33	16	33	16
Signal Hill	1	NULL	1	0
South El Monte	1	3	1	3
South Gate	6	1	6	1
South Pasadena	46	28	46	28
Temple City	38	17	38	17
Torrance	15	84	15	84
Vernon	NULL	NULL	0	0
Walnut	45	27	45	27
West Covina	95	58	95	58
West Hollywood	42	10	42	10
Westlake Village	17	7	17	7
Whittier	94	81	94	81
Chowchilla	30	11	33	12
Madera	75	61	82	67
Madera County Unincorporated	86	43	94	47
Belvedere	6	4	6	4
Corte Madera	6	10	6	10
Fairfax	6	5	6	5
Larkspur	15	15	15	15

Building Department City	HERS Registry Reported		All HERS Raters (Estimated)	
	2008 Code	2013 Code	2008 Code	2013 Code
Marin County Unincorporated	66	45	66	45
Mill Valley	36	17	36	17
Novato	131	73	131	73
Ross	16	7	16	7
San Anselmo	33	15	33	15
San Rafael	79	65	79	65
Sausalito	4	6	4	6
Tiburon	10	4	10	4
Mariposa County Unincorporated	5	3	5	3
Fort Bragg	NULL	NULL	0	0
Mendocino County Unincorporated	5	7	5	7
Point Arena	NULL	NULL	0	0
Ukiah	5	4	5	4
Willits	4	1	4	1
Atwater	39	24	43	26
Dos Palos	10	1	11	1
Gustine	10	10	11	11
Livingston	7	6	8	7
Los Banos	15	19	16	21
Merced	141	60	154	66
Merced County Unincorporated	84	33	92	36
Alturas	NULL	NULL	0	0
Modoc County Unincorporated	NULL	NULL	0	0
Mammoth Lakes	NULL	NULL	0	0
Mono County Unincorporated	NULL	NULL	0	0
Carmel-by-the-Sea	NULL	1	0	1
Del Rey Oaks	NULL	NULL	0	0
Gonzales	NULL	NULL	0	0
Greenfield	NULL	NULL	0	0
King City	1	NULL	1	0
Marina	NULL	NULL	0	0
Monterey	NULL	3	0	3
Monterey County Unincorporated	NULL	15	0	15
Pacific Grove	NULL	1	0	1
Salinas	1	1	1	1
Sand City	NULL	NULL	0	0
Seaside	NULL	1	0	1
Soledad	NULL	NULL	0	0
American Canyon	29	26	29	26
Calistoga	10	8	10	8
Napa	231	143	231	143
Napa County Unincorporated	59	44	59	44
St. Helena	22	12	22	12

Building Department City	HERS Registry Reported		All HERS Raters (Estimated)	
	2008 Code	2013 Code	2008 Code	2013 Code
Yountville	14	7	14	7
Grass Valley	33	27	33	27
Nevada County Unincorporated	204	163	204	163
Truckee	70	31	70	31
Aliso Viejo	7	69	7	69
Anaheim	254	219	254	219
Brea	27	41	27	41
Buena Park	105	42	105	42
Costa Mesa	6	60	6	60
Cypress	61	56	61	56
Dana Point	1	28	1	28
Fountain Valley	52	53	52	53
Fullerton	116	97	116	97
Garden Grove	79	83	79	83
Huntington Beach	17	108	17	108
Irvine	204	152	204	152
La Habra	40	55	40	55
La Palma	25	20	25	20
Laguna Beach	9	33	9	33
Laguna Hills	16	36	16	36
Laguna Niguel	9	68	9	68
Laguna Woods	7	36	7	36
Lake Forest	116	86	116	86
Los Alamitos	19	12	19	12
Mission Viejo	196	140	196	140
Newport Beach	17	81	17	81
Orange	120	115	120	115
Orange County Unincorporated	100	75	100	75
Placentia	74	45	74	45
Rancho Santa Margarita	51	49	51	49
San Clemente	5	31	5	31
San Juan Capistrano	2	25	2	25
Santa Ana	153	70	153	70
Seal Beach	23	7	23	7
Stanton	9	9	9	9
Tustin	53	52	53	52
Villa Park	5	11	5	11
Westminster	23	38	23	38
Yorba Linda	119	111	119	111
Auburn	62	122	62	122
Colfax	3	NULL	3	0
Lincoln	139	142	139	142
Loomis	43	29	43	29

Building Department City	HERS Registry Reported		All HERS Raters (Estimated)	
	2008 Code	2013 Code	2008 Code	2013 Code
Placer County Unincorporated	520	287	520	287
Rocklin	271	210	271	210
Roseville	528	406	528	406
Plumas County Unincorporated	7	5	7	5
Portola	1	NULL	1	0
Banning	20	50	22	55
Beaumont	15	9	16	10
Blythe	26	2	28	2
Calimesa	3	2	3	2
Canyon Lake	36	20	39	22
Cathedral City	295	96	323	106
Coachella	70	3	77	3
Corona	216	156	236	172
Desert Hot Springs	71	38	78	42
Eastvale	18	9	20	10
Hemet	107	67	117	74
Indian Wells	100	64	109	70
Indio	151	80	165	88
Jurupa Valley	62	49	68	54
La Quinta	294	143	322	157
Lake Elsinore	57	44	62	48
Menifee	161	115	176	126
Moreno Valley	233	155	255	170
Murrieta	166	107	182	118
Norco	37	30	40	33
Palm Desert	463	310	506	341
Palm Springs	407	177	445	195
Perris	48	24	52	26
Rancho Mirage	259	130	283	143
Riverside	331	228	362	251
Riverside County Unincorporated	321	169	351	186
San Jacinto	33	25	36	27
Temecula	131	120	143	132
Wildomar	25	20	27	22
Citrus Heights	403	433	441	476
Elk Grove	489	353	535	388
Folsom	348	253	381	278
Galt	69	50	75	55
Isleton	1	1	1	1
Rancho Cordova	273	216	299	238
Sacramento	1935	1208	2116	1328
Sacramento County Unincorporated	2655	1718	2904	1889
Hollister	2	2	2	2

Building Department City	HERS Registry Reported		All HERS Raters (Estimated)	
	2008 Code	2013 Code	2008 Code	2013 Code
San Benito County Unincorporated	NULL	1	0	1
San Juan Bautista	NULL	NULL	0	0
Adelanto	98	83	98	83
Apple Valley	339	126	339	126
Barstow	16	8	16	8
Big Bear Lake	5	4	5	4
Chino	50	47	55	52
Chino Hills	88	66	96	73
Colton	38	24	42	26
Fontana	130	85	142	93
Grand Terrace	14	10	15	11
Hesperia	311	147	311	147
Highland	194	42	212	46
Loma Linda	12	8	13	9
Montclair	40	27	44	30
Needles	NULL	NULL	0	0
Ontario	241	89	264	98
Rancho Cucamonga	146	90	160	99
Redlands	75	78	82	86
Rialto	110	104	120	114
San Bernardino	138	107	151	118
San Bernardino County Unincorporated	180	87	180	87
Twenty-nine Palms	16	8	16	8
Upland	98	71	107	78
Victorville	328	164	328	164
Yucaipa	39	30	43	33
Yucca Valley	37	7	37	7
Carlsbad	16	136	16	136
Chula Vista	77	92	84	101
Coronado	2	10	2	10
Del Mar	NULL	NULL	0	0
El Cajon	100	130	109	143
Encinitas	5	80	5	80
Escondido	215	184	235	202
Imperial Beach	2	2	2	2
La Mesa	27	73	27	73
Lemon Grove	11	38	11	38
National City	18	12	18	12
Oceanside	58	108	58	108
Poway	122	91	133	100
San Diego	432	992	472	1091
San Diego County Unincorporated	393	375	430	412
San Marcos	139	94	152	103

Building Department City	HERS Registry Reported		All HERS Raters (Estimated)	
	2008 Code	2013 Code	2008 Code	2013 Code
Santee	90	58	98	64
Solana Beach	7	26	7	26
Vista	54	74	54	74
San Francisco	7	29	7	29
Escalon	8	44	9	48
Lathrop	20	11	22	12
Lodi	233	164	255	180
Manteca	151	121	165	133
Ripon	59	36	65	40
San Joaquin County Unincorporated	215	131	235	144
Stockton	510	343	558	377
Tracy	175	139	191	153
Arroyo Grande	NULL	6	0	6
Atascadero	NULL	6	0	6
Grover Beach	NULL	NULL	0	0
Morro Bay	NULL	NULL	0	0
Paso Robles	NULL	9	0	9
Pismo Beach	NULL	6	0	6
San Luis Obispo	1	7	1	7
San Luis Obispo County Unincorporated	2	19	2	19
Atherton	1	12	1	12
Belmont	2	12	2	12
Brisbane	NULL	1	0	1
Burlingame	7	10	7	10
Colma	NULL	NULL	0	0
Daly City	2	6	2	6
East Palo Alto	NULL	NULL	0	0
Foster City	3	9	3	9
Half Moon Bay	NULL	1	0	1
Hillsborough	2	6	2	6
Menlo Park	8	24	8	24
Millbrae	1	4	1	4
Pacifica	2	4	2	4
Portola Valley	4	7	4	7
Redwood City	14	33	14	33
San Bruno	1	6	1	6
San Carlos	12	36	12	36
San Mateo	7	26	7	26
San Mateo County Unincorporated	8	12	8	12
South San Francisco	NULL	3	0	3
Woodside	NULL	NULL	0	0
Buellton	NULL	NULL	0	0
Carpinteria	NULL	4	0	4

Building Department City	HERS Registry Reported		All HERS Raters (Estimated)	
	2008 Code	2013 Code	2008 Code	2013 Code
Goleta	NULL	NULL	0	0
Guadalupe	NULL	1	0	1
Lompoc	NULL	NULL	0	0
Santa Barbara	7	28	7	28
Santa Barbara County Unincorporated	15	46	15	46
Santa Maria	NULL	10	0	10
Solvang	NULL	NULL	0	0
Campbell	7	51	7	51
Cupertino	13	45	13	45
Gilroy	1	11	1	11
Los Altos	8	49	8	49
Los Altos Hills	2	14	2	14
Los Gatos	11	34	11	34
Milpitas	18	29	18	29
Monte Sereno	NULL	2	0	2
Morgan Hill	6	24	6	24
Mountain View	11	37	11	37
Palo Alto	11	23	11	23
San Jose	188	451	188	451
Santa Clara	25	60	25	60
Santa Clara County Unincorporated	18	41	18	41
Saratoga	8	35	8	35
Sunnyvale	22	75	22	75
Capitola	NULL	11	0	11
Santa Cruz	3	12	3	12
Santa Cruz County Unincorporated	4	21	4	21
Scotts Valley	1	5	1	5
Watsonville	1	3	1	3
Anderson	30	28	30	28
Redding	295	333	295	333
Shasta County Unincorporated	116	93	116	93
Shasta Lake	22	25	22	25
Loyalton	NULL	NULL	0	0
Sierra County Unincorporated	1	NULL	1	0
Dorris	NULL	NULL	0	0
Dunsmuir	2	1	2	1
Etna	NULL	NULL	0	0
Fort Jones	NULL	NULL	0	0
Montague	NULL	NULL	0	0
Mount Shasta	NULL	1	0	1
Siskiyou County Unincorporated	1	1	1	1
Tule lake	NULL	NULL	0	0
Weed	NULL	NULL	0	0

Building Department City	HERS Registry Reported		All HERS Raters (Estimated)	
	2008 Code	2013 Code	2008 Code	2013 Code
Yreka	NULL	1	0	1
Benicia	96	51	105	56
Dixon	57	24	62	26
Fairfield	192	116	210	128
Rio Vista	22	11	24	12
Solano County Unincorporated	20	11	22	12
Suisun City	55	31	60	34
Vacaville	242	154	265	169
Vallejo	123	67	135	74
Cloverdale	11	10	11	10
Cotati	14	8	14	8
Healdsburg	52	30	52	30
Petaluma	146	79	146	79
Rohnert Park	63	35	63	35
Santa Rosa	458	228	458	228
Sebastopol	29	24	29	24
Sonoma	47	35	47	35
Sonoma County Unincorporated	296	118	296	118
Windsor	87	37	87	37
Ceres	52	38	57	42
Hughson	11	5	12	5
Modesto	469	324	513	356
Newman	8	15	9	16
Oakdale	39	28	43	31
Patterson	54	16	59	18
Riverbank	88	15	96	16
Stanislaus County Unincorporated	140	50	153	55
Turlock	223	46	244	51
Waterford	13	8	14	9
Live Oak	14	10	14	10
Sutter County Unincorporated	51	40	51	40
Yuba City	187	118	187	118
Corning	14	4	14	4
Red Bluff	45	31	45	31
Tehama	NULL	NULL	0	0
Tehama County Unincorporated	79	47	79	47
Trinity County Unincorporated	16	3	16	3
Dinuba	23	17	25	19
Exeter	5	10	5	11
Farmersville	4	4	4	4
Lindsay	13	NULL	14	0
Porterville	120	78	131	86
Tulare	59	39	65	43

Building Department City	HERS Registry Reported		All HERS Raters (Estimated)	
	2008 Code	2013 Code	2008 Code	2013 Code
Tulare County Unincorporated	117	61	128	67
Visalia	191	167	209	184
Woodlake	5	1	5	1
Sonora	7	10	8	11
Tuolumne County Unincorporated	19	29	19	29
Camarillo	19	109	19	109
Fillmore	8	7	8	7
Moorpark	89	49	89	49
Ojai	31	18	31	18
Oxnard	6	42	6	42
Port Hueneme	1	5	1	5
San Buenaventura	4	60	4	60
Santa Paula	26	14	26	14
Simi Valley	211	135	211	135
Thousand Oaks	458	266	458	266
Ventura County Unincorporated	108	96	108	96
Davis	297	223	325	245
West Sacramento	233	89	255	98
Winters	15	11	16	12
Woodland	155	78	170	86
Yolo County Unincorporated	29	37	32	41
Marysville	88	34	88	34
Wheatland	13	7	13	7
Yuba County Unincorporated	72	44	72	44

APPENDIX C. COUNT OF PERMITS BY BUILDING DEPARTMENT (DATA SOURCE: CIRB)

The level of detail reported by building departments via the CIRB data set was highly variable. The original data set did not break out residential and non-residential HVAC permits for any building department. However, through the targeted calling that CIRB performed for this study, they were able to get residential changeouts for some respondents, representing nine percent of building departments.

Another 69 percent of building departments reported undifferentiated HVAC changeouts, and 4 percent reported total mechanical permits only. We ignored the mechanical permits in our initial analysis of the CIRB data, due to multiple layers of uncertainty in using them to estimate residential changeouts (HVAC vs. non-HVAC, residential vs. non-residential, changeout vs. other permit type). Between residential and undifferentiated residential/non-residential HVAC changeouts, we had data for 78 percent of California building departments.

Figure 27 shows the breakdown of CIRB data based on the level of information reported by each building department. "Other" includes building departments that responded, but were unable to provide data due to software limitations or other factors.

Figure 27. Distribution of building department data by reporting type

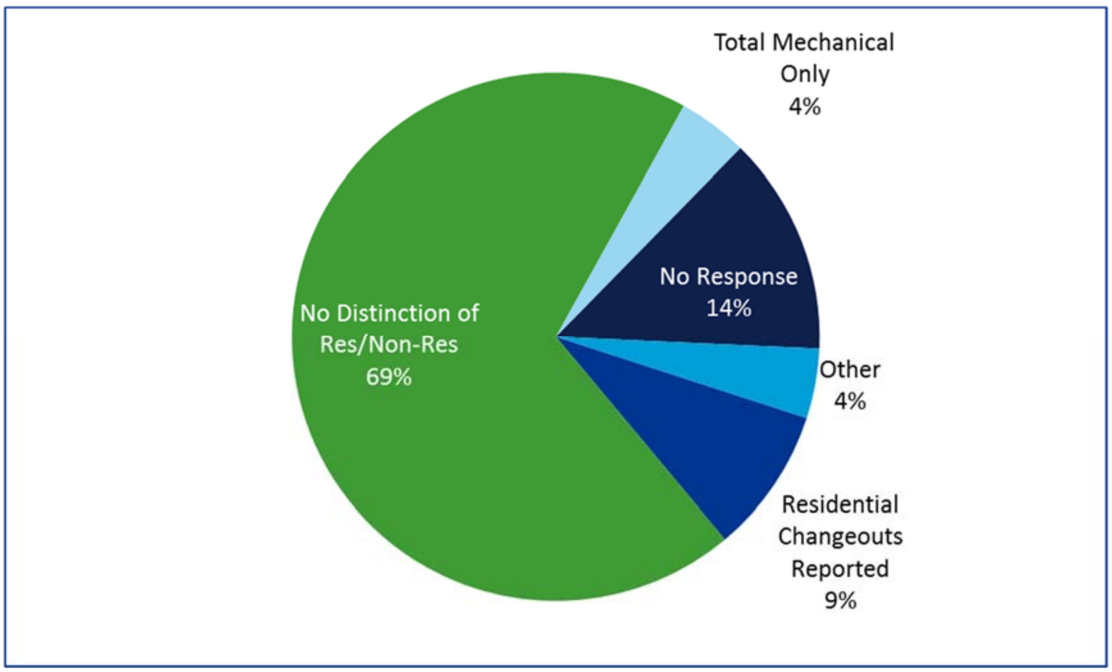


Figure 28 shows the CIRB permit data with our estimate of residential changeouts.

Figure 28. 2014 CIRB Report - permit data and estimated residential changeouts

Building Department City	Initial CIRB Data Set					Supplemental CIRB Data				Estimated Residential Changeouts
	New Single-Family Dwelling Units	New Multi-Family Dwelling Units	HVAC Change-Out Permits	HVAC Change-Out Units	Unspec-ified Mech-anical Permits	Total HVAC Change-outs	Res HVAC Change-outs	Non-Res Change-outs	Mech. Only	
Alameda	18	79	92	104	0					88
Alameda County Unincorporated	32	80	232	235	1					200
Albany	2	0	60	60	1					51
Berkeley	15	252	16	16	0					14
Dublin	481	698	117	128	2					109
Emeryville	0	101	8	17	0					14
Fremont	77	87	0	0	171					
Hayward	240	393	125	135	11					115
Livermore	69	9	332	351	0					299
Newark	8	0	0	0	0					
Oakland	56	7	1	1	0					1
Piedmont	2	0	27	27	0					23
Pleasanton	75	225	84	84	1					71
San Leandro	1	115	133	148	27					126
Union City	0	2	90	97	1					83
Alpine County Unincorporated	3	0	3	3	0		2	1		2
Amador City	0	0	0	0	0		2	0		2
Amador County Unincorporated	13	0	55	55	0					47
Ione	4	0	6	6	0					5
Jackson	2	0	9	9	0					8
Plymouth	0	0	4	4	0					3
Sutter Creek	0	0	13	13	0					11
Biggs	-	-	-	-	-					
Butte County Unincorporated	117	0	167	172	6					146

Building Department City	Initial CIRB Data Set					Supplemental CIRB Data				Estimated Residential Changeouts
	New Single-Family Dwelling Units	New Multi-Family Dwelling Units	HVAC Change-Out Permits	HVAC Change-Out Units	Unspec-ified Mech-anical Permits	Total HVAC Change-outs	Res HVAC Change-outs	Non-Res Change-outs	Mech. Only	
Chico	199	195	127	128	0					109
Gridley	8	0	21	21	0					18
Oroville	18	0	49	80	1					68
Paradise	14	0	93	93	0					79
Angels Camp	2	0	14	22	1					19
Calaveras County Unincorporated	68	0	9	9	0					8
Colusa	0	0	34	34	0					29
Colusa County Unincorporated	57	0	0	0	0					
Williams	0	0	69	69	0					59
Antioch	82	0	301	301	0					256
Brentwood	427	0	50	50	401					43
Clayton	0	0	65	66	0					56
Concord	8	0	251	291	1					248
Contra Costa County Unincorporated	417	0	488	501	0					426
Danville	32	16	0	0	0					
El Cerrito	5	57	73	76	0					65
Hercules	20	0	55	55	0					47
Lafayette	12	40	145	147	0					125
Martinez	38	45	167	167	2					142
Moraga	1	0	142	147	0					125
Oakley	77	0	72	72	0					61
Orinda	52	0	110	114	0					97
Pinole	1	0	34	40	1					34
Pittsburg	217	0	99	100	3					85
Pleasant Hill	3	0	144	144	0					123
Richmond	6	56	3	3	0					3

Building Department City	Initial CIRB Data Set					Supplemental CIRB Data				Estimated Residential Changeouts
	New Single-Family Dwelling Units	New Multi-Family Dwelling Units	HVAC Change-Out Permits	HVAC Change-Out Units	Unspec-ified Mech-anical Permits	Total HVAC Change-outs	Res HVAC Change-outs	Non-Res Change-outs	Mech. Only	
San Pablo	15	21	0	0	0					
San Ramon	12	156	175	175	36					149
Walnut Creek	14	197	459	477	0					406
Crescent City	0	2	9	12	0					10
Del Norte County Unincorporated	7	0	16	16	0					14
El Dorado County Unincorporated	358	4	0	0	1167					
Placerville	9	0	7	7	60					6
South Lake Tahoe	29	28	110	110	30					94
Clovis	483	0	291	319	0					271
Coalinga	17	80	40	40	0					34
Firebaugh	0	0	8	8	0					7
Fowler	33	0	14	14	0					12
Fresno	584	363	0	0	0		1081	10		1081
Fresno County Unincorporated	215	2	206	208	37					177
Huron	0	24	0	0	0					
Kerman	12	0	16	16	0					14
Kingsburg	10	2	38	38	0					32
Mendota	2	0	10	10	0					9
Orange Cove	1	0	4	4	0					3
Parlier	1	25	0	0	0		3	0		3
Reedley	1	0	19	19	8					16
San Joaquin	0	0	1	1	0					1
Sanger	46	43	0	0	0		57	14		57
Selma	5	0	28	32	0					27
Glenn County Unincorporated	5	0	7	7	10					6
Orland	11	3	28	30	0					26
Willows	1	98	43	43	0					37

Building Department City	Initial CIRB Data Set					Supplemental CIRB Data				Estimated Residential Changeouts
	New Single-Family Dwelling Units	New Multi-Family Dwelling Units	HVAC Change-Out Permits	HVAC Change-Out Units	Unspec-ified Mech-anical Permits	Total HVAC Change-outs	Res HVAC Change-outs	Non-Res Change-outs	Mech. Only	
Arcata	6	0	21	21	0					18
Blue Lake	-	-	-	-	-		1	0		1
Eureka	7	2	23	23	3					20
Ferndale	0	0	3	3	0					3
Fortuna	11	33	24	24	2					20
Humboldt County Unincorporated	124	36	28	28	123					24
Rio Dell	0	0	2	2	0					2
Trinidad	0	0	0	0	0					
Brawley	33	6	10	10	19					9
Calexico	4	53	113	129	0					110
Calipatria	0	0	5	5	0					4
El Centro	40	0	91	91	0					77
Holtville	2	0	7	7	0					6
Imperial	97	0	20	20	0					17
Imperial County Unincorporated	3	0	17	17	0					14
Westmorland	0	0	11	11	0					9
Bishop	0	0	9	9	0					8
Inyo County Unincorporated	7	0	63	63	1					54
Arvin	60	0	10	10	1					9
Bakersfield	1340	326	596	610	463					519
California City	1	0	26	54	1					46
Delano	4	0	34	86	3					73
Kern County Unincorporated	426	54	490	496	2					422
Maricopa	0	0	0	0	0		0	0		0
McFarland	67	0	0	0	0		4	8		4
Ridgecrest	8	0	0	0	0				45	
Shafter	105	0	11	11	0					9

Building Department City	Initial CIRB Data Set					Supplemental CIRB Data				Estimated Residential Changeouts
	New Single-Family Dwelling Units	New Multi-Family Dwelling Units	HVAC Change-Out Permits	HVAC Change-Out Units	Unspec-ified Mech-anical Permits	Total HVAC Change-outs	Res HVAC Change-outs	Non-Res Change-outs	Mech. Only	
Taft	0	0	22	22	2					19
Tehachapi	8	0	14	14	0					12
Wasco	28	0	39	41	0					35
Avenal	6	0	1	1	0					1
Corcoran	27	0	7	9	0					8
Hanford	121	72	154	159	1					135
Kings County Unincorporated	12	0	36	36	5					31
Lemoore	99	88	65	69	0					59
Clearlake	7	0	2	2	0					2
Lake County Unincorporated	34	0	29	30	0					26
Lakeport	1	0	10	14	0					12
Lassen County Unincorporated	11	0	16	16	0					14
Susanville	0	0	29	31	0					26
Agoura Hills	14	18	3	3	48					3
Alhambra	3	0	0	0	217				330	
Arcadia	153	95	178	183	33					156
Artesia	3	3	0	0	0	38			8	32
Avalon	0	0	0	0	0					
Azusa	198	90	78	78	11					66
Baldwin Park	18	0	0	0	0					
Bell	0	0	1	1	1					1
Bell Gardens	13	0	0	0	0		2	1		2
Bellflower	6	67	0	0	0					
Beverly Hills	41	130	4	9	0					8
Bradbury	2	0	9	15	1					13
Burbank	22	5	8	10	0					9
Calabasas	3	12	64	64	0					54

Building Department City	Initial CIRB Data Set					Supplemental CIRB Data				Estimated Residential Changeouts
	New Single-Family Dwelling Units	New Multi-Family Dwelling Units	HVAC Change-Out Permits	HVAC Change-Out Units	Unspec-ified Mech-anical Permits	Total HVAC Change-outs	Res HVAC Change-outs	Non-Res Change-outs	Mech. Only	
Carson	28	0	0	0	0					
Cerritos	2	217	135	154	35					131
Claremont	103	0	123	127	0					108
Commerce	0	0	0	0	0				90	
Compton	2	0	1	1	0					1
Covina	3	0	8	8	35					7
Cudahy	6	0	0	0	0		108	3		108
Culver City	5	0	1	1	0		344	232		344
Diamond Bar	47	0	0	0	0	154				131
Downey	13	0	0	0	0					
Duarte	0	0	53	59	5					50
El Monte	50	136	89	97	0					83
El Segundo	3	0	10	10	99					9
Gardena	23	6	0	0	0	287				244
Glendale	19	405	4	4	1					3
Glendora	4	280	0	0	0				420	
Hawaiian Gardens	3	3	12	12	1					10
Hawthorne	129	202	0	0	0					
Hermosa Beach	53	8	0	0	0					
Hidden Hills	7	0	0	0	0		7	0		7
Huntington Park	2	0	0	0	0	113				96
Industry	0	0	0	0	0					
Inglewood	1	2	49	57	34					49
Irwindale	1	0	0	0	0		1	6		1
La Canada Flintridge	8	0	0	0	0		55	9		55
La Habra Heights	4	0	0	0	0				28	
La Mirada	30	0	0	0	0	161			50	137

Building Department City	Initial CIRB Data Set					Supplemental CIRB Data				Estimated Residential Changeouts
	New Single-Family Dwelling Units	New Multi-Family Dwelling Units	HVAC Change-Out Permits	HVAC Change-Out Units	Unspec-ified Mech-anical Permits	Total HVAC Change-outs	Res HVAC Change-outs	Non-Res Change-outs	Mech. Only	
La Puente	6	5	13	13	94					11
La Verne	42	36	122	122	0					104
Lakewood	1	0	0	0	0	112			329	95
Lancaster	106	0	350	356	0					303
Lawndale	3	0	0	0	0	45				38
Lomita	16	0	0	0	0	36			17	31
Long Beach	25	298	0	0	564		341	93		341
Los Angeles	1602	10068	0	0	2					
Los Angeles County Unincorporated	466	363	0	0	0	2486			810	2115
Lynwood	23	0	0	0	0					
Malibu	10	0	0	0	0	24			26	20
Manhattan Beach	86	10	5	6	12					5
Maywood	0	0	0	0	0					
Monrovia	31	0	0	0	38				224	
Montebello	43	0	109	115	0					98
Monterey Park	27	4	0	0	0					
Norwalk	1	0	53	53	0					45
Palmdale	42	0	0	0	0		611	9		611
Palos Verdes Estates	8	0	14	14	18					12
Paramount	2	0	115	158	0					134
Pasadena	22	525	0	0	0					
Pico Rivera	6	0	119	122	0					104
Pomona	35	4	0	0	0				465	
Rancho Palos Verdes	5	0	10	10	0					9
Redondo Beach	71	38	0	0	0					
Rolling Hills	3	0	0	0	0	9			15	8

Building Department City	Initial CIRB Data Set					Supplemental CIRB Data				Estimated Residential Changeouts
	New Single-Family Dwelling Units	New Multi-Family Dwelling Units	HVAC Change-Out Permits	HVAC Change-Out Units	Unspec-ified Mech-anical Permits	Total HVAC Change-outs	Res HVAC Change-outs	Non-Res Change-outs	Mech. Only	
Rolling Hills Estates	7	0	0	0	0	10			9	9
Rosemead	10	0	0	0	144		40	4		40
San Dimas	3	0	0	0	64		74	3		74
San Fernando	0	6	0	0	0					
San Gabriel	12	0	0	0	0					
San Marino	16	0	59	64	0					54
Santa Clarita	290	31	0	0	0		398	19		398
Santa Fe Springs	0	156	0	0	0	56			25	48
Santa Monica	46	65	0	0	0					
Sierra Madre	1	0	29	29	14					25
Signal Hill	18	0	18	18	0					15
South El Monte	80	0	0	0	132					
South Gate	5	221	85	86	0					73
South Pasadena	2	0	40	40	136					34
Temple City	73	153	0	0	0	240			11	204
Torrance	22	2	0	0	0					
Vernon	0	45	15	15	183					13
Walnut	14	0	20	20	107					17
West Covina	31	450	0	0	300					
West Hollywood	22	120	0	0	0	220			87	187
Westlake Village	1	0	0	0	0	76			95	65
Whittier	1	70	0	0	420				420	
Chowchilla	3	0	39	39	0					33
Madera	158	0	102	106	12					90
Madera County Unincorporated	49	4	0	0	0					
Belvedere	1	0	15	16	5					14
Corte Madera	2	0	41	42	0					36

Building Department City	Initial CIRB Data Set					Supplemental CIRB Data				Estimated Residential Changeouts
	New Single-Family Dwelling Units	New Multi-Family Dwelling Units	HVAC Change-Out Permits	HVAC Change-Out Units	Unspec-ified Mech-anical Permits	Total HVAC Change-outs	Res HVAC Change-outs	Non-Res Change-outs	Mech. Only	
Fairfax	2	0	24	25	0					21
Larkspur	30	28	53	71	0					60
Marin County Unincorporated	23	0	16	18	0					15
Mill Valley	10	0	57	60	0					51
Novato	30	0	233	241	2					205
Ross	-	-	-	-	-					
San Anselmo	3	0	63	66	6					56
San Rafael	1	45	0	0	0					
Sausalito	2	3	4	4	7					3
Tiburon	8	0	2	2	0					2
Mariposa County Unincorporated	23	0	15	15	0					13
Fort Bragg	6	2	3	3	0					3
Mendocino County Unincorporated	42	5	18	18	0					15
Point Arena	2	0	0	0	0					
Ukiah	13	0	4	4	0					3
Willits	9	0	7	7	0					6
Atwater	44	0	51	51	0					43
Dos Palos	4	0	6	7	0					6
Gustine	12	0	15	15	0					13
Livingston	0	2	12	12	0					10
Los Banos	36	4	83	84	1					71
Merced	39	0	150	152	0					129
Merced County Unincorporated	68	0	130	130	0					111
Alturas	0	0	0	0	0					
Modoc County Unincorporated	8	0	6	6	0		3	0		3
Mammoth Lakes	14	0	13	13	0					11

Building Department City	Initial CIRB Data Set					Supplemental CIRB Data				Estimated Residential Changeouts
	New Single-Family Dwelling Units	New Multi-Family Dwelling Units	HVAC Change-Out Permits	HVAC Change-Out Units	Unspec-ified Mech-anical Permits	Total HVAC Change-outs	Res HVAC Change-outs	Non-Res Change-outs	Mech. Only	
Mono County Unincorporated	11	0	9	9	0					8
Carmel-by-the-Sea	7	2	8	8	0					7
Del Rey Oaks	0	0	0	0	0					
Gonzales	0	0	1	1	0					1
Greenfield	10	32	17	18	0					15
King City	9	0	9	9	0					8
Marina	3	8	17	18	0					15
Monterey	2	0	0	0	0		22	8		22
Monterey County Unincorporated	164	6	19	20	2					17
Pacific Grove	8	0	0	0	0		21	5		21
Salinas	32	37	11	11	30					9
Sand City	0	0	1	5	0					4
Seaside	0	0	0	0	0					
Soledad	1	0	4	4	0					3
American Canyon	0	0	26	26	0					22
Calistoga	3	0	21	21	0					18
Napa	32	49	279	331	7					282
Napa County Unincorporated	40	0	6	6	93					5
St. Helena	26	0	16	16	4					14
Yountville	2	0	12	12	0					10
Grass Valley	2	88	49	59	0					50
Nevada County Unincorporated	117	3	0	0	0		9	0		9
Truckee	96	6	45	47	0					40
Aliso Viejo	0	0	0	0	0	134			3	114
Anaheim	33	1310	0	0	629					
Brea	112	62	0	0	1	117				100
Buena Park	1	70	0	0	243					

Building Department City	Initial CIRB Data Set					Supplemental CIRB Data				Estimated Residential Changeouts
	New Single-Family Dwelling Units	New Multi-Family Dwelling Units	HVAC Change-Out Permits	HVAC Change-Out Units	Unspec-ified Mech-anical Permits	Total HVAC Change-outs	Res HVAC Change-outs	Non-Res Change-outs	Mech. Only	
Costa Mesa	151	33	23	36	1					31
Cypress	39	0	0	0	0					
Dana Point	31	9	0	0	0					
Fountain Valley	14	0	165	178	0					151
Fullerton	102	343	0	0	0		62	32		62
Garden Grove	30	0	226	237	0					202
Huntington Beach	59	989	1	1	0					1
Irvine	1660	1662	0	0	321					
La Habra	19	13	0	0	0				80	
La Palma	0	0	51	52	0					44
Laguna Beach	20	0	0	0	0				130	
Laguna Hills	0	289	108	113	1					96
Laguna Niguel	38	281	68	68	0					58
Laguna Woods										
Lake Forest	246	513	259	259	27					220
Los Alamitos	0	0	24	24	1					20
Mission Viejo	2	0	6	6	2		65	1		65
Newport Beach	120	543	271	335	2					285
Orange	6	342	3	14	1					12
Orange County Unincorporated	580	414	0	0	0	253			165	215
Placentia	37	10	100	100	0					85
Rancho Santa Margarita	0	0	0	0	49		66	0		66
San Clemente	50	73	81	84	0					71
San Juan Capistrano	61	0	0	0	64					
Santa Ana	67	24	200	200	31					170
Seal Beach	6	0	83	83	58					71
Stanton	52	0	3	3	44					3

Building Department City	Initial CIRB Data Set					Supplemental CIRB Data				Estimated Residential Changeouts
	New Single-Family Dwelling Units	New Multi-Family Dwelling Units	HVAC Change-Out Permits	HVAC Change-Out Units	Unspec-ified Mech-anical Permits	Total HVAC Change-outs	Res HVAC Change-outs	Non-Res Change-outs	Mech. Only	
Tustin	3	0	0	0	40					
Villa Park	1	0	30	30	0					26
Westminster	16	6	75	76	0					65
Yorba Linda	90	4	0	0	0		12	1		12
Auburn	14	0	24	24	65					20
Colfax	0	0	0	0	0		4	0		4
Lincoln	286	0	250	250	0					213
Loomis	10	0	51	51	0					43
Placer County Unincorporated	360	101	311	311	32					265
Rocklin	306	111	324	324	41					276
Roseville	644	164	50	50	765					43
Plumas County Unincorporated	26	0	18	18	0					15
Portola	0	0	0	0	0					
Banning	2	0	0	0	62					
Beaumont	435	0	68	69	0					59
Blythe	6	0	3	3	20					3
Calimesa	51	0	8	8	8					7
Canyon Lake	4	0	5	5	55		20	0		20
Cathedral City	32	0	60	63	214		511	0		511
Coachella	34	0	11	11	0					9
Corona	30	626	0	0	0	385				328
Desert Hot Springs	2	0	0	0	0					
Eastvale	409	0	29	29	2					25
Hemet	138	0	129	137	0					117
Indian Wells	37	0	126	155	0					132
Indio	516	0	311	326	0					277
Jurupa Valley	213	0	154	154	1					131

Building Department City	Initial CIRB Data Set					Supplemental CIRB Data				Estimated Residential Changeouts
	New Single-Family Dwelling Units	New Multi-Family Dwelling Units	HVAC Change-Out Permits	HVAC Change-Out Units	Unspec-ified Mech-anical Permits	Total HVAC Change-outs	Res HVAC Change-outs	Non-Res Change-outs	Mech. Only	
La Quinta	177	111	344	344	0					293
Lake Elsinore	429	0	50	50	170					43
Menifee	465	0	232	232	0					197
Moreno Valley	46	0	324	346	0					294
Murrieta	20	248	34	34	76					29
Norco	0	0	65	66	0					56
Palm Desert	199	122	0	0	0		576	19	446	576
Palm Springs	202	15	352	352	182					300
Perris	207	126	56	62	0					53
Rancho Mirage	38	0	346	375	0					319
Riverside	230	85	0	0	0		2121	97		2121
Riverside County Unincorporated	790	2	0	0	0					
San Jacinto	58	0	55	57	0					49
Temecula	234	596	0	0	0					
Wildomar	3	0	36	36	2					31
Citrus Heights	17	0	0	0	0					
Elk Grove	485	0	506	509	4					433
Folsom	279	0	492	492	32					419
Galt	76	0	96	98	0					83
Isleton	0	0	1	1	0					1
Rancho Cordova	166	56	0	0	0					
Sacramento	257	160	1824	1824	0					1552
Sacramento County Unincorporated	267	10	4	4	0					3
Hollister	50	0	2	2	33					2
San Benito County Unincorporated	25	0	7	7	0					6
San Juan Bautista	3	0	1	1	0		0	0		0

Building Department City	Initial CIRB Data Set					Supplemental CIRB Data				Estimated Residential Changeouts
	New Single-Family Dwelling Units	New Multi-Family Dwelling Units	HVAC Change-Out Permits	HVAC Change-Out Units	Unspec-ified Mech-anical Permits	Total HVAC Change-outs	Res HVAC Change-outs	Non-Res Change-outs	Mech. Only	
Adelanto	36	0	179	179	0					152
Apple Valley	116	10	0	0	0					
Barstow	0	0	6	6	5		17	2		17
Big Bear Lake	47	0	21	21	0					18
Chino	272	136	0	0	0					
Chino Hills	30	297	157	165	1					140
Colton	29	0	13	13	0					11
Fontana	320	123	304	308	0		297	11		297
Grand Terrace	1	0	24	25	0					21
Hesperia	75	2	0	0	0	471				401
Highland	7	0	0	0	0					
Loma Linda	2	46	34	34	21					29
Montclair	10	18	50	51	0					43
Needles	2	0	0	0	0		1	0		1
Ontario	131	306	0	0	0					
Rancho Cucamonga	197	17	281	286	0					243
Redlands	57	0	0	0	0					
Rialto	7	0	0	0	0					
San Bernardino	62	50	0	0	0	483				411
San Bernardino County Unincorporated	389	261	344	364	6					310
Twenty-nine Palms	7	0	66	67	64					57
Upland	41	0	141	141	0					120
Victorville	44	0	351	351	0					299
Yucaipa	37	0	11	11	0					9
Yucca Valley	18	0	11	11	74					9
Carlsbad	186	66	0	0	0					

Building Department City	Initial CIRB Data Set					Supplemental CIRB Data				Estimated Residential Changeouts
	New Single-Family Dwelling Units	New Multi-Family Dwelling Units	HVAC Change-Out Permits	HVAC Change-Out Units	Unspec-ified Mech-anical Permits	Total HVAC Change-outs	Res HVAC Change-outs	Non-Res Change-outs	Mech. Only	
Chula Vista	118	927	336	378	0					322
Coronado	31	0	18	18	57	267				227
Del Mar	13	0	0	0	73		26	4		26
El Cajon	15	6	181	198	0					168
Encinitas	158	2	0	0	297					
Escondido	40	12	0	0	0		357	31		357
Imperial Beach	24	26	6	6	38					5
La Mesa	41	267	145	148	0					126
Lemon Grove	23	0	2	2	15					2
National City	11	111	0	0	0					
Oceanside	75	10	290	312	1					265
Poway	19	0	0	0	254	207				176
San Diego	722	1823	168	189	135					161
San Diego County Unincorporated	609	131	0	0	0					
San Marcos	94	6	180	188	0					160
Santee	4	172	0	0	221					
Solana Beach	9	0	0	0	126		50	10		50
Vista	84	768	0	0	0					
San Francisco	35	3035	10	11	22					9
Escalon	23	0	11	11	1					9
Lathrop	150	0	12	12	0					10
Lodi	21	0	290	326	0					277
Manteca	427	0	212	212	3					180
Ripon	17	0	21	21	24	21			45	18
San Joaquin County Unincorporated	366	15	283	283	0					241
Stockton	75	4	0	0	0		421	38		421

Building Department City	Initial CIRB Data Set					Supplemental CIRB Data				Estimated Residential Changeouts
	New Single-Family Dwelling Units	New Multi-Family Dwelling Units	HVAC Change-Out Permits	HVAC Change-Out Units	Unspec-ified Mech-anical Permits	Total HVAC Change-outs	Res HVAC Change-outs	Non-Res Change-outs	Mech. Only	
Tracy	135	0	243	252	1					214
Arroyo Grande	13	28	16	30	0					26
Atascadero	149	40	21	21	0					18
Grover Beach	12	0	12	12	0					10
Morro Bay	7	21	7	7	1					6
Paso Robles	39	0	0	0	0					
Pismo Beach	106	34	0	0	0					
San Luis Obispo	102	115	0	0	0					
San Luis Obispo County Unincorporated	300	9	67	71	0					60
Atherton	38	0	6	6	5					5
Belmont	7	10	47	47	3					40
Brisbane	34	0	1	1	0					1
Burlingame	19	6	19	19	24					16
Colma	0	0	1	1	0					1
Daly City	14	0	7	8	0					7
East Palo Alto	1	0	12	12	0					10
Foster City	0	273	58	58	1					49
Half Moon Bay	16	115	10	12	0					10
Hillsborough	23	0	11	12	0					10
Menlo Park	47	4	60	61	0					52
Millbrae	3	0	4	4	9					3
Pacifica	3	0	7	7	0					6
Portola Valley	11	0	26	26	59		8	0		8
Redwood City	15	749	25	25	0					21
San Bruno	1	0	22	28	0					24
San Carlos	9	0	51	52	1					44

Building Department City	Initial CIRB Data Set					Supplemental CIRB Data				Estimated Residential Changeouts
	New Single-Family Dwelling Units	New Multi-Family Dwelling Units	HVAC Change-Out Permits	HVAC Change-Out Units	Unspec-ified Mech-anical Permits	Total HVAC Change-outs	Res HVAC Change-outs	Non-Res Change-outs	Mech. Only	
San Mateo	26	142	83	94	1					80
San Mateo County Unincorporated	37	0	0	0	0	88			11	75
South San Francisco	2	3	33	37	1					31
Woodside	9	0	13	13	0					11
Buellton	8	0	3	3	2					3
Carpinteria	2	0	9	9	0					8
Goleta	4	316	0	0	106				154	
Guadalupe	-	-	-	-	-					
Lompoc	22	21	18	18	0					15
Santa Barbara	12	0	1	1	5					1
Santa Barbara County Unincorporated	149	1	14	14	34		39	0		39
Santa Maria	130	214	50	50	60					43
Solvang	42	0	0	0	1					
Campbell	40	4	0	0	0					
Cupertino	35	0	142	153	27					130
Gilroy	226	2	33	35	0					30
Los Altos	33	182	13	13	84					11
Los Altos Hills	26	2	0	0	0					
Los Gatos	40	0	3	4	0		126	3		126
Milpitas	170	1025	6	72	1					61
Monte Sereno	6	0	0	0	0					
Morgan Hill	306	30	60	71	0					60
Mountain View	92	542	12	12	0					10
Palo Alto	93	6	0	0	24					
San Jose	390	4074	0	0	0					
Santa Clara	42	1645	0	0	0					

Building Department City	Initial CIRB Data Set					Supplemental CIRB Data				Estimated Residential Changeouts
	New Single-Family Dwelling Units	New Multi-Family Dwelling Units	HVAC Change-Out Permits	HVAC Change-Out Units	Unspec-ified Mech-anical Permits	Total HVAC Change-outs	Res HVAC Change-outs	Non-Res Change-outs	Mech. Only	
Santa Clara County Unincorporated	46	2	78	82	3					70
Saratoga	26	0	100	102	1					87
Sunnyvale	31	796	0	0	0	320				272
Capitola	3	0	35	36	0					31
Santa Cruz	39	0	6	6	37	6			79	5
Santa Cruz County Unincorporated	41	5	54	54	7					46
Scotts Valley	18	0	0	0	0					
Watsonville	13	4	19	19	0					16
Anderson	20	2	53	54	0					46
Redding	108	3	683	699	0					595
Shasta County Unincorporated	88	0	0	0	0					
Shasta Lake	19	0	50	50	0					43
Loyalton	0	0	0	0	0					
Sierra County Unincorporated	5	0	0	0	0					
Dorris	0	0	0	0	0					
Dunsmuir	2	0	3	3	0					3
Etna	1	0	0	0	0					
Fort Jones	0	0	0	0	0					
Montague	0	0	0	0	0					
Mount Shasta	1	0	2	2	0		1	1		1
Siskiyou County Unincorporated	30	0	0	0	18		20	0		20
Tule lake	0	0	0	0	0					
Weed	4	0	0	0	0				4	
Yreka	1	0	0	0	0					
Benicia	5	0	113	124	1					106
Dixon	23	0	68	68	1					58

Building Department City	Initial CIRB Data Set					Supplemental CIRB Data				Estimated Residential Changeouts
	New Single-Family Dwelling Units	New Multi-Family Dwelling Units	HVAC Change-Out Permits	HVAC Change-Out Units	Unspec-ified Mech-anical Permits	Total HVAC Change-outs	Res HVAC Change-outs	Non-Res Change-outs	Mech. Only	
Fairfield	318	0	149	149	4					127
Rio Vista	132	0	19	19	17					16
Solano County Unincorporated	18	0	39	39	6					33
Suisun City	0	0	0	0	0					
Vacaville	138	0	378	378	5					322
Vallejo	21	0	126	126	21					107
Cloverdale	0	0	23	24	0					20
Cotati	4	0	20	20	0					17
Healdsburg	6	2	56	56	0					48
Petaluma	20	144	175	175	0					149
Rohnert Park	2	0	80	80	1					68
Santa Rosa	186	64	0	0	0		708	84		708
Sebastopol	2	0	32	32	1					27
Sonoma	16	4	0	0	0					
Sonoma County Unincorporated	46	0	328	328	1					279
Windsor	10	0	92	92	0					78
Ceres	44	0	64	65	10					55
Hughson	15	0	13	13	0					11
Modesto	10	50	763	801	0					682
Newman	15	0	26	26	0					22
Oakdale	77	0	59	63	0					54
Patterson	3	0	25	25	0					21
Riverbank	33	0	41	41	1					35
Stanislaus County Unincorporated	101	0	109	113	0					96
Turlock	91	0	0	0	0					
Waterford	0	0	21	21	0					18
Live Oak	1	0	16	16	0					14

Building Department City	Initial CIRB Data Set					Supplemental CIRB Data				Estimated Residential Changeouts
	New Single-Family Dwelling Units	New Multi-Family Dwelling Units	HVAC Change-Out Permits	HVAC Change-Out Units	Unspec-ified Mech-anical Permits	Total HVAC Change-outs	Res HVAC Change-outs	Non-Res Change-outs	Mech. Only	
Sutter County Unincorporated	23	0	37	37	0					31
Yuba City	50	10	121	121	151					103
Corning	1	2	22	27	0					23
Red Bluff	17	0	82	83	0					71
Tehama	-	-	-	-	-		0	0		0
Tehama County Unincorporated	46	2	98	98	1					83
Trinity County Unincorporated	29	0	71	72	0					61
Dinuba	24	0	26	26	18					22
Exeter	26	4	15	15	0					13
Farmersville	3	0	12	12	0					10
Lindsay	20	0	9	11	0					9
Porterville	28	248	122	126	0					107
Tulare	203	2	82	82	0					70
Tulare County Unincorporated	140	24	152	162	1					138
Visalia	398	18	327	341	0					290
Woodlake	5	0	7	7	0					6
Sonora	2	0	0	0	0		5	8	3	5
Tuolumne County Unincorporated	50	4	9	9	46					8
Camarillo	47	252	0	0	0					
Fillmore	39	0	29	29	0					25
Moorpark	178	0	105	106	0					90
Ojai	0	0	22	22	0					19
Oxnard	42	269	0	0	0					
Port Hueneme	5	0	0	0	0					
San Buenaventura	43	69	124	157	0					134
Santa Paula	2	0	1	1	0					1
Simi Valley	3	8	16	16	175					14

Building Department City	Initial CIRB Data Set					Supplemental CIRB Data				Estimated Residential Changeouts
	New Single-Family Dwelling Units	New Multi-Family Dwelling Units	HVAC Change-Out Permits	HVAC Change-Out Units	Unspec-ified Mech-anical Permits	Total HVAC Change-outs	Res HVAC Change-outs	Non-Res Change-outs	Mech. Only	
Thousand Oaks	16	32	0	0	0					
Ventura County Unincorporated	75	2	245	260	0					221
Davis	10	2	88	88	401					75
West Sacramento	61	0	193	274	1					233
Winters	0	0	2	2	24					2
Woodland	128	0	117	117	85					100
Yolo County Unincorporated	19	0	57	58	0					49
Marysville										0
Wheatland	0	100	19	19	0					16
Yuba County Unincorporated	112	0	104	108	0					92

APPENDIX D. METHODOLOGY TO MERGE HERS REGISTRY AND CIRB DATA

Using the CIRB and HERS datasets, we developed five sets of overlapping estimates of permitted units at the building department level and combined them into a final estimate. For consistency with the denominator, we used the data on the number of permitted units rather than the number of permits.[7] The estimates included:

1. **CIRB-based permitted unit count for the full year:** Reliable counts of residential permitted equipment for 48 building departments and estimates of residential permits for another 387 building departments
2. **HERS-based permitted unit count for the first half of the year:** Reliable estimates for climate zones 2 and 9 through 16
3. **CIRB-based permitted unit estimate for the first half of the year:** Same as the full year data, but estimating the share of permits issued in the first 6 months of the year (to use in combination with half-year HERS data)
4. **HERS-based permitted unit count for the second half of the year:** Reliable estimates for all climate zones
5. **CIRB-based permitted unit estimates for the full year based on mechanical permits:** The least reliable of the various estimates, as it required estimating the share of unspecified mechanical permits that were for residential changeouts (used only for a small number of building departments with no other data)

Each of the five estimates provided only a partial picture of total permitted units. Some cover only part of the year while others have gaps and omissions. HERS might report zero inspections for a building department, while CIRB reports that permits were issued, while that situation might be reversed for another building department. Figure 29 shows the values for each of the five components for each building department. We used a combination of all these estimates to create the most comprehensive estimates possible.

APPENDIX C and APPENDIX B show the source of components 1 and 4, respectively. For climate zones that required HERS inspections under the 2008 code, component 2 was simply the number of units inspected under the 2008 code from APPENDIX B. For building departments with data for both halves of the year, we estimated the ratio of 1st half inspections to second-half inspections. We aggregated these by climate region and to the state level. For climate zones that did not require HERS inspections under the 2008, we applied the ratio for the appropriate climate zone to the second-half inspection count to estimate first-half inspections.

To develop estimate number 3 (partial-year permitted units using the CIRB data), we leveraged the data from the many building departments for which we had HERS data for both the first and second half of the year. For each building department with a full year of HERS data, we calculated the percent of permitted units that were issued in the first half of the year. We aggregated from building departments to climate zones and climate regions. Because the HERS requirements are by climate zone, we were unable to calculate a ratio for climate zones 1 and 3 through 8, or for the North Coast or South Coast climate regions.

[7] There can be multiple units per permit in cases where cooling systems and heating systems are replaced simultaneously, or when a permit covers work in multiple units of a multifamily building. State wide, there were 1.09 units installed per permit,

For climate zones 4 and 8, we assigned those zones the average value for their regions (Central Inland and South Inland). For the remaining climate zones, we assigned the average value for an adjacent climate region (North Inland for North Coast, and South Inland for South Coast). We then assigned each building department a "first half of the year share" based on its climate zone.

We applied these shares to our estimates of 2014 residential HVAC changeout units from CIRB to get an estimate of residential permitted units in the first half of the year.

To estimate component 5, we assumed that building department reporting only unspecified mechanical permits had reported both HVAC changeouts and other mechanical permits under that combined value. We looked at building departments that reported changeouts separately from unspecified mechanical to estimate the ratio of residential changeouts to total HVAC and mechanical permits. We applied the resulting ratios, calculated by climate region, to the unspecified mechanical permit counts to create a rough estimate of residential changeouts for those building departments.

Once we had calculated all of the five estimates, we combined them into what we believe are reliable full-year estimates for each building department. Our initial estimate of full-year permitted units combined the HERS data for the second half of the year with the HERS permitted unit estimate for the first half of the year for climate zones 2 and 9 through 16, and with CIRB permitted unit estimates for the first half of the year for climate zones 1 and 3 through 9. However, this initial estimate left 35 building departments with zero permitted units for the year. While it is possible for building departments in sparsely populated areas to issue no permits in a year, 15 of these reported HVAC permits to CIRB and four of those specifically reported residential HVAC permits. Because of this discrepancy, for building departments where our initial estimate resulted in zero permitted units for the year, we instead used the full year CIRB estimate.

This process left 20 building departments with an estimate of zero permits issued in 2014. For these, we turned to our fifth estimation approach, breaking out total mechanical permits. Two building departments showed no permitted units issued using the other four approaches, but still reported unspecified mechanical permits. In the case of Goleta (in the South Coast climate region), CIRB reported 106 unspecified mechanical permits.

That left 18 building departments with zero estimated permits, including: Alturas, Avalon, Biggs, Del Rey Oaks, Dorris, Etna, Fort Jones, Industry, La Habra Heights, Loyalton, Maricopa, Montague, Point Arena, San Juan Bautista, Tehama, Trinidad, Tule lake, and Weed. Most of these are small, or have small residential housing stock (e.g., the City of Industry), and could plausibly have actually issued no permits in a year. Together these building departments represent less 0.2 percent of households in California.

Figure 29 shows the five components and the final combined estimate of residential changeouts.

Figure 29. Five data components used to estimate residential HVAC changeouts

Building Department City	CIRB-based permitted unit count for the full year	HERS-based permitted unit count for the first half of the year	CIRB-based permitted unit estimate for the first half of the year	HERS-based permitted unit count for the second half of the year	CIRB-based permitted unit estimates based on full-year mechanical permits	Combined estimate of residential HVAC changeouts
Alameda	88	158	16	101	0	259

Building Department City	CIRB-based permitted unit count for the full year	HERS-based permitted unit count for the first half of the year	CIRB-based permitted unit estimate for the first half of the year	HERS-based permitted unit count for the second half of the year	CIRB-based permitted unit estimates based on full-year mechanical permits	Combined estimate of residential HVAC changeouts
Alameda County Unincorporated	200	96	31	63	1	94
Albany	51	8	2	5	1	13
Berkeley	14	111	40	71	0	182
Dublin	109	82	70	54	1	124
Emeryville	14	0	0	0	0	14
Fremont		147	38	94	104	241
Hayward	115	58	19	37	7	95
Livermore	299	231	227	152	0	379
Newark		25	10	16	0	41
Oakland	1	161	51	103	0	264
Piedmont	23	11	3	7	0	18
Pleasanton	71	236	236	151	1	387
San Leandro	126	36	9	23	16	59
Union City	83	30	8	19	1	49
Alpine County Unincorporated	2	5	3	3	0	6
Amador City	2	0	0	0	0	2
Amador County Unincorporated	47	85	85	44	0	129
Ione	5	26	26	11	0	37
Jackson	8	23	23	6	0	29
Plymouth	3	3	3	2	0	5
Sutter Creek	11	15	15	6	0	21
Biggs		0	0	0	0	0
Butte County Unincorporated	146	142	135	95	4	230
Chico	109	176	176	82	0	258
Gridley	18	14	14	7	0	21
Oroville	68	49	41	33	1	74
Paradise	79	91	91	30	0	121
Angels Camp	19	18	10	12	1	22
Calaveras County Unincorporated	8	106	94	70	0	164
Colusa	29	16	16	10	0	26
Colusa County Unincorporated		17	17	8	0	25
Williams	59	7	6	5	0	11

Building Department City	CIRB-based permitted unit count for the full year	HERS-based permitted unit count for the first half of the year	CIRB-based permitted unit estimate for the first half of the year	HERS-based permitted unit count for the second half of the year	CIRB-based permitted unit estimates based on full-year mechanical permits	Combined estimate of residential HVAC changeouts
Antioch	256	191	141	126	0	267
Brentwood	43	105	70	69	273	139
Clayton	56	47	19	31	0	50
Concord	248	320	320	197	1	517
Contra Costa County Unincorporated	426	481	447	317	0	764
Danville		231	220	152	0	372
El Cerrito	65	47	8	30	0	77
Hercules	47	16	7	10	0	26
Lafayette	125	61	55	40	0	95
Martinez	142	124	124	79	1	203
Moraga	125	35	25	23	0	48
Oakley	61	59	55	39	0	94
Orinda	97	36	23	24	0	47
Pinole	34	14	10	9	1	23
Pittsburg	85	80	73	53	2	126
Pleasant Hill	123	93	75	61	0	136
Richmond	3	41	14	26	0	67
San Pablo		3	0	2	0	5
San Ramon	149	172	172	103	25	275
Walnut Creek	406	313	282	206	0	488
Crescent City	10	0	0	0	0	10
Del Norte County Unincorporated	14	0	0	0	0	14
El Dorado County Unincorporated		845	808	566	698	1374
Placerville	6	70	70	37	41	107
South Lake Tahoe	94	77	77	34	18	111
Clovis	271	303	303	149	0	452
Coalinga	34	42	42	12	0	54
Firebaugh	7	4	4	1	0	5
Fowler	12	15	14	10	0	24
Fresno	1081	955	950	629	0	1579
Fresno County Unincorporated	177	298	278	196	25	474
Huron		2	0	1	0	1
Kerman	14	14	8	9	0	17
Kingsburg	32	37	37	13	0	50

Building Department City	CIRB-based permitted unit count for the full year	HERS-based permitted unit count for the first half of the year	CIRB-based permitted unit estimate for the first half of the year	HERS-based permitted unit count for the second half of the year	CIRB-based permitted unit estimates based on full-year mechanical permits	Combined estimate of residential HVAC changeouts
Mendota	9	9	2	6	0	8
Orange Cove	3	4	4	0	0	4
Parlier	3	47	47	3	0	50
Reedley	16	32	32	18	5	50
San Joaquin	1	3	2	2	0	4
Sanger	57	29	25	19	0	44
Selma	27	29	24	19	0	43
Glenn County Unincorporated	6	16	16	2	6	18
Orland	26	22	22	3	0	25
Willows	37	25	25	6	0	31
Arcata	18	0	0	0	0	18
Blue Lake	1	0	0	0	0	1
Eureka	20	0	0	0	2	20
Ferndale	3	0	0	0	0	3
Fortuna	20	0	0	0	1	20
Humboldt County Unincorporated	24	0	0	0	74	24
Rio Dell	2	0	0	0	0	2
Trinidad		0	0	0	0	0
Brawley	9	33	33	7	14	40
Calexico	110	24	24	2	0	26
Calipatria	4	0	0	0	0	4
El Centro	77	64	64	8	0	72
Holtville	6	0	0	0	0	6
Imperial	17	13	13	8	0	21
Imperial County Unincorporated	14	19	19	2	0	21
Westmorland	9	0	0	0	0	9
Bishop	8	0	0	0	0	8
Inyo County Unincorporated	54	1	1	0	1	1
Arvin	9	26	5	17	1	22
Bakersfield	519	767	651	505	315	1156
California City	46	12	10	7	1	17
Delano	73	32	32	18	2	50
Kern County Unincorporated	422	521	521	227	1	748

Building Department City	CIRB-based permitted unit count for the full year	HERS-based permitted unit count for the first half of the year	CIRB-based permitted unit estimate for the first half of the year	HERS-based permitted unit count for the second half of the year	CIRB-based permitted unit estimates based on full-year mechanical permits	Combined estimate of residential HVAC changeouts
Maricopa	0	0	0	0	0	0
McFarland	4	2	2	1	0	3
Ridgecrest		38	21	23	0	44
Shafter	9	114	114	11	0	125
Taft	19	12	10	8	1	18
Tehachapi	12	15	9	10	0	19
Wasco	35	23	23	8	0	31
Avenal	1	12	2	8	0	10
Corcoran	8	9	9	4	0	13
Hanford	135	167	160	110	1	270
Kings County Unincorporated	31	38	38	7	3	45
Lemoore	59	52	52	33	0	85
Clearlake	2	2	2	1	0	3
Lake County Unincorporated	26	15	15	5	0	20
Lakeport	12	0	0	0	0	12
Lassen County Unincorporated	14	4	4	3	0	7
Susanville	26	0	0	0	0	26
Agoura Hills	3	181	76	108	36	184
Alhambra		115	115	42	161	157
Arcadia	156	66	66	26	25	92
Artesia	32	9	9	5	0	14
Avalon		0	0	0	0	0
Azusa	66	59	59	26	8	85
Baldwin Park		28	28	15	0	43
Bell	1	2	0	1	1	3
Bell Gardens	2	3	0	2	0	5
Bellflower		35	25	21	0	56
Beverly Hills	8	182	182	25	0	207
Bradbury	13	0	0	0	1	13
Burbank	9	105	105	42	0	147
Calabasas	54	131	131	25	0	156
Carson		60	31	36	0	96
Cerritos	131	97	97	52	26	149
Claremont	108	85	73	51	0	124
Commerce		3	3	1	0	4

Building Department City	CIRB-based permitted unit count for the full year	HERS-based permitted unit count for the first half of the year	CIRB-based permitted unit estimate for the first half of the year	HERS-based permitted unit count for the second half of the year	CIRB-based permitted unit estimates based on full-year mechanical permits	Combined estimate of residential HVAC changeouts
Compton	1	15	15	6	0	21
Covina	7	54	54	32	26	86
Cudahy	108	1	1	0	0	1
Culver City	344	87	69	52	0	139
Diamond Bar	131	65	65	33	0	98
Downey		91	91	49	0	140
Duarte	50	45	45	17	4	62
El Monte	83	17	12	10	0	22
El Segundo	9	13	0	8	74	21
Gardena	244	57	27	34	0	91
Glendale	3	200	200	95	1	295
Glendora		64	64	29	0	93
Hawaiian Gardens	10	1	1	0	1	1
Hawthorne		32	12	19	0	51
Hermosa Beach		2	0	1	0	3
Hidden Hills	7	5	5	2	0	7
Huntington Park	96	7	3	4	0	11
Industry		0	0	0	0	0
Inglewood	49	239	239	37	25	276
Irwindale	1	0	0	0	0	1
La Canada Flintridge	55	30	30	13	0	43
La Habra Heights		0	0	0	0	0
La Mirada	137	80	64	48	0	112
La Puente	11	42	42	19	70	61
La Verne	104	65	45	39	0	84
Lakewood	95	109	94	65	0	174
Lancaster	303	330	283	197	0	480
Lawndale	38	7	2	4	0	11
Lomita	31	0	0	0	0	31
Long Beach	341	210	58	134	420	344
Los Angeles		2147	2147	1064	1	3211
Los Angeles County Unincorporated	2115	755	753	451	0	1204
Lynwood		3	3	1	0	4
Malibu	20	20	4	13	0	33
Manhattan Beach	5	42	10	27	9	69
Maywood		2	0	1	0	3

Building Department City	CIRB-based permitted unit count for the full year	HERS-based permitted unit count for the first half of the year	CIRB-based permitted unit estimate for the first half of the year	HERS-based permitted unit count for the second half of the year	CIRB-based permitted unit estimates based on full-year mechanical permits	Combined estimate of residential HVAC changeouts
Monrovia		65	41	39	28	80
Montebello	98	24	24	12	0	36
Monterey Park		52	43	31	0	74
Norwalk	45	88	88	36	0	124
Palmdale	611	373	349	223	0	572
Palos Verdes Estates	12	22	3	14	13	36
Paramount	134	13	7	8	0	21
Pasadena		303	303	152	0	455
Pico Rivera	104	28	19	17	0	36
Pomona		98	98	56	0	154
Rancho Palos Verdes	9	42	4	27	0	69
Redondo Beach		38	1	24	0	62
Rolling Hills	8	0	0	0	0	8
Rolling Hills Estates	9	0	0	0	0	9
Rosemead	40	19	19	11	107	30
San Dimas	74	42	42	22	48	64
San Fernando		5	5	3	0	8
San Gabriel		64	64	28	0	92
San Marino	54	70	70	20	0	90
Santa Clarita	398	115	115	68	0	183
Santa Fe Springs	48	9	9	3	0	12
Santa Monica		67	12	43	0	110
Sierra Madre	25	33	33	16	10	49
Signal Hill	15	1	1	0	0	1
South El Monte		5	1	3	98	4
South Gate	73	6	6	1	0	7
South Pasadena	34	47	46	28	101	74
Temple City	204	38	38	17	0	55
Torrance		132	15	84	0	216
Vernon	13	0	0	0	136	13
Walnut	17	45	45	27	80	72
West Covina		97	95	58	223	153
West Hollywood	187	42	42	10	0	52
Westlake Village	65	17	17	7	0	24
Whittier		136	94	81	312	175
Chowchilla	33	33	33	12	0	45
Madera	90	103	82	68	8	150

Building Department City	CIRB-based permitted unit count for the full year	HERS-based permitted unit count for the first half of the year	CIRB-based permitted unit estimate for the first half of the year	HERS-based permitted unit count for the second half of the year	CIRB-based permitted unit estimates based on full-year mechanical permits	Combined estimate of residential HVAC changeouts
Madera County Unincorporated		94	94	48	0	142
Belvedere	14	6	6	4	3	10
Corte Madera	36	16	6	10	0	26
Fairfax	21	7	6	5	0	11
Larkspur	60	22	15	15	0	30
Marin County Unincorporated	15	70	66	45	0	115
Mill Valley	51	36	36	17	0	53
Novato	205	131	131	73	1	204
Ross		16	16	7	0	23
San Anselmo	56	33	33	15	4	48
San Rafael		97	79	65	0	144
Sausalito	3	9	4	6	4	15
Tiburon	2	10	10	4	0	14
Mariposa County Unincorporated	13	5	5	3	0	8
Fort Bragg	3	0	0	0	0	3
Mendocino County Unincorporated	15	10	5	7	0	12
Point Arena		0	0	0	0	0
Ukiah	3	6	5	4	0	9
Willits	6	4	4	1	0	5
Atwater	43	43	43	27	0	70
Dos Palos	6	11	11	1	0	12
Gustine	13	17	11	11	0	22
Livingston	10	11	8	7	0	15
Los Banos	71	32	16	21	1	37
Merced	129	155	155	66	0	221
Merced County Unincorporated	111	92	92	37	0	129
Alturas		0	0	0	0	0
Modoc County Unincorporated	3	0	0	0	0	3
Mammoth Lakes	11	0	0	0	0	11
Mono County Unincorporated	8	0	0	0	0	8
Carmel-by-the-Sea	7	2	0	1	0	3

Building Department City	CIRB-based permitted unit count for the full year	HERS-based permitted unit count for the first half of the year	CIRB-based permitted unit estimate for the first half of the year	HERS-based permitted unit count for the second half of the year	CIRB-based permitted unit estimates based on full-year mechanical permits	Combined estimate of residential HVAC changeouts
Del Rey Oaks		0	0	0	0	0
Gonzales	1	0	0	0	0	1
Greenfield	15	0	0	0	0	15
King City	8	1	1	0	0	1
Marina	15	0	0	0	0	15
Monterey	22	5	0	3	0	8
Monterey County Unincorporated	17	23	0	15	1	38
Pacific Grove	21	2	0	1	0	3
Salinas	9	2	1	1	18	3
Sand City	4	0	0	0	0	4
Seaside		2	0	1	0	3
Soledad	3	0	0	0	0	3
American Canyon	22	39	29	26	0	55
Calistoga	18	12	10	8	0	18
Napa	282	231	231	143	4	374
Napa County Unincorporated	5	66	59	44	56	103
St. Helena	14	22	22	12	2	34
Yountville	10	14	14	7	0	21
Grass Valley	50	40	33	27	0	60
Nevada County Unincorporated	9	243	204	163	0	367
Truckee	40	70	70	31	0	101
Aliso Viejo	114	108	7	69	0	177
Anaheim		366	254	219	468	585
Brea	100	69	27	41	1	110
Buena Park		105	105	42	181	147
Costa Mesa	31	94	6	60	1	154
Cypress		94	61	56	0	150
Dana Point		44	1	28	0	72
Fountain Valley	151	83	52	53	0	136
Fullerton	62	162	116	97	0	259
Garden Grove	202	139	79	83	0	222
Huntington Beach	1	169	17	108	0	277
Irvine		254	204	152	239	406
La Habra		92	40	55	0	147
La Palma	44	33	25	20	0	53

Building Department City	CIRB-based permitted unit count for the full year	HERS-based permitted unit count for the first half of the year	CIRB-based permitted unit estimate for the first half of the year	HERS-based permitted unit count for the second half of the year	CIRB-based permitted unit estimates based on full-year mechanical permits	Combined estimate of residential HVAC changeouts
Laguna Beach		52	9	33	0	85
Laguna Hills	96	56	16	36	1	92
Laguna Niguel	58	106	9	68	0	174
Laguna Woods		60	7	36	0	96
Lake Forest	220	144	116	86	20	230
Los Alamitos	20	20	19	12	1	32
Mission Viejo	65	234	196	140	1	374
Newport Beach	285	127	17	81	1	208
Orange	12	192	120	115	1	307
Orange County Unincorporated	215	125	100	75	0	200
Placentia	85	75	74	45	0	120
Rancho Santa Margarita	66	82	51	49	36	131
San Clemente	71	49	5	31	0	80
San Juan Capistrano		42	2	25	48	67
Santa Ana	170	153	153	70	23	223
Seal Beach	71	23	23	7	43	30
Stanton	3	15	9	9	33	24
Tustin		87	53	52	30	139
Villa Park	26	18	5	11	0	29
Westminster	65	60	23	38	0	98
Yorba Linda	12	186	119	111	0	297
Auburn	20	182	62	122	39	184
Colfax	4	3	3	0	0	3
Lincoln	213	212	139	142	0	281
Loomis	43	43	43	29	0	72
Placer County Unincorporated	265	520	520	287	19	807
Rocklin	276	314	271	210	25	481
Roseville	43	606	528	406	458	934
Plumas County Unincorporated	15	7	7	5	0	12
Portola		1	1	0	0	1
Banning		92	22	55	46	77
Beaumont	59	17	16	10	0	26
Blythe	3	28	28	2	15	30
Calimesa	7	3	3	2	6	5
Canyon Lake	20	39	39	22	41	61

Building Department City	CIRB-based permitted unit count for the full year	HERS-based permitted unit count for the first half of the year	CIRB-based permitted unit estimate for the first half of the year	HERS-based permitted unit count for the second half of the year	CIRB-based permitted unit estimates based on full-year mechanical permits	Combined estimate of residential HVAC changeouts
Cathedral City	511	323	323	106	159	429
Coachella	9	77	77	3	0	80
Corona	328	289	237	173	0	410
Desert Hot Springs		78	78	42	0	120
Eastvale	25	20	20	10	1	30
Hemet	117	124	117	74	0	191
Indian Wells	132	119	110	71	0	181
Indio	277	166	166	89	0	255
Jurupa Valley	131	90	68	54	1	122
La Quinta	293	322	322	158	0	480
Lake Elsinore	43	82	62	49	126	111
Menifee	197	212	176	127	0	303
Moreno Valley	294	288	255	172	0	427
Murrieta	29	197	182	118	57	300
Norco	56	55	41	33	0	74
Palm Desert	576	574	507	343	0	850
Palm Springs	300	446	446	196	135	642
Perris	53	53	53	27	0	80
Rancho Mirage	319	284	284	144	0	428
Riverside	2121	422	363	252	0	615
Riverside County Unincorporated		352	352	187	0	539
San Jacinto	49	47	36	28	0	64
Temecula		223	144	133	0	277
Wildomar	31	37	27	22	1	49
Citrus Heights		728	442	479	0	921
Elk Grove	433	594	536	391	3	927
Folsom	419	425	381	280	22	661
Galt	83	84	76	55	0	131
Isleton	1	2	1	1	0	2
Rancho Cordova		363	299	239	0	538
Sacramento	1552	2121	2121	1337	0	3458
Sacramento County Unincorporated	3	2910	2910	1902	0	4812
Hollister	2	3	2	2	22	5
San Benito County Unincorporated	6	2	0	1	0	3
San Juan Bautista	0	0	0	0	0	0

Building Department City	CIRB-based permitted unit count for the full year	HERS-based permitted unit count for the first half of the year	CIRB-based permitted unit estimate for the first half of the year	HERS-based permitted unit count for the second half of the year	CIRB-based permitted unit estimates based on full-year mechanical permits	Combined estimate of residential HVAC changeouts
Adelanto	152	139	98	83	0	181
Apple Valley		339	339	126	0	465
Barstow	17	16	16	8	4	24
Big Bear Lake	18	6	5	4	0	9
Chino		87	55	52	0	107
Chino Hills	140	122	96	73	1	169
Colton	11	45	42	27	0	69
Fontana	297	157	142	94	0	236
Grand Terrace	21	18	15	11	0	26
Hesperia	401	311	311	147	0	458
Highland		213	213	46	0	259
Loma Linda	29	15	13	9	16	22
Montclair	43	50	44	30	0	74
Needles	1	0	0	0	0	1
Ontario		264	264	99	0	363
Rancho Cucamonga	243	167	160	100	0	260
Redlands		144	82	86	0	168
Rialto		192	121	115	0	236
San Bernardino	411	197	151	118	0	269
San Bernardino County Unincorporated	310	180	180	87	4	267
Twenty-nine Palms	57	16	16	8	48	24
Upland	120	132	107	79	0	186
Victorville	299	328	328	164	0	492
Yucaipa	9	55	43	33	0	76
Yucca Valley	9	37	37	7	55	44
Carlsbad		213	16	136	0	349
Chula Vista	322	144	77	92	0	236
Coronado	227	16	2	10	42	26
Del Mar	26	0	0	0	54	26
El Cajon	168	241	110	144	0	254
Encinitas		125	5	80	221	205
Escondido	357	341	236	204	0	440
Imperial Beach	5	3	2	2	28	5
La Mesa	126	114	27	73	0	187
Lemon Grove	2	60	11	38	11	98
National City		19	18	12	0	31

Building Department City	CIRB-based permitted unit count for the full year	HERS-based permitted unit count for the first half of the year	CIRB-based permitted unit estimate for the first half of the year	HERS-based permitted unit count for the second half of the year	CIRB-based permitted unit estimates based on full-year mechanical permits	Combined estimate of residential HVAC changeouts
Oceanside	265	169	58	108	1	277
Poway	176	169	134	101	189	235
San Diego	161	1554	432	992	100	2546
San Diego County Unincorporated		694	431	415	0	846
San Marcos	160	174	152	104	0	256
Santee		107	99	64	164	163
Solana Beach	50	41	7	26	94	67
Vista		116	54	74	0	190
San Francisco	9	45	7	29	13	74
Escalon	9	74	9	49	1	58
Lathrop	10	22	22	12	0	34
Lodi	277	276	255	182	0	437
Manteca	180	204	166	134	2	300
Ripon	18	65	65	40	16	105
San Joaquin County Unincorporated	241	236	236	145	0	381
Stockton	421	577	559	380	0	939
Tracy	214	234	192	154	1	346
Arroyo Grande	26	9	0	6	0	15
Atascadero	18	9	0	6	0	15
Grover Beach	10	0	0	0	0	10
Morro Bay	6	0	0	0	1	6
Paso Robles		14	0	9	0	23
Pismo Beach		9	0	6	0	15
San Luis Obispo		11	1	7	0	18
San Luis Obispo County Unincorporated	60	29	2	19	0	48
Atherton	5	19	1	12	3	31
Belmont	40	19	2	12	2	31
Brisbane	1	2	0	1	0	3
Burlingame	16	16	7	10	15	26
Colma	1	0	0	0	0	1
Daly City	7	9	2	6	0	15
East Palo Alto	10	0	0	0	0	10
Foster City	49	14	3	9	1	23
Half Moon Bay	10	2	0	1	0	3
Hillsborough	10	9	2	6	0	15

Building Department City	CIRB-based permitted unit count for the full year	HERS-based permitted unit count for the first half of the year	CIRB-based permitted unit estimate for the first half of the year	HERS-based permitted unit count for the second half of the year	CIRB-based permitted unit estimates based on full-year mechanical permits	Combined estimate of residential HVAC changeouts
Menlo Park	52	38	8	24	0	62
Millbrae	3	6	1	4	5	10
Pacifica	6	6	2	4	0	10
Portola Valley	8	11	4	7	36	18
Redwood City	21	52	14	33	0	85
San Bruno	24	9	1	6	0	15
San Carlos	44	56	12	36	1	92
San Mateo	80	41	7	26	1	67
San Mateo County Unincorporated	75	19	8	12	0	31
South San Francisco	31	5	0	3	1	8
Woodside	11	0	0	0	0	11
Buellton	3	0	0	0	1	3
Carpinteria	8	6	0	4	0	10
Goleta		0	0	0	79	79
Guadalupe		2	0	1	0	3
Lompoc	15	0	0	0	0	15
Santa Barbara	1	44	7	28	4	72
Santa Barbara County Unincorporated	39	72	15	46	21	118
Santa Maria	43	16	0	10	36	26
Solvang		0	0	0	1	1
Campbell		77	7	51	0	128
Cupertino	130	68	13	45	18	113
Gilroy	30	17	1	11	0	28
Los Altos	11	74	8	49	57	123
Los Altos Hills		21	2	14	0	35
Los Gatos	126	52	11	34	0	86
Milpitas	61	44	18	29	1	73
Monte Sereno		3	0	2	0	5
Morgan Hill	60	36	6	24	0	60
Mountain View	10	56	11	37	0	93
Palo Alto		35	11	23	16	58
San Jose		685	188	451	0	1136
Santa Clara		91	25	60	0	151
Santa Clara County Unincorporated	70	62	18	41	2	103
Saratoga	87	53	8	35	1	88

Building Department City	CIRB-based permitted unit count for the full year	HERS-based permitted unit count for the first half of the year	CIRB-based permitted unit estimate for the first half of the year	HERS-based permitted unit count for the second half of the year	CIRB-based permitted unit estimates based on full-year mechanical permits	Combined estimate of residential HVAC changeouts
Sunnyvale	272	114	22	75	0	189
Capitola	31	17	0	11	0	28
Santa Cruz	5	19	3	12	22	31
Santa Cruz County Unincorporated	46	33	4	21	4	54
Scotts Valley		8	1	5	0	13
Watsonville	16	5	1	3	0	8
Anderson	46	42	30	28	0	58
Redding	595	497	295	333	0	628
Shasta County Unincorporated		139	116	93	0	209
Shasta Lake	43	37	22	25	0	47
Loyalton		0	0	0	0	0
Sierra County Unincorporated		1	1	0	0	1
Dorris		0	0	0	0	0
Dunsmuir	3	2	2	1	0	3
Etna		0	0	0	0	0
Fort Jones		0	0	0	0	0
Montague		0	0	0	0	0
Mount Shasta	1	1	0	1	0	1
Siskiyou County Unincorporated	20	1	1	1	11	2
Tule lake		0	0	0	0	0
Weed		0	0	0	0	0
Yreka		1	0	1	0	1
Benicia	106	105	105	56	1	161
Dixon	58	62	62	27	1	89
Fairfield	127	210	210	128	3	338
Rio Vista	16	24	24	12	12	36
Solano County Unincorporated	33	22	22	12	4	34
Suisun City		60	60	34	0	94
Vacaville	322	265	265	170	3	435
Vallejo	107	123	123	67	13	190
Cloverdale	20	15	11	10	0	21
Cotati	17	14	14	8	0	22
Healdsburg	48	52	52	30	0	82

Building Department City	CIRB-based permitted unit count for the full year	HERS-based permitted unit count for the first half of the year	CIRB-based permitted unit estimate for the first half of the year	HERS-based permitted unit count for the second half of the year	CIRB-based permitted unit estimates based on full-year mechanical permits	Combined estimate of residential HVAC changeouts
Petaluma	149	146	146	79	0	225
Rohnert Park	68	63	63	35	1	98
Santa Rosa	708	458	458	228	0	686
Sebastopol	27	36	29	24	1	53
Sonoma		52	47	35	0	82
Sonoma County Unincorporated	279	296	296	118	1	414
Windsor	78	87	87	37	0	124
Ceres	55	64	57	42	7	99
Hughson	11	12	12	6	0	18
Modesto	682	545	514	359	0	873
Newman	22	26	9	17	0	26
Oakdale	54	47	43	31	0	74
Patterson	21	59	59	18	0	77
Riverbank	35	96	96	17	1	113
Stanislaus County Unincorporated	96	153	153	55	0	208
Turlock		244	244	51	0	295
Waterford	18	14	14	9	0	23
Live Oak	14	15	14	10	0	24
Sutter County Unincorporated	31	60	51	40	0	91
Yuba City	103	187	187	118	90	305
Corning	23	14	14	4	0	18
Red Bluff	71	46	45	31	0	76
Tehama	0	0	0	0	0	0
Tehama County Unincorporated	83	79	79	47	1	126
Trinity County Unincorporated	61	16	16	3	0	19
Dinuba	22	29	25	19	12	44
Exeter	13	17	5	11	0	16
Farmersville	10	6	4	4	0	8
Lindsay	9	14	14	0	0	14
Porterville	107	132	132	86	0	218
Tulare	70	65	65	43	0	108
Tulare County Unincorporated	138	128	128	68	1	196

Building Department City	CIRB-based permitted unit count for the full year	HERS-based permitted unit count for the first half of the year	CIRB-based permitted unit estimate for the first half of the year	HERS-based permitted unit count for the second half of the year	CIRB-based permitted unit estimates based on full-year mechanical permits	Combined estimate of residential HVAC changeouts
Visalia	290	281	209	185	0	394
Woodlake	6	5	5	1	0	6
Sonora	5	17	8	11	0	19
Tuolumne County Unincorporated	8	43	19	29	28	48
Camarillo		171	19	109	0	280
Fillmore	25	12	8	7	0	15
Moorpark	90	89	89	49	0	138
Ojai	19	31	31	18	0	49
Oxnard		66	6	42	0	108
Port Hueneme		8	1	5	0	13
San Buenaventura	134	94	4	60	0	154
Santa Paula	1	26	26	14	0	40
Simi Valley	14	226	211	135	130	346
Thousand Oaks		458	458	266	0	724
Ventura County Unincorporated	221	161	108	96	0	204
Davis	75	375	326	247	273	573
West Sacramento	233	255	255	99	1	354
Winters	2	18	16	12	16	28
Woodland	100	170	170	86	58	256
Yolo County Unincorporated	49	62	32	41	0	73
Marysville	0	88	88	34	0	122
Wheatland	16	13	13	7	0	20
Yuba County Unincorporated	92	72	72	44	0	116

APPENDIX E. MAPC ONLINE SCREENER SURVEY INSTRUMENT

The following pdf file contains the survey.

MAPC Online Survey Instrument.pdf

APPENDIX F. DEMOGRAPHIC COMPARISON OF MAPC SAMPLE FRAME TO RESPONDENTS

MAPC Sample Frame	Matches the Sample Frame as outlined in Section 3 of Volume I (main report)
MAPC Respondents	Screener Survey completed
Have Changeout	Completed screener and changeout that triggered permit
Onsite Visit	Wider net than previous two columns, includes all that were in sample frame, and households that did and did not complete screener survey.

Figure 30. Summary comparison of household characteristics

Characteristic	MAPC Sample Frame (n=16,526)	MAPC Respondents (n=1,461)	Have Changeout (n=324)	Onsite Visit (n=172)
Average Income	$79,430	$84,067	$78,903	$93,127
Average Square Footage of Home	1,763	1,851	1,858	1,869
Average Age of Home	32	30	32	36
Average Number of Residents	2.9	2.8	2.9	2.3
Percent Own Home	77%	87%	94%	98%

Figure 31. Comparison of Households/respondents by primary language

Primary Language	MAPC Sample Frame (n=16,526)	MAPC Respondents (n=1,461)	Have Changeout (n=324)	Onsite Visit (n=172)
Asian	5%	3%	1%	1%
English	84%	88%	93%	97%
Spanish	6%	5%	3%	0%
Other	2%	2%	2%	0%
No Response	4%	3%	0%	1%

Figure 32. Comparison of households/respondents by education

Education Level	MAPC Sample Frame (n=16,526)	MAPC Respondents (n=1,461)	Have Changeout (n=324)	Onsite Visit (n=172)
Grades 1-8	2%	1%	0%	0%
Grades 9 - 12	3%	2%	1%	1%
HS Graduate	9%	7%	6%	3%
Some College	26%	27%	22%	14%
College Graduate	31%	29%	33%	38%
Postgraduate Degree	23%	30%	33%	43%
No Response	5%	5%	5%	0%

Figure 33. Comparison of households/respondents by head-of-household ethnicity

Head-of-Household Ethnicity	MAPC Sample Frame (n=16,526)	MAPC Respondents (n=1,461)	Have Changeout (n=324)	Onsite Visit (n=172)
American Indian AK Native	1%	1%	1%	1%
Asian Pacific Islander	11%	8%	4%	4%
African American	4%	3%	1%	2%
Caucasian	58%	63%	68%	71%
Hispanic Latino	14%	14%	14%	15%
Mixed	2%	4%	1%	1%
Other	2%	3%	3%	2%
No Response	7%	5%	8%	5%

Figure 34. Comparison of households by average number of residents in age group

Age Groups	MAPC Sample Frame (n=16,378)	MAPC Respondents (n=1,454)	Have Changeout (n=322)	Onsite Visit (n=172)
Newborn to 18 years	0.8	0.7	0.7	0.4
19 to 64 years	1.7	1.7	1.5	1.3
65 years and older	0.4	0.4	0.7	0.6

Figure 35. Comparison of households by HVAC system maintenance response

HVAC System Maintenance Response	MAPC Sample Frame	MAPC Respondents	Have Changeout	Onsite Visit
Population and Sample for Heating Systems	16,443	1,458	322	172
Heating systems	30%	33%	39%	36%
Population and Sample for Cooling Systems	12,351	1,196	261	126
Cooling Systems	33%	36%	41%	37%

Note: Percent of respondents who answered, "Yes, Maintenance has been performed in the past 12 Months." For the sample frame, this was based on the response to the RASS.

APPENDIX G. BOTTOM-UP REPORTED CHANGEOUT RATE AND THE POSSIBILITY OF STRATEGIC NON-RESPONSE/MISREPORTING

In addition to typical concerns about demographic response bias, we were also concerned that the subject matter dealing with code compliance would bias the responses. We designed the survey to conceal our interest in permits in order to avoid, to the extent possible, underreporting of changeouts by those who had performed work without a permit. Despite our efforts, it is possible that homeowners with unpermitted work were less likely to respond, or responded but were dishonest in their answers related to unpermitted work.

To cast some light on the possibility of strategic response bias (both strategic non-response and strategic mis-reporting), we looked at the changeout rate implied by the MAPC survey. Based on the survey results, just over 20% of households had a changeout between the beginning of 2010 and the time of the survey (approximately six years).[8] In order for respondents misreporting that they had no changeout (whether strategically or accidentally) or strategic non-response to explain a significant portion of the difference between the top-down and the bottom-up permitting rate, the actual changeout rate in the survey sample would have had to be much higher than 20%.

To assess whether that was the case, we wanted to compare the reported changeout rate from the MAPC survey to an independent estimate of changeouts. We looked to the stock accounting we did for the top-down analysis (to estimate the denominator of the top-down permit rate) to estimate a statewide changeout rate. Making the comparison presented a number of challenges, including:

- Differences in the population represented (state for top-down, RASS population for bottom-up)
- The top-down analysis counted changeouts units while the bottom-up counted changeouts (a changeout may include multiple equipment units, such as a furnace and AC unit)
- Accounting for the households removed from the MAPC sample frame
- The extended time frame of the MAPC surveys (one year and four months)[9]

The top-down analysis produced the number of unit shipments rather than the number of changeouts. As previously discussed, households may replace multiple equipment units at the same time (for example an air conditioner and furnace), and this is only counted as one changeout. In order to compare the top-down results to the bottom-up changeouts, we had to convert our top-down shipments estimate into an estimate of changeouts by reducing the shipments to account for the additional unit(s) in joint replacements. We relied on the CIRB data on number of permits versus number of permitted units to estimate and subtract out the extra units.

Of households with eligible HVAC equipment (the MAPC sample frame from Volume I, Chapter 3 and APPENDIX F extrapolated to the entire state), the changeout rate over the 6 years was 59%. Due to the high level of uncertainty in the top-down estimate of total changeouts, we also calculated the changeout rate assuming that our estimate was too high by 20% (as discussed earlier in this section, we received comments suggesting that our estimate of total shipments is too high). With that change, we estimated 47% of homes with eligible equipment had a changeout over the 6-year period. Even using the more conservative

[8] Based on the weighted values from APPENDIX F, (number of respondents with verified and eligible changeouts divided by number of completed MAPC screener survey respondents).

[9] The MAPC survey asked about changes since January of 2010. The surveys were conducted between May 2015 through mid-September 2016. Depending on when each survey was done, the respondent was reporting changeouts over a period ranging from 5 years and 5 months to 6 years and 9 months. Because the top-down analysis was on a calendar year, we looked at shipments from the beginning of 2010 to the end of 2015 for the comparison.

48% estimate suggests that the MAPC survey under estimates changeouts by 58% (comparing the 48% changeout rate to the 20% changeout rate implied by the MAPC results). This makes a strong case that respondents under-reported changeouts over the period of interest, whether because they did not remember the work or were strategically omitting unpermitted work. Assuming the higher changeout rate reduces the permitting rate from 29% to 12%.

What are the implications of this finding? The analysis says more about what is happening than why it is happening. There are four possible explanations for the low reported rate of changeouts:

1. Stategic non-response. Households with unpermitted work declined to respond to the survey
2. Accidental mis-reporting. Survey respondents do not report changeouts either because they do not remember (either the changeout or the date of the changeout) or were not aware of the changeout (for example, due to resident turnover)
3. Strategic mis-reporting. Survey respondents with unpermitted work do not report the unpermitted changeout
4. Sample bias. The characteristics of the respondents could result in a lower rate of changeouts than the population

The initial idea behind the analysis was to disprove the possibility of strategic non-response. If we had found that the changeout rate from the top-down analysis were the same as the rate of changeouts from the MAPC survey, it would have ruled out strategic non-response. Since the MAPC survey underestimates, strategic non-response remains a possibility (but not a certainty).

Accidental mis-reporting seems highly likely to be a factor in the low reported rate of changeouts. The survey relies on respondents accurately reporting work done up to 6 and a half years previously. Even if the respondent has been in the home for the full period of interest, he or she may not recall work that was done, or may not include it because they misremember the date. If the respondent was not present in the home for the full period of interest, they may be unaware of changeouts done prior to their occupancy.

Strategic mis-reporting, like strategic non-response, remains a possibility, but not a certainty.

Number 4 seems unlikely, since the household characteristics skew toward more home ownership and higher education, which seem unlikely to result in lower changeouts.

Of the four possible explanations, strategic non-response and strategic mis-reporting would lead to an overestimate of the permit rate. The omission of these changeouts decrease the denominator in the permit rate calculation, while the permit count stays the same.

Accidental mis-reporting, if proportional across all changeouts, permitted and unpermitted, would not introduce bias into the permit rate estimate. However, due to sample bias, that may not be the case. The differential turnover rates between renters and homeowners, combined with the overrepresentation of homeowners among respondents, open the possibility of bias in the permit rate. However, it is unknown which group is more likely to pull a permit: owner/residents or owners of rental units. While there may be a systematic distortion, we do not know the direction or magnitude.

APPENDIX H. LOGIT MODELING DETAILED RESULTS

This Appendix provides all fitness tests and modeling results developed for the report in Section 4.2.

Figure 36. Logit Model Fitness Tests

	Correlations and significance			
	Implementing permitted HVAC changeouts		Implementing HVAC changeouts	
Independent variables	Spearman's Rho	pval	Spearman's Rho	pval
% in HH between 18 and 64	(0.04)	0.49	(0.05)	0.08
Ethnicity or Language = Asian	(0.06)	0.30	(0.05)	0.08
Coastal	0.08	0.14	0.02	0.44
Education=High school or less	(0.11)	0.05	0.00	0.96
Education= PG and above	0.07	0.22	0.00	0.93
Ethnicity=African American	0.00	0.94	(0.03)	0.27
Ethnicity=Asian	(0.06)	0.30	(0.04)	0.10
Ethnicity=Caucasian	0.04	0.51	0.00	1.00
Ethnicity=Latino	0.04	0.41	0.01	0.68
Ethnicity=Other	(0.04)	0.46	0.01	0.66
Fuel type = Electric	0.11	0.04	0.05	0.08
Fuel type=Natural Gas	(0.10)	0.05	0.02	0.35
Fuel type=other	0.02	0.77	(0.06)	0.02
Binary dummy =1 if > 33% of HH > > 64 (high proportion of seniors in HH)	0.05	0.33	0.08	0.00
Binary dummy =1 if > 75% of HH > 19 or > 64 (high proportion of young and/or old in HH)	(0.02)	0.67	0.05	0.07

HH size > 2	0.02	0.78	(0.03)	0.26
Binary dummy =1 if homes built 1977 or earlier	(0.05)	0.35	0.07	0.01
Ethnicity=Asian	0.03	0.52	(0.04)	0.09
Language=English	(0.02)	0.72	0.02	0.47
Language=Other	(0.08)	0.13	0.03	0.27
Language=Spanish	0.03	0.59	0.02	0.35
Region=Central inland	0.09	0.10	(0.03)	0.30
Region=North Coast	0.03	0.55	(0.05)	0.05
Region=North Inland	(0.05)	0.34	(0.02)	0.55
Region=South Coast	0.08	0.14	0.02	0.44
Region=South Inland	(0.13)	0.02	0.04	0.10
Education, ordinal	0.11	0.04	0.01	0.64
Home age, ordinal	(0.02)	0.67	0.10	0.00
Income, ordinal	0.04	0.51	(0.03)	0.30
% in HH over 64 years	0.04	0.43	0.08	0.00
Number of residents in household	(0.00)	0.96	(0.00)	0.87
Own vs rent	0.04	0.45	0.08	0.00
% in HH under 19 years	0.01	0.81	(0.05)	0.08

Figure 37. Odds Ratio Analysis

Logit model - PERMIT

Odds Ratio Estimates				
Effect	Point Estimate	95% Wald Confidence Limits		We can interpret the odds ratio as follows: for a one unit change in the predictor variable, the odds ratio for a positive outcome is expected to change by the respective coefficient, given the other variables in the model are held constant. The CI is equivalent to the **Chi-Square** test statistic: if the CI includes one, we'd fail to reject the null hypothesis that a particular regression coefficient equals zero and the odds ratio equals one, given the other predictors are in the model.
Coastal	1.47	0.84	2.58	
Fuel type - Electric	0.55	0.05	5.63	
Fuel type - Natural Gas	0.23	0.03	1.93	
Fuel type - Other	0.29	0.03	2.95	
Education level - High scho	0.36	0.12	1.10	
Home owner	1.60	0.46	5.57	All the CI for the Odds ratio include one. We fail to reject the null that these reg coeffs are equal to zero.
Homes built in 1977 or earlie	0.77	0.47	1.27	
Homes with over 1/3rd of re	1.22	0.73	2.05	
Asian Ethnicity or Language	0.49	0.14	1.77	

Hosmer and Lemeshow Goodness-of-Fit Test			
Chi-Square	DF	Pr > Chi Sq	It tests the null hypothesis that there is no difference between the observed and predicted values of the response variable. Therefore, when the test is not significant, as in this example, we can not reject the null hypothesis and say that the model fits the data well.
7.6225	7	0.3671	**Not significant, model does NOT fit the data**

Model Fit Statistics			
Criterion	Intercept Only	Intercept and Covariates	
AIC	409.363	412.581	We want the intercepts and covariate model to have lower AIC. SC, and -2Log L
SC	413.212	451.075	This is not the case here
-2 Log L	407.363	392.581	Predictors are not adding explanatory power.

R-Square	0.0417	Max-rescaled R-Square	0.0604

Testing Global Null Hypothesis: BETA=0				
Test	Chi-Square	DF	Pr > ChiSq	
Likelihood Ratio	14.7812	9	0.0971	Chi-sq that at least one of the predictors are not equal to ZERO in the model.
Score	14.4238	9	0.108	In our Permit model ALL predictors are not significantly different from zero.
Wald	13.276	9	0.1505	

Figure 38. Logit Models

Logit model - HVAC

Model Fit Statistics			
Criterion	Intercept Only	Intercept and Covariates	
AIC	1598.916	1586.11	We want the intercepts and covariate model to have lower AIC. SC, and -2Log L
SC	1604.197	1638.91	This is marginally the case here for 2 out of 3 fit statistics
-2 Log L	1596.916	1566.11	Predictors are adding very little explanatory power.

R-Square	0.021	Max-rescaled R-Square	0.0315	Low pseudo - rsq

Testing Global Null Hypothesis: BETA=0				
Test	Chi-Square	DF	Pr > ChiSq	
Likelihood Ratio	30.8112	9	0.0003	Chi-sq that at least one of the predictors are not equal to ZERO in the model.
Score	29.3806	9	0.0006	In our HVAC model at least ONE predictor is significantly different from zero.
Wald	28.3932	9	0.0008	

Analysis of Maximum Likelihood Estimates					
Parameter	DF	Estimate	Standard Error	Wald Chi-Square	Pr > Chi Sq
Intercept	1	-1.7961	0.6358	7.9791	0.0047
Coastal	1	0.0729	0.1527	0.2279	0.6331
Fuel type - Electric	1	0.3225	0.6725	0.2299	0.6316
Fuel type - Natural Gas	1	-0.1471	0.5966	0.0608	0.8052
Fuel type - Other	1	-0.6358	0.641	0.9836	0.3213
Education level - High scho	1	0.0327	0.2193	0.0222	0.8816
Home owner	1	0.6711	0.2528	7.0468	0.0079
Homes built in 1977 or earlie	1	0.2441	0.1266	3.7168	0.0539
Homes with over 1/3rd of re	1	0.2757	0.1336	4.2612	0.039
Asian Ethnicity or Language	1	-0.4018	0.2702	2.2104	0.1371

Logit model - HVAC

Odds Ratio Estimates			
Effect	Point Estimate	95% Wald Confidence Limits	
Coastal	1.08	0.80	1.45
Fuel type - Electric	1.38	0.37	5.16
Fuel type - Natural Gas	0.86	0.27	2.78
Fuel type - Other	0.53	0.15	1.86
Education level - High scho	1.03	0.67	1.59
Home owner	1.96	1.19	3.21
Homes built in 1977 or earlie	1.28	1.00	1.64
Homes with over 1/3rd of re	1.32	1.01	1.71
Asian Ethnicity or Language	0.67	0.39	1.14

Odds higher for HVAC changeout for owners and homes with older residents and older homes

Hosmer and Lemeshow Goodness-of-Fit Test		
Chi-Square	DF	Pr > Chi Sq
6.8471	7	0.445

It tests the null hypothesis that there is no difference between the observed and predicted values of the response variable. Therefore, when the test is not significant, as in this example, we can not reject the

Not significant, model does NOT fit the data

APPENDIX I. DETAILED RESULTS: ENERGY EFFICIENCY OF RESIDENTIAL HVAC CHANGEOUTS

Figure 39. Residential HVAC changeout compliance requirement details

Compliance Requirement	Code Details	2008 Threshold	2013 Threshold
Minimum Efficiency	HVAC equipment must be certified by the manufacturer to meet specific efficiency requirements. (Section 112).	SEER 13, AFUE 78, or HSPF 7.7	SEER 14, AFUE 78, or HSPF 8.0 for packaged units, HSPF 8.2 for all split systems.
Programmable Thermostat	All unitary heating and/or cooling systems that are not controlled by a central energy management control system shall have a setback thermostat.	Yes/No	Yes/No
Load Calculations	Building cooling and heating loads - must be calculated in accordance with ASHRAE Handbook, SMACNA Res. Manual, or ACCA Manual J. The cooling and heating loads are two of the criteria that shall be used for equipment sizing and selection.	Yes/No (no sizing requirement based on loads in 2008 code)	Yes/No (no sizing requirement based on loads in 2013 code)
Duct insulation	Unless ducts are enclosed entirely in conditioned space, the minimum allowed duct insulation value is R-4.2.	R-4.2	R-4.2
Refrigerant Line Insulation	Section 150(j)2 –cooling system lines shall be thermally insulated with minimum thickness as calculated by Equation 150-A.	Yes/No	Yes/No
Refrigerant Charge	Proper refrigerant charge must be confirmed through field verification (HERS) and diagnostic testing in accordance with Reference Residential Appendix RA3.2 or have a Charge Indicator Display.	Diagnostic within tolerance of target. CZ 2 and CZs 8-15. Dependent on scope.	Diagnostic within tolerance of target. CZ 2, and CZs 8-15. Dependent on scope.
Airflow	Completely new (equipment, ducts, etc.) air cooling system fans must maintain airflow greater than 350 cfm per nominal ton of cooling capacity.	350 cfm per ton. CZs 10-15. Dependent on scope.	350 cfm per ton. All CZs. Dependent on scope.
Fan power index	Completely new (equipment, ducts, etc.) air cooling must have a supply fan power index of less than 0.58 W per measured cfm. (The above limitation clause applies to this requirement.)	0.58 W/cfm. CZs 10-15. Dependent on scope	0.58 W/cfm. CZs 10-15. Dependent on scope
Measurement Access (Part of Refrigerant Charge)	TMAH are used for temperature measurement (for the refrigerant charge protocol).	Yes/No	Yes/No
Probe or Hole for Static Pressure Meas.		N/A	Yes/No
Additional Duct insulation	Depending on Climate Zone, duct insulation must have a minimum R-value from 4.2 to 8.0.	R-value	R-value

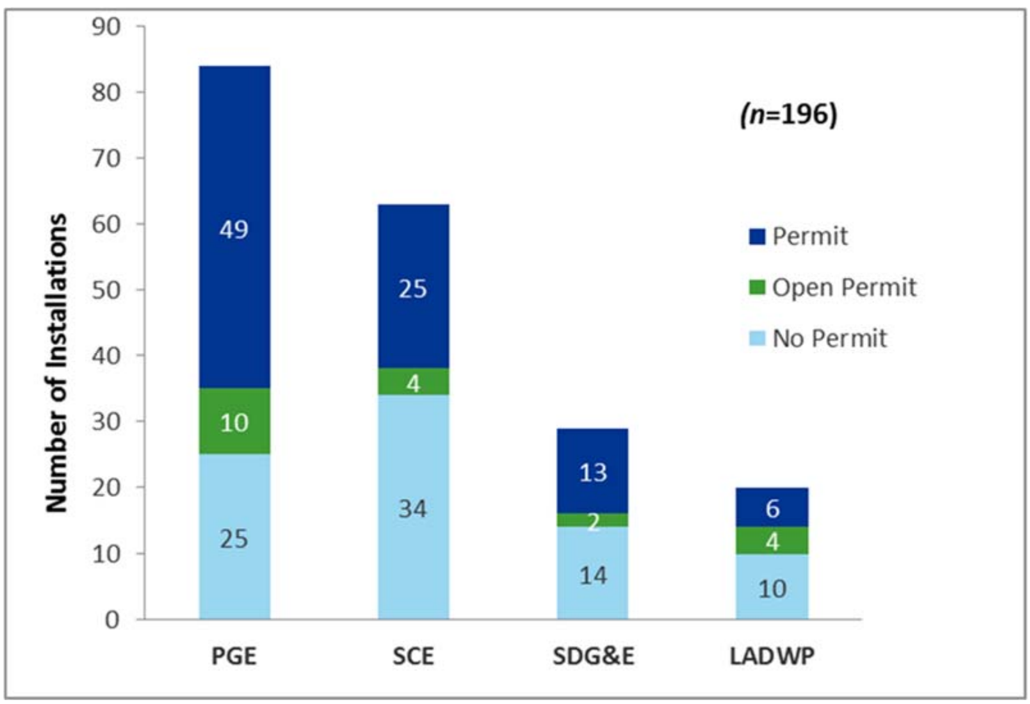
Compliance Requirement	Code Details	2008 Threshold	2013 Threshold
Duct Leakage	When a space-conditioning system is altered by the installation or replacement of space-conditioning equipment the duct system that is connected to the new or replacement space-conditioning equipment shall be sealed, as confirmed through field verification and diagnostic testing. Section 152(b)E	6% total leakage (new ducts), 15% total leakage (existing), or 10% leakage to outside, or 60% improvement, or smoke test. Dependent on scope. CZs 2, 9-16.	6% total leakage (new ducts), 15% total leakage (existing), or 10% leakage to outside. Dependent on scope. All CZ's.

Permit status by utility

Figure 40. Sample distribution by electric utility service, compares the number of permits that occurred in each of the four utility service territories. The sample with the highest permit rate is in the PG&E service territory and the lowest is in the SCE service territory. There were no statistically meaningful differences in permit status by utility service provider in the sampled sites.

A total of 68 unique jurisdictions were represented among the 196 sites. Several *county* jurisdictions in Southern California contained multiple installations, but none of the jurisdictions (all types) with multiple installations had more than 10, and the average was 3.6 installations. The jurisdiction counts by utility are: PG&E 25 jurisdictions, SCE/SCG 34 jurisdictions, SDG&E 7 jurisdictions, and LADWP/SCG contained 2 jurisdictions.

Figure 40. Sample distribution by electric utility service



The sample of installations in Los Angeles Department of Water and Power territory also received gas service from SCG.

Requirement-level results

Requirement-level results are presented in one table per requirement. The final requirement-level compliance rates ranged from 0% to 100% for each requirement, but there is no overall compliance rate across requirements. If there was any uncertainty about which requirements applied to a changeout site the study team generally tested for all requirements. Therefore, the study has collected additional data that may inform energy efficiency program planning and future work papers that are beyond the scope of code compliance.

Figure 41 compares compliance with the unit minimum-efficiency requirement by permit status: no permit, open permit, and final permit. All changeouts met the unit minimum efficiency requirement. This is what would be expected; unit minimum efficiency standards are set by the US Department of Energy and must be met by manufacturers. New sales are required to meet these minimum efficiencies. This requirement is a yes/no determination.

Figure 41. Minimum efficiency requirement by permit status

	Permit Status	Met Requirement?		Total
		Yes	No	
Minimum Efficiency	No permit	83	-	**83**
	Open permit	20	-	**20**
	Permit	93	-	**93**
	Total	**196**	-	**196**

Mandatory, all CZs, efficiency thresholds as follows: SEER 13.0 pre-2015, 14.0 post Jan. 1, 2015, HSPF 7.7 pre-2015, 8.0 for packaged and 8.2 for split systems post Jan. 1, 2015, and AFUE 0.78

Figure 42Figure 41 compares the presence of programmable thermostats by permit status. The requirement states that all unitary heating and/or cooling systems that are not controlled by a central energy management control system must have a setback thermostat (a clock mechanism that allows the building occupant to program operation for at least 24 hours). This requirement applies to all CZs. Not all thermostats met the requirement although they may have at the original time of changeouts.

Figure 42. Programmable thermostat requirement by permit status

	Permit Status	Met Requirement?		Total
		Yes	No	
Programmable Thermostat	No permit	57	24	**81**
	Open permit	15	1	**16**
	Permit	78	12	**90**
	Total	**150**	**37**	**187**

Mandatory, all CZs, threshold yes or no. All categories included regardless of size for completeness and consistency

Figure 43 compares the duct insulation requirement by permit status. The requirement states that there must be insulation wrapped around ducting units unless ducts are enclosed entirely in conditioned space. The minimum allowed duct insulation value is R-4.2 and is applicable to all climate zones. Under the 2013 Standard the minimum duct insulation increased from R-4.2 to R-6.0 in CZ 6-8. A total of 88% (56 out of 64) of the changeouts met the requirement.

Figure 43. Duct insulation requirement by permit status

	Permit Status	Meet Requirement?		Total
		Yes	No	
Duct Insulation	No permit	57	0	**57**
	Open permit	15	0	**15**
	Permit	79	0	**79**
	Total	**151**	**0**	**151**

Mandatory, All Climate Zones, threshold R-4.2 Packaged units and heat-only systems are exempt from this requirement, so this requirement is applicable only to 104 units.

Figure 44 compares refrigerant-line insulation by permit status. Refrigerant lines in unconditioned space must be insulated. Nearly all changeouts where refrigerant lines could be observed on split systems had refrigerant-line insulation. Packaged units and heat-only systems are exempt from this requirement, so this requirement is applicable only to 104 units.

Figure 44. Refrigerant-line insulation requirement by permit status

	Permit Status	Met Requirement?		Total
		Yes	No	
Refrigerant-Line Insulation	No permit	36	0	**36**
	Open permit	10	1	**11**
	Permit	53	4	**57**
	Total	**99**	**5**	**104**

Mandatory, all CZs, threshold: Insulation thickness based on pipe diameter

Figure 45 compares refrigerant charge by permit status. The sample sizes were too small to be statistically significant. According to the Standards, for a system to comply it must have the proper refrigerant charge confirmed through HERS field verification and diagnostic testing in accordance with procedures set forth in the Reference Residential Appendix RA3.2, or the unit must be equipped with an approved charge indicator display. At the time of writing there are no approved charge indicator displays available on the market. HERS verification of refrigerant charge is required only in CZ 2 and CZs 8-15, and package systems are generally exempt from the requirement. The refrigerant-charge measurement protocols require that the system first be shown to have airflow of at least 300 cfm. We used subcool/superheat targets as specified in the Standards to determine compliance.

Figure 45. Refrigerant charge requirement by permit status

	Permit Status	Met Requirement?		Total
		Yes	No	
Refrigerant Charge	No permit	13	6	**19**
	Open permit	3	4	**7**
	Permit	22	13	**35**
	Total	**38**	**23**	**61**

Prescriptive, CZ 2, and CZs 8-15, diagnostic within tolerance of target

Figure 46 compares airflow-rate compliance by permit status. To comply with the Standards, when entirely new or replacement HVAC systems, including new/replacement duct systems, are installed, the system must be tested and confirmed through field verification to have airflow greater than 350 cfm per nominal ton of cooling capacity for CZs 10-15. This requirement does not apply to the much more common occurrence when only some of the HVAC components are new or replaced. This prescriptive requirement is mandatory under the 2013 code for completely new systems and new ducted systems in all climate zones.

Figure 46. Airflow requirement by permit status

	Permit Status	Met Requirement?		Total
		Yes	No	
Airflow	No permit	3	19	**22**
	Open permit	-	9	**9**
	Permit	10	29	**39**
	Total	**13**	**57**	**70**

Prescriptive, CZs 10-15, threshold 350 cfm per ton (system)

Figure 47 compares fan energy consumption (watt draw) by permit status. To comply with the Standards, when entirely new or replacement duct systems are installed, the system must be tested and confirmed through field verification to have an air-handler fan power index of less than 0.58 W per measured cfm for CZs 10-15. The requirement does not apply to the more common occurrence when the entire duct system is not new or replaced. In 2008 this was a prescriptive requirement; in 2013 it is a mandatory measure. The compliance rate is somewhat higher in the permitted changeouts (68%) than in the no-permit/open permit changeouts (59%).

Figure 47. Fan watt-draw requirement by permit status

	Permit Status	Met Requirement?		Total
		Yes	No	
Fan power index	No permit	13	8	**21**
	Open permit	4	4	**8**
	Permit	26	12	**38**
	Total	**43**	**24**	**67**

Prescriptive, CZs 10-15, <0.58 W/cfmcfm

Figure 48 compares the presence of TMAH (Temperature Measurement Access Holes) and PSPP (Permanent Static Pressure Probes), both of which are required in CZ 10-15. TMAH and PSPP in the plenum allow non-intrusive measurement of supply and return air temperature and humidity. Most changeouts (over eighty-five percent), where applicable, met this compliance requirement.

Figure 48. Measurement access requirement by permit status

	Permit Status	Met Requirement?		Total
		Yes	No	
Measurement Access	No permit	65	11	**76**
	Open permit	17	2	**19**
	Permit	75	13	**88**
	Total	**157**	**26**	**183**

Prescriptive, CZs 10-15, temperature, and pressure, threshold yes or no. Despite not being required an additional 52 units met this requirement.

Figure 49 compares the presence of additional duct insulation required by the Standards by permit status. Additional insulation is a prescriptive requirement for any new ducts that are more than 40 feet long installed in unconditioned space and in certain climate zones. For this measure, the permit sample sizes were too small (12 cases) and not statistically significant to extrapolate results. All ducts in *unconditioned* space must be insulated to at least R-4.2, and depending on the climate zone, more insulation may be required up to a maximum of R-8.0 in more extreme environments. As shown, all changeouts met the additional duct installation requirement regardless of the permit status.

Figure 49. Additional duct insulation requirement by permit status

	Permit Status	Met Requirement?		Total
		Yes	No	
Additional Duct Insulation	No permit	58	-	**58**
	Open permit	15	-	**15**
	Permit	78	-	**78**
	Total	**151**	**0**	**151**

Prescriptive, varies by CZ from 4.2 to 8.0, threshold R-value from 4.2 to 8.0

Figure 50 compares how often changeouts met the duct-leakage requirements by permit status. When an HVAC system is altered by the installation or replacement of components (including replacement of the air handler, outdoor condensing unit of a split system air conditioner or heat pump, cooling or heating coil, or the furnace heat exchanger), or at least 40 feet of ducting in unconditioned space are replaced, or the entire duct system is new/replaced, the duct system must be tested and confirmed through field verification to have no more air leakage than is allowed by the Standards. Compliance targets are 15 percent of nominal airflow total leakage, or 10 percent of nominal airflow leakage to outside the conditioned space, or 60 percent measured improvement, or compliance using smoke test and sealing all accessible leaks. The duct sealing requirement applies in climate zones 2 and 9-16. When duct sealing is required under the 2013 Standards, the requirement extends to all climate zones. Finally, the 60 percent measured improvement compliance path is not available under the 2013 Standards.

To determine if permit status affected duct leakage status, field inspectors first measured total leakage. Systems that exceeded the 15 percent total leakage target were then subjected to leakage-to-outside testing. The evaluation team did not have access to pre-installation leakage rates and so were unable to verify a 60 percent leakage reduction, and smoke tests were beyond the scope of the project. As a result, we only considered total-leakage rate and leakage-to-outside rate in determining compliance. While Figure 50 shows poor compliance across all permitting groups, it is possible that in some cases the duct sealing requirement was met through either a 60 percent reduction in leakage or a smoke test. The evaluation team did not attempt to obtain compliance documentation that would identify which duct sealing option was used.

Figure 50. Duct leakage requirement by permit status

	Permit Status	Met Requirement?		Total
		Yes	No	
Duct Leakage	No permit	30	34	**64**
	Open permit	11	5	**16**
	Permit	38	30	**68**
	Total	**79**	**69**	**148**

Adjusted for code cycles, 15% total leakage (changeout) or 6% total leakage (entire system replacement including ducts)

The next three figures, Figure 51, Figure 52, and Figure 53 display total pass/fail numbers for airflow, duct leakage, and fan watt draw, all by permit status.

Figure 51. Airflow by Permit Status

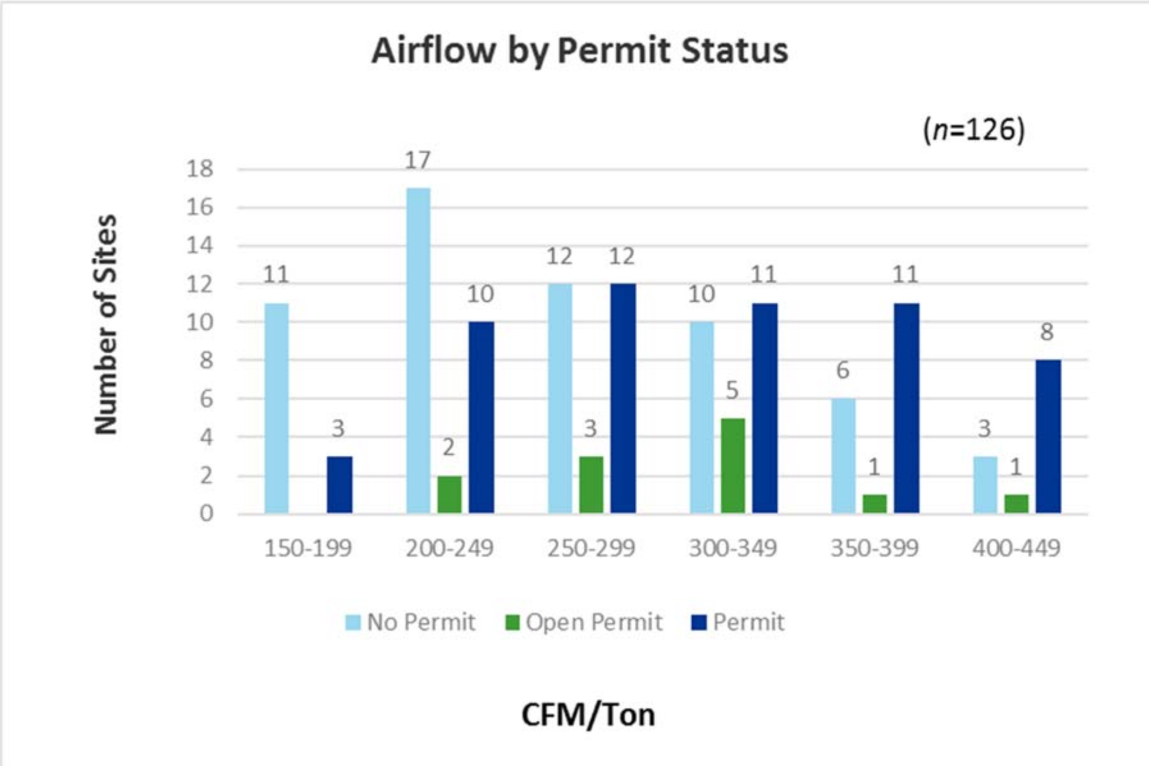


Figure 52. Duct Leakage Rates by Permit Status

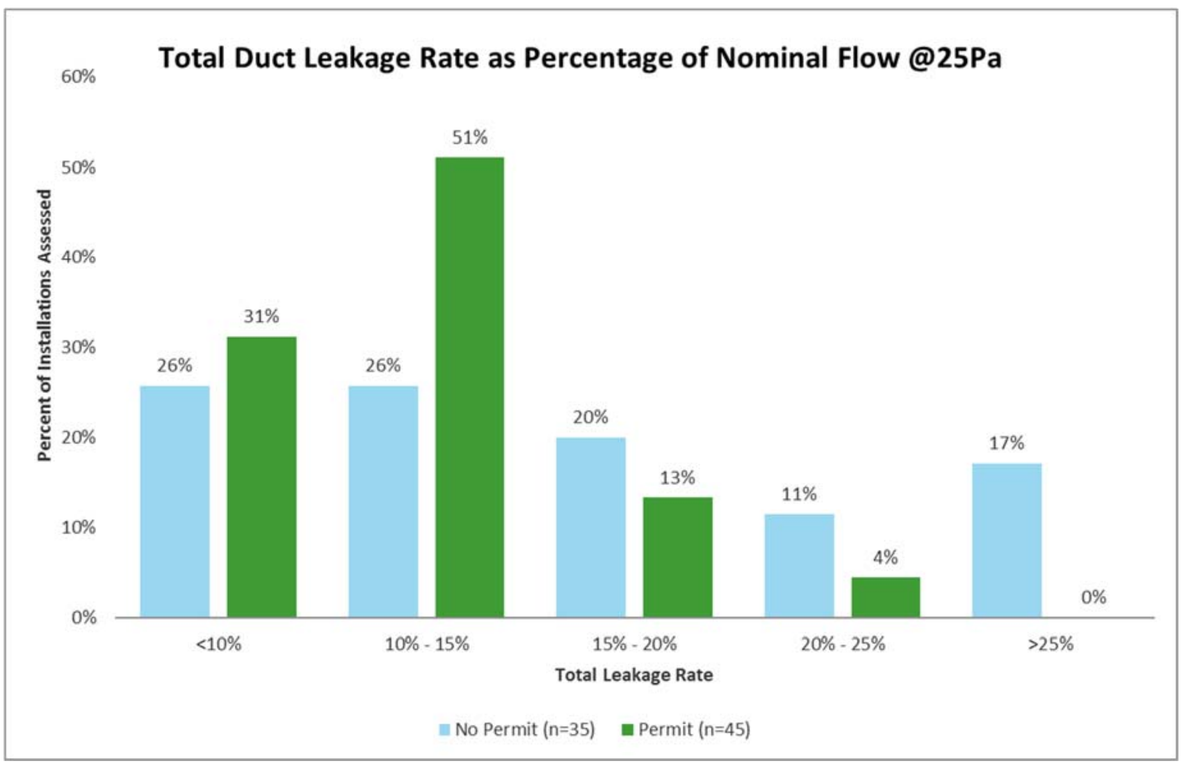


Figure 53. Fan Watt Draw by Permit Status

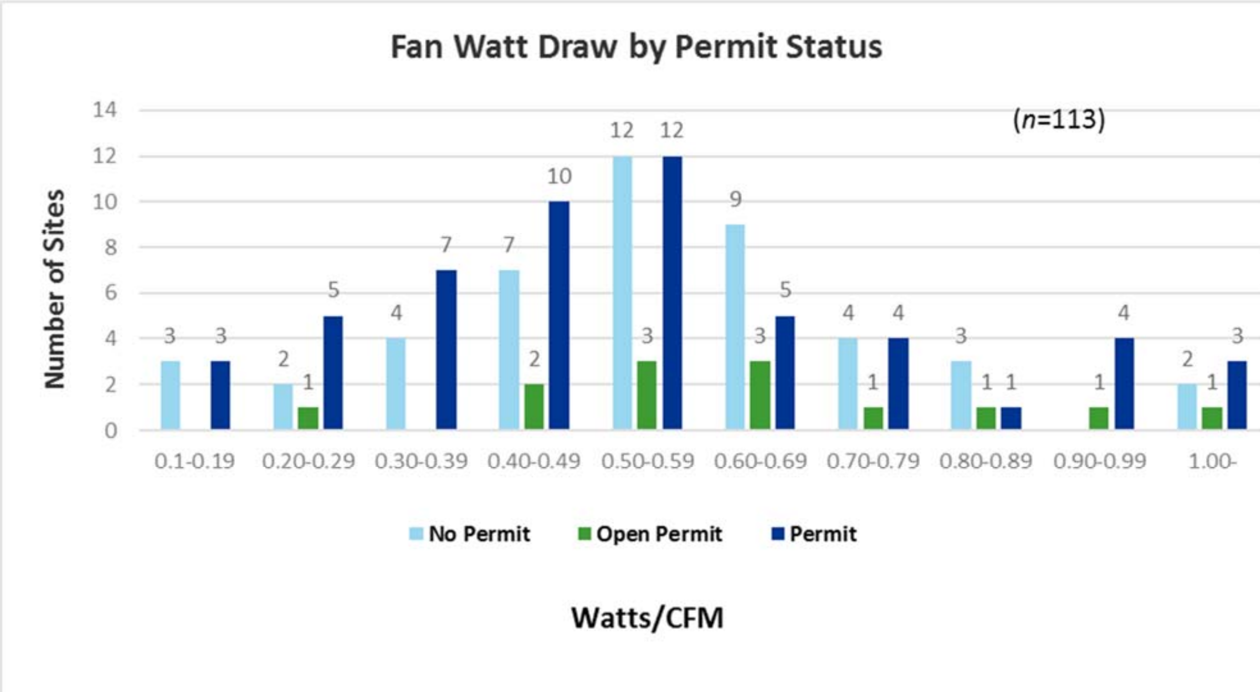
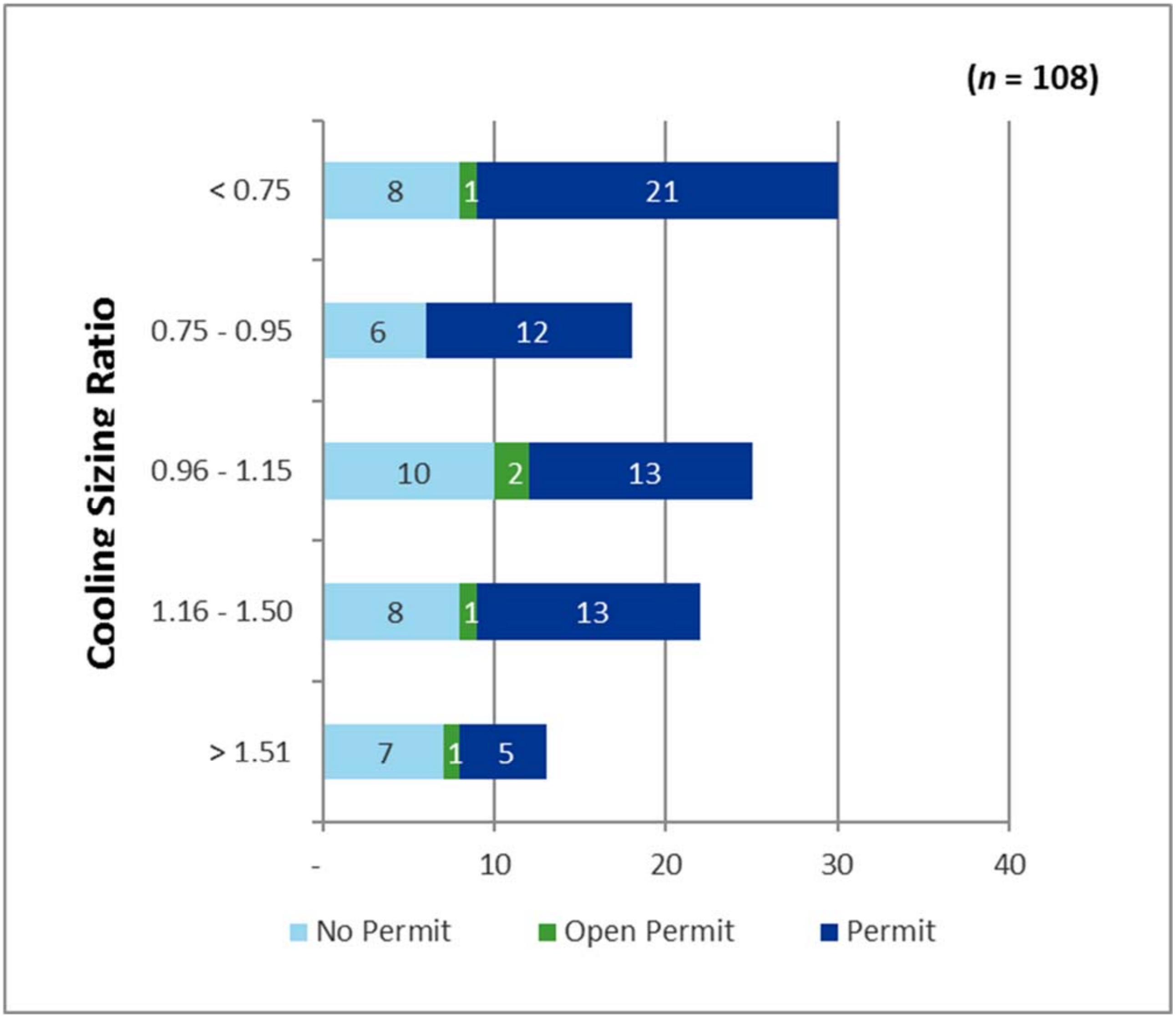


Figure 54 displays the cooling sizing ratio (the ratio of installed equipment cooling capacity to calculated cooling load) by permit status. A cooling size ratio greater than 1.0 means the equipment is oversized; a ratio less than 1.0 means the equipment is undersized for the cooling load. Load calculations were performed for 39 unpermitted sites, 5 sites with open permits, and 64 permitted sites.

Figure 54. Installed Equipment vs. Calculated Cooling Loads



APPENDIX J. METHODOLOGY FOR MEASURING COMPLIANCE

This appendix presents the methodology memo, results were published on 31 July 2016, and can be referenced here:
http://www.energydataweb.com/cpucFiles/pdaDocs/1346/HVAC6%20Memo%20on%20partial%20Compliance_31July2015-OUT.pdf

Objective: Determine Rate of Compliant Units

This memo is an addendum to the Research Plan for HVAC Permit and Code Compliance Market Assessment (HVAC 6) released on 2/25/2015. This memo presents the methods to determine partial compliance of HVAC changeouts to the requirements of the 2008 Title 24, Part 6 requirements. The scope of this memo is limited to methods of partial compliance. For further information on the studies objectives, scope, additional methods and timelines please refer to the research plan.[10]

The objective of this task is to investigate whether residential heating, ventilation, and air conditioning (HVAC) equipment replacements (changeouts) meet California's energy code requirements (Title 24, Part 6) and develop a method to assess compliance rates. Compliance rates will be compared between a permitted and non-permitted installation. It is assumed that the energy-related metrics for permitted changeouts result in greater energy savings than non-permitted changeouts. Furthermore, State and Federal building energy code programs declare that the success of energy saving through codes and standards initiatives depends not only on a stringent code but also on robust code enforcement to improve the level of compliance. And that effective code compliance and code enforcement helps achieve all intended energy savings, reduces operating costs, increases building resale value and provides a healthy built environment while minimizing environmental impact.[11]

While it may appear on the surface that compliance is a pass/fail determination, in reality, it is more complex. An HVAC unit changeout can be viewed as fully compliant, partially compliant, or fully non-compliant. Full compliance is indicated when all requirements are met, partial compliance when some are met but not all, applicable code compliance requirements are met, and fully non-compliant when none of the code requirements are met. Some provisions of the HVAC energy code can be verified as a simple "yes" or "no," while other provisions require performance or diagnostic measurements to determine if the installed units meet specified threshold values. This means that some requirements have degrees of compliance within them and cases exist above and below the minimum code threshold. The degree of compliance across different code requirements cannot be expressed as a simple average for a given site or sample because the energy efficiency impacts of the different requirements may vary.

A compliance evaluation refers to a set of processes and procedures where information is provided, assessed, and checked to determine whether mechanical systems effectively meet applicable energy code requirements. An HVAC changeout compliance assessment consists of onsite inspections and testing to determine if Title 24 mandatory and prescriptive requirements were met for the inspected units. This memo outlines the analysis and reporting structure proposed for estimating level of compliance of HVAC

[10] The final Research Plan is available at http://www.energydataweb.com/cpucFiles/pdaDocs/1239/HVAC%20WO6%20Final%20MAPC%20Research%20Plan_25Feb2015.pdf.

[11] Building Energy Code, Compliance https://www.energycodes.gov/compliance

changeouts based on the onsite inspections as described in the research plan[12]. This memo provides the proposed method and examples for residential code compliance analysis. The intent of this analysis is to inform CPUC planning and policy decisions. An addendum to the memo will add the tables for non-residential code compliance analysis which follows a similar methodology.

Scope Limitations

The study will address both types of HVAC changeout situations: altered space conditioning with mechanical cooling systems and entirely new or replacement space-conditioning systems (all HVAC equipment and ducts replaced). If the entirely new HVAC equipment includes an addition and/or renovation to an existing building, the dwelling will be excluded from the study. The study focuses on changeouts that do not include the possibility of a compliance trade-off approach, which applies to additions and new construction. Additionally, the code cycle will also be restricted to projects that complied with or should have complied with the 2008 Standards and will exclude projects permitted under the 2013 Standards or permitted under pre-2008 Standards. Researchers will exclude 2013 projects given small samples, the recent effective date of the current code and learning curve from both contractors and code officials to adopt the code.

The permit status will be independently verified by evaluators through a building department's public records request and a HERS registry certificate request. Many code requirements under the 2008 code were climate zone specific for changeouts therefore HERS certificates will only exist for certain equipment types in certain climatic zones. Researchers will assess compliance consistent with the Title-24 and HERS documentation on inspection and testing procedures and calculations of the metrics for measured requirements.

There are several types of variations that we do not currently know about the population, such as regional variation in enforcement and the frequency in which each requirement applies to a given replacement. In these calculations we continue to assume overall variation is higher than the variation for a specific mandatory or prescriptive requirement. The variation estimates used for sampling are based on the research team's experience and standard evaluation assumptions. The relative precision of the study's results may be different if the variation in the observed sample differs from the assumptions.

Residential Code Requirements

California Energy Code sets requirements that are dependent on the type of HVAC system components installed in existing buildings. These requirements for low-rise residential buildings are specified in sections 152(a) and (b) of the 2008 Standards. The requirements can be categorized into the following:

- HVAC changeouts in alterations to existing buildings (within study scope)
- HVAC changeouts in additions to existing buildings (out of study scope)

Mandatory requirements are requirements that must be met in every project no matter which compliance path is chosen. Prescriptive requirements are requirements that either must be met by every project, or if the requirement is not met, a trade-off must be made to "make up" for not meeting that requirement. Trade-offs are tightly defined by the building code, and the code allows trades to be made between various parts of the building. An example of an envelope trade-off might be that a building owner might choose to install more insulation in the roof to "make up" for putting in more window area than the code allows[13]. As described by the U.S. D.O.E., Building Energy Codes Program, compliance approach options are a: (a)

[12] http://www.energydataweb.com/cpucFiles/pdaDocs/1224/HVAC%20WO_06%20Draft%20Final%20MAPC%20Research%20Plan_23Jan2015.pdf

[13] DOE, Step 2. Choose a compliance path within the applicable energy code; https://www.energycodes.gov/resource-center/ace/compliance/step2

Performance approach—to use no more time dependent valuation energy from depletable sources than the energy budget, calculated or (b) Prescriptive approach—in accordance with all the applicable requirements.

Figure 55 and Figure 56 present the measures and metrics for prescriptive-level compliance. Figure 55 applies to complete system changeouts and Figure 56 applies to equipment only changeouts with no modifications to the ductwork. Duct-only replacements are not considered part of this study. Additional code details of the measures are provided in the research plan and have been excerpted to an appendix. Under column “DEER/CASE Energy Impact” a ‘Yes’ means the Energy Commission and DEER attribute direct savings; 'No’ means those sources do not directly attribute savings. For each situation marked “No” we have provided additional clarification. In all cases all measures will be verified and reported. The following measures have no official direct saving estimates:

- **Thermostats:** Thermostats are considered an enabling technology. They allow occupants the opportunity to save energy compared to their previous thermostats. When this measure was pulled from DEER there was a report providing several details about how programmable thermostats were used based on RASS survey results and analyzing those results using the DEER prototypes.
- **Load Calculations**: It is true that sizing has an energy impact, but the mandatory measure is to perform the load calculations. The code does not specify a sizing target relative to the load calculations.
- **Refrigerant line**: It is true that added line insulation will produce savings. Since DEER and CASE do not provide values we did not have a source to cite. Developing savings estimates would be beyond the scope of this project as it would require estimating typical line temperatures at DEER loading conditions.
- **Measurement Access** : There are no direct savings from this item. It is also rolled into the refrigerant charge requirements.

Figure 55. Residential HVAC changeout compliance measures – 2008 Title 24 entire system changeout projects (All Equipment + Ducts + Air Handler)

Requirement	Applicability	Threshold	DEER/CASE Energy Impact
Minimum Efficiency, Split Systems	Mandatory, All Climate Zones	SEER 13, AFUE 80, HSPF 7.7	Yes
Programmable Thermostat	Mandatory, All Climate Zones	Yes/No	No*
Load Calculations	Mandatory, All Climate Zones	Yes/No (no sizing requirement based on load calculations in 2008 code)	No
Duct insulation	Mandatory, All Climate Zones	R-4.2	Yes
Refrigerant Line Insulation	Mandatory, All Climate Zones	Insulation thickness based on pipe diameter	No*
Refrigerant Charge	Prescriptive, CZ 2, and CZ's 8-15.	Diagnostic within tolerance of target	Yes

Requirement	Applicability	Threshold	DEER/CASE Energy Impact
Airflow	Prescriptive, CZ 10-15	350 cfm per ton	Yes
Fan power index	Prescriptive, CZ 10-15	<0.58 W/cfmcfm	Yes
Measurement Access	Prescriptive, CZ 10-15, Temperature and Pressure	Yes/No	No
Additional Duct insulation	Prescriptive, Varies by CZ from 4.2 to 8.0	R-value	Yes
Duct Leakage	Prescriptive, CZ 2, 9-16	More than 40 feet Replaced or Added - 15% Total Leakage, or 10% leakage to outside, 60% improvement, or all accessible leaks sealed verified with smoke test Entire Duct System - 6% Total Leakage	Yes

*- There were no estimates of programmable thermostat and refrigerant line energy savings in DEER or CASE reports.

Figure 56. Residential HVAC changeout compliance measures – 2008 Title 24 equipment-only changeout projects (No Duct Changeout)

Requirement	Applicability	Threshold	DEER/CASE Energy Impact
Minimum Efficiency	Mandatory, All Climate Zones	SEER 13, AFUE 80, HSPF 7.7	Yes
Programmable Thermostat	Mandatory, All Climate Zones	Yes/No	No
Load Calculations	Mandatory, All Climate Zones	Yes/No (no sizing requirement based on load calculations in 2008 code)	No
Refrigerant Charge	Prescriptive, CZ 2, and CZ's 8-15.	Diagnostic within tolerance of target	Yes
Airflow	Prescriptive, CZ 2, and CZ's 8-15.	300 cfm per ton	Included in Refrigerant Charge

It will be relatively straightforward to report compliance levels for each requirement across sampled projects. Of the planned sample size of, all 200 residential changeouts will be in the mandatory requirements sample, while less than 200 changeouts will likely be in the prescriptive requirements sample. The samples do not require any special consideration since all requirements are assessed the same way across sites.

Note that the sample size will vary because the requirements vary based on complete system changeout or equipment only changeout and climate zone. The final report will show two tables consistent with this memo’s Figure 55 and Figure 56—one for complete system changeout and another for equipment only changeout, but this may not be meaningful if the sample size is large for one situation and small for the other. We do not yet know the frequency of the two situations. Based on the actual outcome we will determine if we can or cannot further separate the analysis by permitted and non-permitted for each changeout scope as the sample sizes warrant.

Weighting Scheme to Estimate Site-level and Aggregated Compliance

Ultimately the energy code and efforts to study and improve compliance center on increasing the energy efficiency of HVAC changeouts. A simple approach to determining partial compliance for each site may or may not have the desired result. An approach that equally weights the applicable requirements may not reflect the "lost opportunity" in terms of energy efficiency of an energy-weighted approach, but it does describe how many of the requirements are being met. In addition to reporting compliance levels for each requirement, the study will report two site-level metrics based on different approaches to aggregation of requirements:

- **Measure Compliance**: All requirements applicable to a site are considered, including those with no direct energy efficiency impact. This metric is estimated by taking the simple average of the requirement-level scores across requirements at each site. Some requirements are pass/fail and are scored 100% or 0% respectively. Requirements referencing a threshold value are scored based on deviation from the threshold, with the value capped at 100%, so that exceeding code on one requirement cannot be a trade-off for non-compliance with another requirement. We are considering lower limits as well including 150 cfm/ton for airflow and 60% for total duct leakage. This acknowledges that we will not find a case where airflow is 1 cfm/ton or duct leakage is 90%. This should help set the range of requirement-level compliance scores.
- **Energy Savings Compliance**: Only requirements with estimated potential savings are considered. If a requirement has an energy-weight of zero it will not be included for any changeouts. This metric is estimated by taking the energy-weighted average of the requirement-level scores for a site.

As its first step, the project team developed a compliance calculator to estimate compliance levels for each verifiable mandatory and prescriptive requirement. This tool requires inputs of onsite findings and measurements and produces the two site-level scores of partial compliance. The site-level results will be used to estimate nominal compliance rate and the potential energy impact of the estimated level of compliance.

The compliance calculator is primarily intended to measure compliance rates among residential projects and for the most common HVAC system types (central ducted heating and cooling). This memo introduces the overall methodology and cites the data sources used for the compliance calculator. The energy code provides the specifics for each requirement as described previously. Measure compliance is only based on site findings relative to the code requirements. Energy Savings Compliance necessitates requirement-level estimates of energy impacts. The team relied on secondary data sources to inform estimates of the relative impact on statewide energy consumption of compliance or non-compliance of an individual requirement within an individual project. The data sources were grouped into three categories:

- **The DEER (Database for Energy Efficient Resources[14])**: data source established the requirement-level-weights for a few mandatory and prescriptive requirements. The DEER results were chosen as the primary data sources because the results are directly applicable to replacements, duct sealing, and refrigerant charge to existing buildings, which is the situation for HVAC changeouts.

[14] http://www.energy.ca.gov/deer

- **Title 24 CASE Reports**: provided the data for several requirements not in DEER. These reports were developed by the investor-owned utilities (IOUs) and others.
- **Unsourced**: some requirements lacked estimated direct energy savings and thus they will be reported on individually, but will not be combined in the partial compliance rate.

A full list of references is included at the end of his memo. The weights in this memo are considered the best available information currently available.

Although not currently available, an even better option would be compliance software based estimates using DEER prototype characteristics. The CEC is developing these types of estimates. The timing to include those estimates in this study may work, but until they are available this study will plan to use the weights developed with the methods described in this memo. For some requirements, there are estimates of savings in DEER and CASE reports. After reviewing the differences the team decided to adjust the CASE report savings to better align with DEER so that the weighting scheme would not be skewed to CASE reports simply due to different calculation methods and modeling assumptions. The difference can be illustrated for the electric and gas savings of duct sealing in the applicable climate zones.

Figure 57 shows the side by side comparison of the values and overall difference used to estimate an adjustment factor. The percentages show the DEER value divided by the CASE report value. All of the DEER values are lower than the CASE reports with one exception for Climate Zone 15 (Desert) gas savings. The average relative difference is greater for electric savings than gas savings. After reviewing these results across climate zones and fuels the project team developed adjustment factors that could be applied to CASE report savings estimates for other requirements. The overall adjustments are factors of 0.25 for electric and 0.50 for gas. The figure also establishes a factor by climate zone that could be applied. This memo uses a single factor across climate zones. We intend to provide a detailed spreadsheet with all factors after the memo has completed the vetting process so that it is available to the HVAC PCG and other stakeholders.

Figure 57. Comparison of DEER and CASE savings for duct sealing to inform adjustment

	Electric Savings, kWh			Gas Savings, therm		
Climate Zone	DEER	CASE	DEER / CASE	DEER	CASE	DEER / CASE
CZ2	33	90	36%	14	37	39%
CZ9	92	253	36%	8	12	67%
CZ10	87	818	11%	10	13	74%
CZ11	105	556	19%	13	36	36%
CZ12	66	264	25%	12	35	35%
CZ13	123	580	21%	13	32	39%
CZ14	197	543	36%	15	42	35%
CZ15	260	1329	20%	5	5	104%
CZ16	62	301	21%	30	66	45%
Adjustment	**Electric, kWh**		**25%**	**Gas, therm**		**50%**

The reporting is divided into air conditioner and heat pump changeouts which use weights based on electric energy savings and furnace changeouts which use weights based on gas savings. The research plan included example tables with a single column for requirement weights. That is the case for any individual site, but changeouts in different climate zones have different weights since the requirements vary by climate zone and some replacements may not be subject to some of the requirements. A site-level example is provided on how the weights and measurements will work (Figure 58). After the example, figures are shown that expand those draft figures to show weights that will be used for changeouts in different climate zones.

This example figure does not take into account minimum values for each metric. As mentioned previously values are being developed, but all requirements may not be covered by past field studies. Airflow, charge diagnostics, and duct leakage are well covered in past CPUC evaluations, but fan power index is more limited. We have not set all thresholds in this memo since the focus was on the weights.

Figure 58. Example AC replacement measure compliance and energy savings compliance using weights

Measure (M = Mandatory, P = Prescriptive)	AC Changeout Weight CZ 10 (kWh)	Onsite Finding – Site X	Site X Requirement-Level Compliance	Site X Energy Potential Scores
Load Calculations (M)	0	Y	100%	NA
Measurement Access (P)	0	N	0%	NA
Minimum Efficiency (M)	87	14 SEER	100%	87
Programmable Thermostat (M)	0	Y	100%	0
Duct Insulation (M)	21	N	0%	-
Refrigerant Charge (P)	82	SH 10% high	90%	74
Airflow (P)	18	325 cfm	93%	17
Fan power index (P)	291	0.65 W/cfm	89%	260
Additional Duct Insulation (P)	20	None	0%	-
Duct Sealing (P)	87	18%	83%	72
Measure Compliance = Average Requirement-Level Compliance	**66%**	**Energy Savings Compliance = Sum of Score / Sum of Weights**		**85%**

SH=superheat

At the site level there are multiple options to combine electric and gas savings where replacements affect both electricity and gas consumption. This study looks at the population of replaced heating and cooling equipment separately, but if necessary, site level compliance will use the simplified Site-to-Source energy ratio and standard unit conversions to produce a source BTU estimate.

Figure 59 shows the partial compliance weights for single-family residential air conditioner changeouts. The data sources are listed as descried above. There is also a designation for how compliance is determined for each individual requirement. Figure 60 shows the partial compliance weights for single-family residential furnace changeouts. The format is the same as Figure 58. The primary difference is the weights are in therm, not kWh.

Figure 59. AC replacement partial compliance weights for single-family residences

Requirement	Source	CZ1	CZ2	CZ3	CZ4	CZ5	CZ6	CZ7	CZ8	CZ9	CZ10	CZ11	CZ12	CZ13	CZ14	CZ15	CZ16
Minimum Efficiency	DEER 2011	-	34	22	59	16	64	78	101	116	87	100	74	129	148	189	69
Load Calculations	No Direct Savings	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Programmable Thermostat	No Savings based on DEER	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Duct Insulation	CASE Report *0.25	6	7	5	10	5	10	6	13	20	16	28	17	31	NA	NA	NA
Mandatory Requirements		**6**	**41**	**27**	**69**	**21**	**74**	**84**	**114**	**136**	**103**	**128**	**91**	**160**	**148**	**189**	**69**
Refrigerant Charge	DEER 2011	-	29	NA	NA	NA	NA	NA	69	83	82	98	61	117	155	187	48
Airflow																	
Fan power index	CASE Report *0.25	-	NA	NA	NA	NA	NA	NA	NA	NA	73	127	71	132	114	249	NA
Additional Duct Insulation	CASE Report *0.25	3.6	4.7	2.8	6.6	3	15.9	10.1	21.5	13	10.3	18.3	10.7	20.5	NA	NA	NA
Duct Sealing	DEER 2011	-	33	NA	NA	NA	NA	NA	NA	92	87	105	66	123	197	260	62
Prescriptive Requirements		**4**	**67**	**3**	**7**	**3**	**16**	**10**	**91**	**188**	**252**	**348**	**209**	**393**	**466**	**696**	**110**
TOTAL		**10**	**108**	**30**	**76**	**24**	**90**	**94**	**205**	**324**	**355**	**476**	**300**	**553**	**614**	**885**	**179**

Figure 60. Gas Furnace replacement partial compliance weights for single-family residences

Requirement	Source	CZ1	CZ2	CZ3	CZ4	CZ5	CZ6	CZ7	CZ8	CZ9	CZ10	CZ11	CZ12	CZ13	CZ14	CZ15	CZ16
Minimum Efficiency	DEER 2011	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Load Calculations	No Direct Savings	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Programmable Thermostat	No Savings based on DEER	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Duct Insulation	CASE Report *0.5	2	2	1	3	1	1	0	1	1	2	3	3	3	NA	NA	NA
Mandatory Requirements		**2**	**2**	**1**	**3**	**1**	**1**	**0**	**1**	**1**	**2**	**3**	**3**	**3**	**-**	**-**	**-**
Refrigerant Charge	DEER 2011	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Airflow	No Gas Estimate	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Fan power index	CASE Report *0.5	NA	NA	NA	NA	NA	NA	NA	NA	NA	-2	-4	-4	-3	-4	-1	-7
Additional Duct Insulation	CASE Report *0.5	1.1	1.3	0.8	1.8	0.9	1.2	0.5	1.4	0.8	1.1	2	2	1.8	NA	NA	NA
Duct Sealing	DEER 2011	NA	14	NA	NA	NA	NA	NA	NA	8	10	13	12	13	15	5	30
Prescriptive Requirements		**1.1**	**15.7**	**0.8**	**1.8**	**0.9**	**1.2**	**0.5**	**1.4**	**8.9**	**9.2**	**11.5**	**10.9**	**11.4**	**10.5**	**4.7**	**22.9**
TOTAL		**3**	**18**	**2**	**5**	**2**	**2**	**1**	**2**	**10**	**11**	**15**	**14**	**14**	**10.5**	**5**	**23**

Aggregating Site-Level Compliance

Getting beyond a site level estimate of partial compliance, these energy-related weights also play a role in expanding the sample to the larger population to estimate overall compliance at a statewide level or IOU-territory level. The energy potential compliance approach also inherently weights the results toward climate zones with greatest potential savings when aggregated to a statewide estimate. As constructed, reporting these metrics should produce the best estimate available of the partial compliance relative to the code requirements and accounting for the energy saving aspects of the HVAC changeout code.

In the final report, three metrics will be used to describe overall statewide compliance.

- **Requirement-Level Compliance Rate**: The requirement-level compliance rate will be presented in a table with a row for each requirement along with the sample size and any relevant statistics. The final requirement-level compliance rate will be a percentage between 0% and 100%
- **Measure Compliance Rate**: The nominal compliance rate will provide an estimate of the how often changeouts meet all the requirements and accounts for the as-found conditions being close to or far from the threshold established by code. This simplified metric will only be reported for the entire sample.
- **Energy Savings Compliance Rate**: The energy savings compliance rate will provide an estimate of partial compliance that accounts for different requirements having different energy impacts. This metric will be used in all additional analyses for the report. When reporting compliance for permitted versus non-permitted changeouts we will report the energy potential compliance rate for each group. Partial compliance comparisons by climate region (groups of climate zones) will also be reported using the energy potential compliance metric.

A mock-up of the table showing all metrics is shown below in Figure 61.

Figure 61. Mock-up table of reported requirement-level compliance, measure compliance, and energy savings compliance

Requirements (M = Mandatory, P = Prescriptive)	Sample Size	Requirement-level Compliance Rate
Load Calculations (M)	200	X%
Measurement Access (P)	120	X%
Minimum Efficiency (M)	200	X%
Programmable Thermostat (M)	200	X%
Duct Insulation (M)	200	X%
Refrigerant Charge (P)	100	X%
Airflow (P)	80	X%
Fan-Watt Draw (P)	80	X%
Additional Duct Insulation (P)	80	X%
Duct Sealing (P)	90	X%
Measure Compliance = Average Requirement Level Compliance	200	**X%**
Energy Savings Compliance = Sum of Score ÷ Sum of Weights	200	**X%**

Figure 62 provides a mock-up of the additional types of where energy potential compliance is used.

Figure 62. Mock-up table of reported compliance for permitting groups and regional groups

Group	Sample Size (Not actual)	Energy Potential Compliance Rate	Energy Potential Compliance Relative Precision at 90% Confidence Interval
All Changeouts	200	X%	+/- y%
Permitted	40	X%	+/- y%
Non-Permitted	160	X%	+/- y%
Coastal	60	X%	+/- y%
Inland	60	X%	+/- y%

For the 2008 Title 24 Residential Measures, there are mandatory requirements that apply to any equipment that is installed and prescriptive measures where some requirements are limited to completely new or replacement HVAC systems where all components of the system, including all ducts, are replaced in altered existing buildings.

APPENDIX K. SOURCE REFERENCES FOR MEASURING COMPLIANCE

The following table provides a list of all of the sources used to develop the compliance measurement methodology and links to those documents.

Figure 63. References used for calculating compliance

Title of Document	Web Link	Res/Non-Res	Measure Details
Residential Ducts – Duct Sealing, Cooling Coil Airflow, Fan power index, and Measured Static Pressure 2013 California Building Energy Efficiency Standards, California Utilities Statewide Codes and Standards Team October 2011	https://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=1&cad=rja&uact=8&ved=0CB8QFjAA&url=http%3A%2F%2Fwww.energy.ca.gov%2Ftitle24%2F2013standards%2Fprerulemaking%2Fdocuments%2F2011-05-31_workshop%2Freview%2F2013_CASE_R_12_Ducts_Draft_052711.pdf&ei=WgeDVZqdBKu_ygP3_52wCA&usg=AFQjCNEN_X5vIGx6wfc_sEOKb12i2zqDXw&sig2=h_9-U88NXJms74busAFImw&bvm=bv.96042044,d.bGQ	Res	Duct Sealing Airflow Fan power index Static Pressure
Residential Roof Envelope Measures 2013 California Building Energy Efficiency Standards, California Utilities Statewide Codes and Standards Team October 2011	https://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=1&cad=rja&uact=8&ved=0CB4QFjAA&url=http%3A%2F%2Fwww.energy.ca.gov%2Ftitle24%2F2013standards%2Fprerulemaking%2Fdocuments%2Fcurrent%2FReports%2FResidential%2FEnvelope%2F2013_CASE_R_Roof_Measures_Oct_2011.pdf&ei=kweDVeuQIKXoywPHtbG4CA&usg=AFQjCNFdxjRPPz_gPy07Nw4Dl4tL5pIANg&sig2=3RQocMbZtCiKJ_V64yWvVA&bvm=bv.96042044,d.bGQ	Res	Duct Insulation Roof Insulation
"Programmable Communicating Thermostats (PCT's)", Presentation by PIER and Southern California Edison	http://www.energy.ca.gov/title24/2008standards/prerulemaking/documents/ 2006-02-22+23_workshop/presentations/2006-02-23_PROGRAM_COMMUN_THERMOSTATS.PDF	Res/Non-Res	Programmable Communicating Thermostat
"Demand Responsive Control of Air Conditioning via Programmable Communicating Thermostats (PCTs)." Posted February 15, 2006	http://www.energy.ca.gov/title24/2008standards/prerulemaking/documents/ 2006-02-22+23_workshop/2006-02-15_PROGRAMBLE_COMM.PDF	Res/Non-Res	Programmable Communicating Thermostat
"Revision to the Residential ACM Calculation for Indoor Air Quality Ventilation" - PIER Research for the 2008 Residential Building Standards – March 2006 Workshop	http://www.energy.ca.gov/title24/2008standards/prerulemaking/documents/2006-03-28_workshop/2006-03-27_AIR_VENTILATION.PDF	Res	Indoor air quality
"Revisions to the Residential Standards and ACM Calculations," presented by Bruce Wilcox, 2007-06-13	http://www.energy.ca.gov/title24/2008standards/prerulemaking/documents/2007-06-13-15_workshop/presentations/Wilcox070613c1.pdf	Res	Residential ACM Calculation

Title of Document	Web Link	Res/Non-Res	Measure Details
"Revisions to the Residential ACM Calculations," presented by Bruce Wilcox, 2007-06-15	http://www.energy.ca.gov/title24/2008standards/prerulemaking/documents/2007-06-13-15_workshop/presentations/Wilcox070615b1.pdf	Res	Residential ACM Calculation, Duct leakage, air tightness, furnace fan
Air-conditioning Refrigeration Technology Inst., "Whole House Ventilation System Options – Phase I Simulation Study Final Report" 2007-03-05	http://www.energy.ca.gov/title24/2008standards/prerulemaking/documents/2007-06-13-15_workshop/comments/AIR-CONDITIONING_REFRIGERATION_TECHNOLOGY_INST_2007-03-05.PDF	Res	Whole House Ventilation System Options
"Design/sizing Methodology and Economic Evaluation of Central-Fan-Integrated 22. Supply Ventilation Systems", Armin F Rudd, 1998-08-23-28	http://www.energy.ca.gov/title24/2008standards/prerulemaking/documents/2007-06-13-15_workshop/comments/ARMIN_F_RUDD_DESIGN-SIZING_METHOLOGY_2007-06-15.PDF	Res	Integrated Supply Ventilation System
"Clean Breathing in Production Homes", Armin Rudd & Joseph Lstiburek 2001-05/06	http://www.energy.ca.gov/title24/2008standards/prerulemaking/documents/2007-06-13-15_workshop/comments/ARMIN_RUDD_AND_JOSEPH_LSTIBUREK_CLEAN_BREATHING_2007-06-13.PDF	Res	Indoor air quality
CEC Staff Document: Calcs. For Cec 1.2wpercfm,2007-06-06	http://www.energy.ca.gov/title24/2008standards/prerulemaking/documents/2007-06-13-15_workshop/comments/Calcs%20for%20CEC%201.2Wpercfm.xls	Res	Fan Power Index (W/cfm)
"Central Hot Water Distribution Systems in Multifamily Buildings, Proposed Code Changes 2008," presentation by Nehemiah Stone and Owen Howlett, Heschong Mahone Group, 2006-07-12 & 13	http://www.energy.ca.gov/title24/2008standards/prerulemaking/documents/v2006-07-12_workshop/presentations/2006-07-10_CNTRL_HOT_WTR_MULTIFAMLY_BLDGS.PDF	Res	Central Hot Water Distribution System
"62.2-2004: ASHRAE'S Residential Ventilation Standard," presented by Max Sherman, 2006-07-12	http://www.energy.ca.gov/title24/2008standards/prerulemaking/documents/2006-07-12_workshop/presentations/2006-07-11_RESIDENTIAL_VENTILATION_STANDARD.PDF	Res	Residential Ventilation Standard
"Update on PCTs," presented by Mazi Shirakh, 2006-07-12	http://www.energy.ca.gov/title24/2008standards/prerulemaking/documents/2006-07-12_workshop/presentations/2006-07-12_PCT_SHIRAKH_MAZI.PDF		Programmable Communicating Thermostat

Title of Document	Web Link	Res/Non-Res	Measure Details
"Furnace Fan power index and Airflow in Cooling Mode," and "Air Conditioner Airflow, Refrigerant Charge and TXVs," presented by Bruce Wilcox, John Proctor (Proctor Engineering Group), Ken Nittler (EnerComp, Inc.) and Rick Chitwood (Chitwood Energy Management), 2006-07-12	http://www.energy.ca.gov/title24/2008standards/prerulemaking/documents/2006-07-12_workshop/presentations/2006-07-17_FAN_FLOW_WATT_DRAW.PDF	Res	Part 1: Furnace Fan power index and Airflow in Cooling Mode Part 2: Air Conditioner Airflow, Refrigerant Charge, and TXVs
"Report on Applicability of Residential Ventilation Standards in California," Max Sherman and Jennifer McWilliams, Lawrence Berkeley National Laboratory, 06-2005	http://www.energy.ca.gov/title24/2008standards/prerulemaking/documents/2006-07-12_workshop/reviewdocs/2006-07-11_RESIDENTIAL_VENTILATION_REPORT_LBNL.PDF	Res	Residential Ventilation Standard
"Ventilation Behavior and Household Characteristics in New California Houses, Philip Prince and Max Sherman, Lawrence Berkeley National Laboratory, 04-2006	http://www.energy.ca.gov/title24/2008standards/prerulemaking/documents/2006-07-12_workshop/reviewdocs/2006-07-11_VENTILATION_BEHAVIOR_REPORT_LBNL.PDF	Res	Ventilation Requirement
Measure Information Template – "Air Conditioner Airflow, Refrigerant Charge and TXVS – Overview," based on field tests by Proctor Engineering Group and Robert Morris and Associates, 2005-09-21	http://www.energy.ca.gov/title24/2008standards/prerulemaking/documents/2006-07-12_workshop/reviewdocs/AIR_CONDITIONER_REFRIGERANT_TXVS_OVERVIEW.PDF	Res	Air Conditioner Airflow, Refrigerant Charge and TXVS
"Appendix RJ – Charge Indicator Light," 2006-07-12	http://www.energy.ca.gov/title24/2008standards/prerulemaking/documents/2006-07-12_workshop/reviewdocs/APPENDIX_RJ_CHARGE_INDICATOR_LIGHT.PDF	Res	Refrigerant Charge Indicator
Measure Information Template – "Fan power index and Airflow," Bruce Wilcox, John Proctor, Rick Chitwood and Ken Nittler, 2006-07-12	http://www.energy.ca.gov/title24/2008standards/prerulemaking/documents/2006-07-12_workshop/reviewdocs/FAN_WATT_DRAW_AND_AIR_FLOW.pdf	Res	Furnace Fan power index and Airflow in Cooling and Air Distribution Modes

Title of Document	Web Link	Res/Non-Res	Measure Details
Measure Information Template – "Air Conditioner Airflow, Refrigerant Charge and TXVS – Multi-Zone Airflow Overview," based on field tests by Chitwood Energy Management and Robert Morris and Associates, 2005-09-21	http://www.energy.ca.gov/title24/2008standards/prerulemaking/documents/2006-07-12_workshop/reviewdocs/MULTI-ZONE_AIRFLOW_OVERVIEW.PDF	Res	Air Conditioner Airflow, Refrigerant Charge and TXVS
Measure Information Template – "Central Hot Water Distribution Systems in Multifamily Buildings, " Heschong Mahone Group, 2006-06-23	http://www.energy.ca.gov/title24/2008standards/prerulemaking/documents/2006-07-12_workshop/reviewdocs/MULTIFAMILY_SYSTEM_MEASURE_CASE.PDF	Res	Central Hot Water Distribution Systems
Referigerant_Charge_Air_Flow_Appendix_B, 2005 Residential ACM Manual	http://www.energy.ca.gov/title24/2008standards/prerulemaking/documents/2006-07-12_workshop/reviewdocs/REFERIGERANT_CHARGE_AIR_FLOW_APPENDIX_B2.PDF	Res	Building cooling temperature
Residential_Multi-Zone_Airflow, Appendix RE, 2005 Residential ACM Manual	http://www.energy.ca.gov/title24/2008standards/prerulemaking/documents/2006-07-12_workshop/reviewdocs/RESIDEDENTIAL_MULTI-ZONE_AIRFLOW_ACM.PDF	Res	Fan Flow and Air Handler Fan Watt Draw, refrigerant charge
Residential_Airflow_Appendix_RD, 2005 Residential ACM Manual Measure Information Template – "Residential_Distribution_System Leakage," Ken Nittler and Bruce Wilcox, 2006-07-10	http://www.energy.ca.gov/title24/2008standards/prerulemaking/documents/2006-07-12_workshop/reviewdocs/RESIDENTIAL_DISTRIBUTION_SYSTEMS.PDF	Res	Low Leakage Air Handlers and Low Leakage Ducts in Conditioned Spaces
Measure Information Template – "Residential Evaporative Cooling," Southern California Gas Co., 2006-05-08	http://www.energy.ca.gov/title24/2008standards/prerulemaking/documents/2006-05-18_workshop/2006-05-11_COOLING_REVISED.PDF	Res	Evaporative Cooling
"Suggestions for HVAC Efficiency Improvements for the 2008 California Buildings Energy Efficiency Standards," presentation by Robert Mowris & Associates, 2006-03-28	http://www.energy.ca.gov/title24/2008standards/prerulemaking/documents/2006-03-28_workshop/2006-03-28_HVAC_EFFICIENCY.PDF	Res	TXV Installation and refrigerant charge

Title of Document	Web Link	Res/Non-Res	Measure Details
"Revision to the Residential ACM Calculation for Furnace Fan Modeling," presentation by Ken Nittler and Bruce Wilcox, 2006-03-28	http://www.energy.ca.gov/title24/2008standards/prerulemaking/documents/2006-03-28_workshop/2006-03-28_FURNACE_FAN.PDF	Res	Residential ACM Calculation for Furnace Fan Modeling
"UZM Residential ACM Attic/Duct Models," presentation by Ken Nittler and Bruce Wilcox, 2006-03-28	http://www.energy.ca.gov/title24/2008standards/prerulemaking/documents/2006-03-28_workshop/2006-03-28_ETTIC_MODELING.PDF	Res	UZM Residential ACM Attic/Duct sealing
"Revision to Residential ACM Calculation for Furnace Fan Modeling," Bruce Wilcox and Ken Nittler, 2006-03-17	http://www.energy.ca.gov/title24/2008standards/prerulemaking/documents/2006-03-28_workshop/2006-03-27_FURNACE_FAN.PDF	Res	ACM Calculation for Furnace Fan Modeling
"Revision to the Residential ACM Calculation for Indoor Air Quality Ventilation," Bruce Wilcox and Ken Nittler, 2006-03-17	http://www.energy.ca.gov/title24/2008standards/prerulemaking/documents/2006-03-28_workshop/2006-03-27_AIR_VENTILATION.PDF	Res	ACM Calculation for Indoor Air Quality Ventilation, ventilation rate and envelop leakage
Southern California Edison CASE Draft Report, "Demand Responsive Control of Air Conditioning via Programmable Communicating Thermostats (PCTs)," 2006-02-14	http://www.energy.ca.gov/title24/2008standards/prerulemaking/documents/2006-02-22+23_workshop/2006-02-15_PROGRAMBLE_COMM.PDF	Res/Non-Res	Programmable Communicating Thermostats
"Impacts of PCT to Residential Thermostat Industry," presentation by Dan O'Donnell, Director, Product Management Electronic Controls, Honeywell, 2006-02-16	http://www.energy.ca.gov/title24/2008standards/prerulemaking/documents/2006-02-16_workshop/O_DONNELL_DAN_HONEYWELL.PDF	Res	Programmable Communicating Thermostat

Title of Document	Web Link	Res/Non-Res	Measure Details
"Review of Literature Related to Residential Ventilation Requirements" - paper by Jennifer McWilliams and Max Sherman, Lawrence Berkeley National Laboratory, June 2005, Publication # LBNL-57236	http://www.energy.ca.gov/title24/2008standards/prerulemaking/documents/2005-10-24+25_workshop/2005-10-24+25_LBNL_RES_VENTILATION.PDF	Res	Ventilation Requirement
"Report on Applicability of Residential Ventilation Standards in California" - paper by Max H. Sherman and Jennifer A. McWilliams, Lawrence Berkeley National Laboratory, June 2005, Publication # LBNL-58713	http://www.energy.ca.gov/title24/2008standards/prerulemaking/documents/2005-10-24+25_workshop/2005-10-24+25_LBNL_RES_VENTILATION-2.PDF	Res	Residential Ventilation Standards
"Residential Key Topics," presented by Charles Eley, Architectural Energy Corporation, 2005-10-24 & 25	http://www.energy.ca.gov/title24/2008standards/prerulemaking/documents/2005-10-24+25_workshop/presentations/Eley%20Residential%20Key%20Topics%2010-24-05.pdf	Res	TXV Installation and duct leakage
"Residential Evaporative Cooling," SCGC and SDGE CASE Study, 2005-10-25	http://www.energy.ca.gov/title24/2008standards/prerulemaking/documents/2005-10-24+25_workshop/presentations/Hoeschele%20EvapClg%2010-24-05.pdf	Res	Evaporative Cooling
CASE Update: "Programmable Communicating Thermostats (PCT's)," presented by John McHugh, SCE Codes & Standards Program, 2005-10-24	http://www.energy.ca.gov/title24/2008standards/prerulemaking/documents/2005-10-24+25_workshop/presentations/McHugh%20DR_PCT_T-24%2010-24-05.pdf	Res/Non-Res	Programmable Communicating Thermostats
"Duct Tape," presented by Bill Pennington, CEC, 2005-10-24	http://www.energy.ca.gov/title24/2008standards/prerulemaking/documents/2005-10-24+25_workshop/presentations/Pennington%20Duct%20Tape%2010-24-05.pdf	Res/Non-Res	Duct leakage

APPENDIX L. ON-SITE DATA COLLECTION INSTRUMENT

Site ID:	
Occupant Name	
Address 1:	
Address 2:	
City & Zip:	
Occupant Phone:	
Mo/Yr of Home Performance Work Completion:	
Any maintenance or service calls since installation? If yes, describe problem and solution. Use back if necessary.	
Performance work type:	1 for 1 replacement | New unit existing building | New unit in renovated building
On-site equipment	Furnace only AC only Both
Circle ALL replaced equipment:	Furnace/AHU Condensing Unit Evaporative Coil Ducts
Number of Bedrooms/Bathrooms:	
Number of Year Round Occupants:	
Is Home All-Electric?	
How many feet of ductwork were changed out? (Ask occupant)	All over 40' 40' or less None
Inspector(s):	
Site Visit Date & Time:	
Dwelling Type:	
Year Built:	
Stories:	

Notes:

SITE CHECKLIST	
Photos	
All sides of building	☐
Furnace nameplate	☐
Evaporative Coil nameplate	☐
Condensing Unit nameplate	☐
TrueFlow grid(s) placement	☐
Refrigerant line insulation	☐
Unusual observations, situations, etc.	☐
Photos of gift card(s)	☐
Site Sketch	
Sketch shows windows	☐
Sketch shows doors	☐
Sketch shows wall lengths	☐
Incentive	
Incentive paid	☐
IVF signed	☐
Scope of Work	
Scope Captured	☐
Test Results	
Duct Leakage	☐
Airflow	☐
Refrigerant Charge	☐
Spot Power (fan, condenser)	☐ ☐
AHU Watt meter retrieved (if installed)	☐
Thermostat reset to as-found	☐
System operational on departure	☐

THERMOSTAT INFO	
T-STAT TYPE	Programmable/Mechanical/Other
If not programmable, was a programmable t-stat	Yes No

replaced?	
Cool-To temperature (record before changing)	
Heat-To temperature (record before changing)	
System Nameplate Info (TAKE PHOTO)	
Location of Furnace/Fan Coil	Attic Garage Cond. Space Other (describe)
TYPE OF UNIT	Package Split Hydronic System Package Heat Pump Split Heat Pump w/Elec supply Other (describe)
Fan Type	Single-speed two-speed variable-speed
HEATING FUEL TYPE	Gas Propane Electric Wood Other
CONDENSER (OUTDOOR) MANF	
CONDENSER MODEL #	
CONDENSER SERIAL #	
TAKE PHOTO OF FULL NAMEPLATE	
HEATING SYSTEM MANUFACTURER	
HEATING MODEL NUMBER	
HEATING SERIAL NUMBER	
TAKE PHOTO OF FULL NAMEPLATE	
EVAP COIL MANUF.	
COIL MODEL #	
COIL SERIAL #	
TAKE PHOTO OF FULL NAMEPLATE	
PREDOMINANT SUPPLY DUCT LOCATION	Attic Crawl Space No Ducts Cond. Space Other (describe)
SUPPLY DUCT R-VALUE	4.2 6.0 8.0 Other
SUPPLY DUCT TYPE	FLX Duct Sheet Metal Wall Cavity Asbestos Insulated Other
RETURN DUCT LOCATION	Attic Crawl Space No Ducts Cond. Space Other (describe)
RETURN DUCT R-VALUE	4.2 6.0 8.0 Other
RETURN DUCT TYPE	FLX Duct; Sheet Metal; Wall Cavity; Asbestos Insulated; Other
What percentage of total ducting is the return ducting?	0 % 10% 25% 50% 75% 90% 100%
Are ALL ducts in conditioned space?	YES NO

TOTAL DUCT LEAKAGE TEST	
System #	
Test 1	
Duct Pressure 25Pa (*P_{25}*)	
Duct Blaster Ring @25Pa	Open 1 2 3
Duct Blaster cfm near 25Pa (*Q_{25}*)	______cfm
Leakage at 25Pa as % of Nominal Flow (400 cfm/ton)	
Duct Pressure near 50 Pa (P_{50})	50Pa Other______________
Duct Blaster Ring @50Pa	Open 1 2 3
Duct Blaster cfm near 50 Pa *(Q_{50})*	______cfm
* Flow Exponent Correct? (if not perform test 2, then test 3 if necessary)	YES NO
Please note any areas with excessive leakage:	

Please note any evidence of recent air sealing:	
Test 2*	
Duct Pressure 25Pa (*P_{25}*)	
Duct Blaster Ring @25Pa	Open 1 2 3
Duct Blaster cfm near 25Pa (*Q_{25}*)	______cfm
Leakage at 25Pa as % of Nominal Flow	
Duct Pressure near 50 Pa (P_{50})	50Pa Other______________
Duct Blaster Ring @50Pa	Open 1 2 3
Duct Blaster cfm near 50 Pa *(Q_{50})*	______cfm
* Flow Exponent Correct? (if not perform test 3)	YES NO
Test 3*	
Duct Pressure 25Pa (*P_{25}*)	
Duct Blaster Ring @25Pa	Open 1 2 3
Duct Blaster cfm near 25Pa (*Q_{25}*)	______cfm
Leakage at 25Pa as % of Nominal Flow	
Duct Pressure near 50 Pa (P_{50})	50Pa Other______________
Duct Blaster Ring @50Pa	Open 1 2 3
Duct Blaster cfm near 50 Pa *(Q_{50})*	______cfm
* Flow Exponent Correct?	YES NO
If total leakage at 25Pa divided by nominal airflow exceeds 15% and duct system not a total replacement, proceed to Duct Leakage to Outside test.	If flow exponent *n* is not between 0.50 and 0.75, repeat the test.
Notes:	$n = \dfrac{\ln\left(\frac{Q_{50}}{Q_{25}}\right)}{\ln\left(\frac{P_{50}}{P_{25}}\right)}$

DUCT LEAKAGE TO OUTSIDE TEST (if total leakage test fails)	
System #	
Test 1	
House Pressure 25 Pa	25Pa Other______________
Duct Pressure near 0Pa	
Duct Blaster Ring @25Pa	Open 1 2 3
Duct Blaster cfm@ 25 Pa House Pressure	______cfm
Leakage at 25Pa as % of Actual Flow	
House Pressure 50 Pa (or as near 50 Pa as possible)	50Pa Other______________
Duct Pressure near 0Pa	
Duct Blaster Ring @50Pa	Open 1 2 3
Duct Blaster cfm@ 50 Pa House Pressure	______cfm

* Flow Exponent Correct? (if not perform test 2, then test 3 if necessary)	YES NO
Presence and type of auxiliary ventilation?	None Supply Only Balanced Supply/Exhaust HRV ERV
Please note any areas with excessive leakage	
Please note any evidence of recent duct sealing	
Test 2*	
House Pressure 25 Pa	25Pa Other_______________
Duct Pressure near 0Pa	
Duct Blaster Ring @25Pa	Open 1 2 3
Duct Blaster cfm@ 25 Pa House Pressure	______cfm
Leakage at 25Pa as % of Actual Flow	
House Pressure 50 Pa (or as near 50 Pa as possible)	50Pa Other_______________
Duct Pressure near 0Pa	
Duct Blaster Ring @50Pa	Open 1 2 3
Duct Blaster cfm@ 50 Pa House Pressure	______cfm
* Flow Exponent Correct? (if not perform test 3)	YES NO
Test 3*	
House Pressure 25 Pa	25Pa Other_______________
Duct Pressure near 0Pa	
Duct Blaster Ring @25Pa	Open 1 2 3
Duct Blaster cfm@ 25 Pa House Pressure	______cfm
Leakage at 25Pa as % of Actual Flow	
House Pressure 50 Pa (or as near 50 PA as possible)	50Pa Other_______________
Duct Pressure near 0Pa	
Duct Blaster Ring @50Pa	Open 1 2 3
Duct Blaster cfm@ 50 Pa House Pressure	______cfm
* Flow Exponent Correct?	YES NO

TrueFlow Test

As-Found Cooling Stage[1] (circle one) Low Low-Med Med Med-Hi Hi

		Grid 1 size: 14 20				Grid 2 size: 14 20			
		Filter Size:				Filter Size:			
NSOP	Test #	TFSOP	Flow	Plate Pressure	Time	TFSOP	Flow	Plate Pressure	Time
	1								
	2								
	3								

Remote return	YES / NO	No. of Returns	

[1]For single-speed systems, circle "low"

Static Pressure Test

Cooling Mode							
Static Pressure Across Unit (Supply Plenum to Return Plenum)				Static Pressure Across Fan (if taps available)			
Test #	ESP (Pa)	Time		Test #	ESP (Pa)	Time	
1				1			
2				2			

Spot Power Measurements			
Compressor (Amprobe)			
Unit in Cooling Mode (wet coils)		Value	Time
	Volts1 Ph-Gnd V1		
	Volts2 Ph-Gnd V2		
	Amps1 A1		
	Amps2 A2		
	Power 1 W1		
	Power 2 W2		
	Power Factor1 PF1		
	Power Factor2 PF2		
Furnace / AHU (WattsUp or Amprobe)			
Unit in Cooling Mode (wet coils)		Value	Time
Fan Speed as-found	Power Across Unit[1]		
	Power Factor Across Unit		
	Power Across Fan[2]		
	Power Factor Across Fan		
[1] *If AHU power is hard-wired, use Amprobe. If AHU is plugged into an outlet, use WattsUp.*			
[2] *If possible, also measure power across fan only*			

Refrigerant Charge Measurements

Estimated refrigerant line-set length (distance from condensing unit to evap. unit)			Suction line dia.*	_	Suction line ins. Thickness*	
	Instantaneous Gauges					
Stage 1	Test 1	Time	Test 2	Time		
Suction Temperature (larger, cold line)						
Suction Pressure						
Liquid Line Temperature						
Liquid Line Pressure (as available)						
Discharge Line Temperature						
Discharge Line Pressure (if liquid line unavailable)						
Ambient Temp						
Compressor Fan Exhaust Temp						
Refrigerant Type	R-22	R-410a	Other			
Logger Information	Hobo Micro Station Serial #			Temp/RH Sensor Serial #		
Ambient Temp/RH						
Condenser exhaust Temp/RH						
Temp Splits Supply						
Temp Splits Return						
Attic Ambient (if used)						
Temp. Measurement Access Holes (TMAH) present on both sides of evap coil? (Y/N)						
Permanently-Installed Static Pressure Probe in supply plenum? (Y/N)						
Charge Indicator Display present? (Y/N) (If yes, describe reading in comments)						
Permanently-Installed Saturation Temperature Sensor? (Y/N)						
Other site notes, comment, etc.						

DNV GL Incentive Verification
My signature below indicates that I received $150 in American Express gift cards as an incentive for my participation in the CPUC-sponsored HVAC study. I understand that these gift cards should be considered the same as cash and that neither DNV GL nor the CPUC are responsible for lost, expired or stolen cards.
Printed Name:___________________________________
Signature:_______________________________________
Date:_________________________
Expiration Date:_______________
Gift Card #:_______________________________________
Surveyor Name:___________________________________
SITE ID:____

Data for Manual J Calculation

Site ID	Surveyor Name
Date & Time	Site Address

General

1. What is front orientation of home?______________
2. What is the total conditioned floor area of the home served by the replacement unit(s)?________________
3. What is the average ceiling height?_______________
4. Total # of people that live in the home?___________
5. What is the approximate age of home?__________
6. What is the roof color? (choose one) Light Dark
7. Duct System Location? (circle) Crawlspace Attic Garage Other

- If other explain:____

8. Duct Insulation R-Value? R 4.2 R6 R8 Other:____________

Surfaces

9. Wall framing type? 2x4 2x6 Other(Explain):_________________________
10. Total wall area to ambient (all four orientations; exclude wall to garage)
11. North_________
12. South_________
13. East__________
14. West_________
15. Total wall area to Attic (Knee Wall)__________
16. Total wall area to garage___________
17. Total ceiling area to attic__________
18. Attic Insulation R-value/#Inches _________ (Blown-in? Y/N)
19. Total door area____________
20. For each different floor surface provide area for each
    a) Slab on grade_________
    b) Over Crawl___________

c) Over Open Space__________

d) Over Garage___________

e) Over Other__________ Explain:_____________________________________

Window

(use predominant window type)

21. Window Type: Vinyl Metal Wood

22. Number of Panes________________

23. Low-E? Yes No

24. Total Skylight area___________

25. Predominant overhang projects ______ feet/inches and is _______ feet/inches above windows

26. Window area for each Orientation
North_________
South_________
East__________
West_________

Fireplace

27. How many fireplaces? Flue Open______ Flue Closed______

SKETCH OF BUILDING FLOOR PLAN

(Not included)

APPENDIX M. ON-SITE TESTING PROTOCOL

On-site Field Protocols and Procedures

Introduction

This document provides field data collection protocols and procedures for the residential portion of the Market Assessment of Permitting and Compliance study (HVAC 6). Its purpose is to ensure rigorous onsite data collection, allowing analysts to verify compliance with 2008 Title 24. Section 2 allows evaluation of fan airflow and fan power draw, Section 3 allows evaluation of refrigerant charge and power draw for condensing units, Sections 4 and 5 allow evaluation of duct leakage and building infiltration, and Section 6 provides for the collection of building characteristics to support evaluation of system sizing. This document covers all onsite activities conducted during the initial and any subsequent site visits. Refer to the M&V plan for details related to the instrumentation discussed in this document.

Airflow Testing Protocol

Temp/RH and AHU Power Logger Installation Procedure

1. Attach a Hobo Micro Station data logger (with two temp/RH sensors) to a computer, open Hoboware and launch the logger. Make sure that the logging interval is one minute and that Start Logging is set to Interval. Place the Micro Station in an outdoor shaded area near the condensing unit to capture ambient temperature and RH. Choose a location that will remain in the shade throughout the site visit. Place one Temp/RH sensor near the intake grill; place the other on top of the condensing unit in the path of the air from the fan.

2. Launch a second Micro Station in the same manner and place the Temp/RH sensors in the return plenum or register.

3. For power-plug-equipped (non-hard-wired) air handlers, make sure the unit is turned off at the thermostat and plug the air handler into a plug load meter (Watt's Up or equivalent).

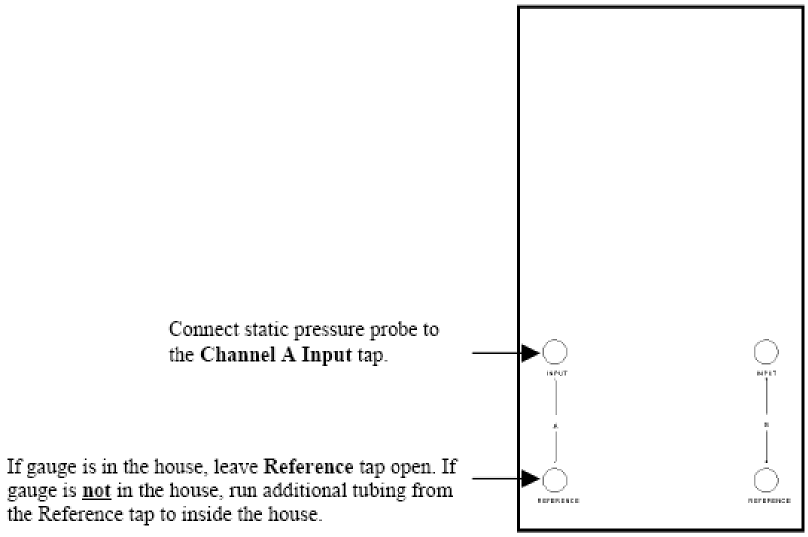
True Flow Test Procedure

Perform the True Flow test as follows:

1. Record External Static Pressure (static pressure across unit):
    a. Turn the system on and let it run for fifteen minutes to reach equilibrium (fifteen minutes should yield a wet evaporator coil).
    b. Once the system has reached equilibrium, record the static pressure. With the system running, place one static probe in the return plenum and one in the supply plenum. Use the DG-700 to record the pressure across the unit. Record the static pressure and time on the site instrument.
2. Measure Normal System Operating Pressure (NSOP):
    a. Install the static pressure probe at any of three locations:
        i. Into the side surface of the supply plenum.
        ii. In a "dead-end" corner of the supply plenum.
        iii. In the side surface of the return plenum. The side of the return plenum used should not have a trunk line, return duct or return register connected to it, and should be located at least 24 inches upstream from the True Flow metering plate and at least 24 inches from any 90° corners. (But don't use the return plenum for the static pressure probe if the system has a remote filter grille.)

Connect the static pressure probe using a tube to the **Channel A Input** tap on a DG 700 gauge.

Point the probe into the direction of air flow. If you're not sure of the direction, rotate the probe until the lowest pressure is displayed. This will minimize the effect of air velocity on pressure readings. If necessary, run a tube from the DG 700 gauge to inside the building.



Make sure all supply and return registers are open. Open a window or door between the building and outside to prevent pressure changes in the building during the test. If the air handler fan is installed in an unconditioned zone (e.g. crawlspace, attic), open any vents or access doors connecting that zone to the outside (or to the building) to prevent pressure changes in the zone during the test.

Using the DG 700:

Push the Mode button 4 times to "PR/AH". The NSOP icon will begin flashing in the Channel A display

Once the unit has reached steady state press the Start button to begin NSOP measurement. In the Channel B display window a timer will begin counting. The Channel A display window will average out the NSOP readings taken. Be careful not to step on the tube or move the pitot during this period. After the Pressure reading has stabilized for 2 to 3 minutes, simultaneously record on the site form the NSOP pressure from the Channel A display and press the Enter button on the DG 700.

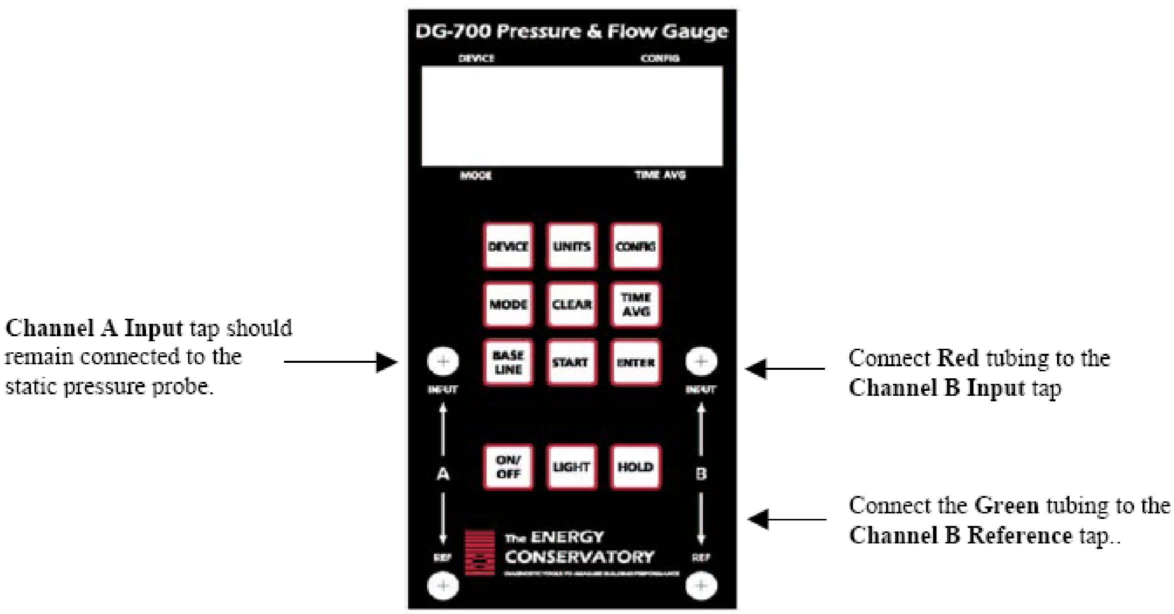
The NSOP value is now stored in the gauge. On Channel B, ADJ should appear in the window. In the next test the gauge will calculate the Adjusted cfm for you. **DO NOT wait until the system is turned off to press enter. Note that if unable to run a tube from the second pressure tab into the building, the user must manually record the NSOP reading. The differential pressure measured across the building envelope will have to be added to this value.**

Measure TFSOP and airflow:

Make sure you DO NOT turn off the DG700 Pressure Gauge.

Turn the unit off and replace the filter with the TrueFlow metering plate(s). (For systems with two returns, place the TrueFlow plates at the air handler if possible. If it's not possible, then place a TrueFlow plate in both returns, measure the flows separately as described below, and add the flows together.) Make sure the face of the grid with diamonds faces into the air flow. All filter positions MUST be filled with TrueFlow plates. Use enough plates and adapters to completely fill the filter rack. Adjust the plate seals to make sure no air bypasses the plates. Take pictures of the plate installation. Close all panels while being careful not to pinch the tubes. It may be necessary to drill a small hole in the panel or filter grate to run the tubes through. If the TrueFlow metering plate is installed at a remote return, please note this on the site instrument. The airflow measurement will be biased by leakage in the return ducts and this will be taken into account during analysis.

From one of the metering plates, connect the Red pressure tube to the Channel B Input and the Green pressure tube to the Channel B Reference.



a. If the system is off, turn it back on.
b. Using the DG 700:
   i. Push the Device button 6 times to display TF on Channel A
   ii. Push the Config button to display plate 14 or 20 on Channel B depending upon the plate you are using.
   iii. Channel A displays the TFSOP and Channel B display the Adjusted cfm. Record 3 sets of measurements. **If it was necessary to measure differential pressure across the building envelope (i.e. the reference probe for tap A is not located within the space), the user must record the actual differential pressure readings across the True Flow plate on channel B. These readings will be used with NSOP,**

TFSOP, and envelope differential pressure to calculate airflow back in the office.

c. If more than one plate is installed in the unit, repeat steps d and f for all plates.

3. Take indoor fan spot power measurements.
   a. Ensure measurements are recorded over a wet evaporator coil.

   b. For non-hardwired air handlers record the values from the Watts-Up installed earlier. If the air handler is hardwired, don the proper PPE, brief your safety observer, and conduct spot measurements of fan at panel with a power meter (Amprobe or equivalent).

   c. If possible, also perform spot power measurements across just the fan.

   d. Record power, power factor, and time for AHU/furnace unit and, if possible, just the fan.

4. Turn system off and return to pre-test conditions, except for reinstalling filters (which should remain uninstalled during duct leakage tests). Remove the Watts-Up meter if installed.

Refrigerant Charge and Condensing Unit Power Spot Test Procedure

This test can only be performed if the condenser air entering temperature (a value close to outside ambient temperature) is greater than 55°F. If the condenser air entering temperature is between 55° and 65°F, establish a return air dry bulb temperature in plenum sufficiently high that the return air dry bulb temperature will be not less than 70°F prior to the measurements at the end of the 15 minute period.
Note: This test can be set up and performed in conjunction with the airflow test.

Test the AC system for correct refrigerant charge

4. Ensure system is off and disconnect the power outside at the A/C unit. Remove panels as necessary to access power lines in order to take spot power measurements.

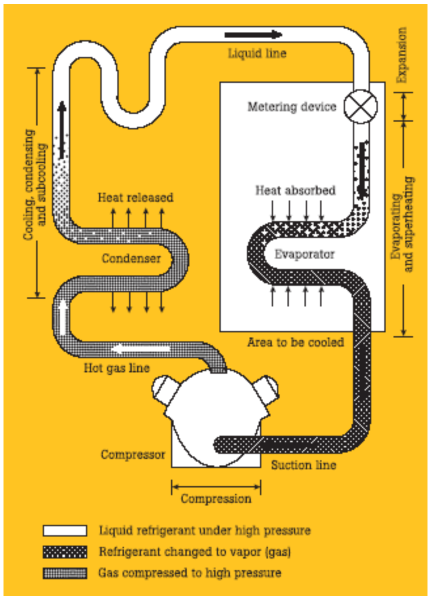
5. Photograph condenser coils, unit location, Schrader valves. Note any damage. For split systems, measure and record the diameter of the suction line and the thickness of insulation on the suction line between condensing unit and structure. Also make a note if there is no insulation or if the insulation appears badly weathered.

6. Turn the A/C system on so it begins to reach steady state. Ensure that the temperature setting on the thermostat is low enough that it won't cycle off during testing. If necessary, use jumper leads (or cycle through the test modes on more modern units after referring to the unit manual) to force the unit into cooling mode.

7. Check for refrigerant leaks along refrigerant lines, especially around service valves. Record location and intensity of leaks (number of LEDs lit on most refrigerant meters indicates intensity). Use tape for high intensity leaks and if sealed make customer/decision maker aware of temporarily sealed leaks. Abort test if high intensity leaks cannot be temporarily sealed.

8. Have Schrader valve repair tool and extra cores easily accessible. Slowly unscrew service caps and check for leaks. Repair cores as needed to test unit.

9. At the outdoor condensing unit identify the suction and discharge lines using the infrared thermometer if available.



Note:

- **Suction side = cold large insulated pipe**
- **Discharge/liquid (line) side = hot smaller pipe, may not be insulated**

10. Service valves are typically located inside the panels of packaged systems, necessitating the removal of side panels or fan grill covers to access the refrigerant lines and possibly the test valves. Split systems will generally have test ports outside the condensing unit. In both cases, test ports are sometimes located on dead end runs of the refrigerant lines where temperature readings are generally inaccurate. The temperature probes should be installed to measure evaporator input and output temperature. The evaporator outlet or suction line temperature will be measured close to the input of the compressor. The evaporator output or liquid line temperature will be measured between the condenser coil and evaporator coil. To the best of your ability, run the temperature sensor lines and pressure hoses outside of package systems so that any panels affecting airflow can be replaced and the system returned as closely as possible to normal operating conditions. Attach the appropriate pressure gauge or manifold (R-22 or R-410a) to the service port(s).

a. Hoses should be filled with the appropriate refrigerant prior to testing

b. Always wear appropriate Personal Protective Equipment (PPE) including gloves and safety glasses when connecting or removing pressure hoses.

11. Attach one K-type "pipe clamp" temperature sensor to the suction line near the logger's temperature sensor. Attach the K-type connector to a Fluke Type 52-II digital thermometer (or similar).

12. Position the logging suite's ambient temperature sensor so that it records condenser entering air dry-bulb and is out of direct sunlight. Take pictures of all temperature sensor locations whenever possible.

13. Be sure that all unit cabinet panels that affect airflow over the coil(s) are in place before making measurements. The temperature sensors shall remain attached to the system until logging is complete.

MAKE SURE UNIT HAS BEEN RUNNING FOR AT LEAST 15 MINUTES BEFORE RECORDING MEASUREMENTS

14. Record the readings on the Crystal gauge and thermometer attached to the suction line, move the Crystal gauge and "pipe clamp" temperature sensor to the discharge/liquid line, let the readings stabilize, and record the pressure and temperature readings for the discharge/liquid line.

Take Spot Power Measurements for Condensing Unit

1. Suit up. Make sure you properly use all appropriate Personal Protective Equipment (PPE) and follow all DNV GL safety procedures.
2. Take phase-to-ground spot power measurements on the condenser unit using the power meter. (Residential systems will typically have single-phase 240V power, tapped to provide two 120V legs, but if 3-phase power is found you will record spot power measurements on all three legs.) Record volts, amps, power, power factor (pf), and time. Spot measurements should be taken on the line side of the disconnect whenever possible.

3. Wait a minute and take another set of spot power measurements. Then move the amp clamp over to the next leg and record two more sets of measurements, then repeat for the 3rd leg if equipped.

4. Turn the system off and wait for the compressor to cycle off. First turn the ball valve on the Crystal gauge hose to the off position. Next disconnect all pressure hoses and remove all temperature sensors. Replace any cabinet panels that were removed and return system to pre-test conditions.

5. Do not discharge refrigerant from the hose once removed. All of the hoses will be equipped with a seal-right valve on the test port side and a locking ball valve on the gauge side. This should enable the hoses to retain the refrigerant for a week's worth of site visits. At the end of the week it is a good idea to discharge the refrigerant and relieve the pressure on the hoses prior to storage.

6. Run the unit to ensure proper operation.

7. Check for refrigerant leaks along refrigerant lines, especially around service valves. Record location and intensity of leaks (number of LEDs lit on most refrigerant meters indicates intensity). If new leaks were introduced, consult senior staff for appropriate actions.

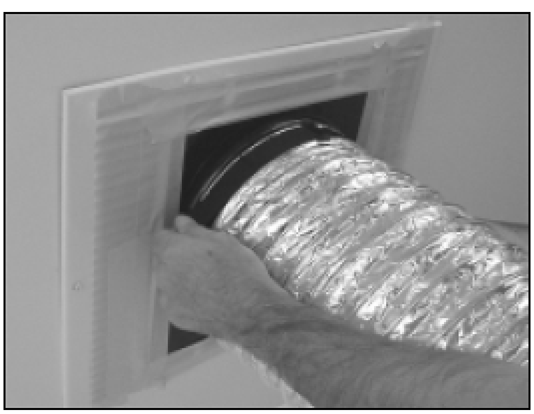
8. Remove the Micro Station logger from the return plenum or register.

Total Duct Leakage Testing Protocol

1. Make sure all air filters are removed.

2. Tape all system registers with Duct Sealing tape. Use appropriate tape (Blue Painters Tape) for friable surfaces.

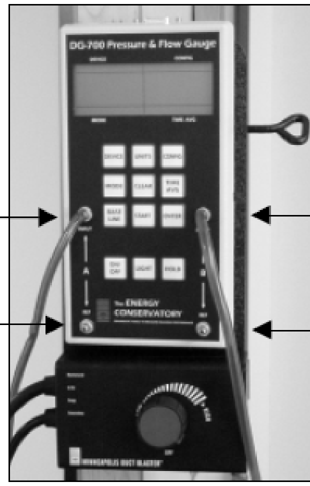
3. Install the duct blaster at the duct system at the central return or air handler cabinet (the return will be the most common installation). In the case of multiple returns, seal off the smallest returns and use the largest return for the test.



4. Connect the **Green** pressure tubing to the **Input** tap on **Channel A** and the **Red** pressure tubing to the **Input** tap on **Channel B.**

Connect the **Green** tubing to the **Channel A Input** tap. ***The other end of the Green tubing will be connected to the duct system (section 5.5.a).***

Channel A Reference tap should be connected to the inside of the building (if the Duct Blaster fan is installed inside the building, leave the tap open).

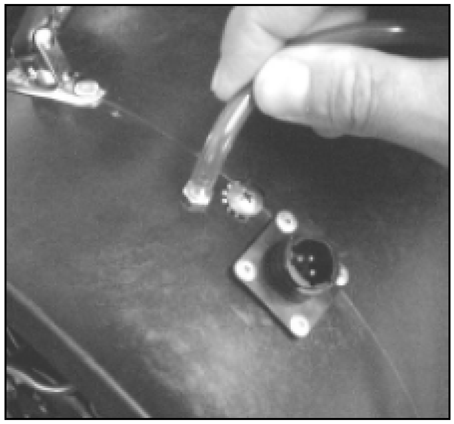


Connect the **Red** tubing to the **Channel B Input** tap. ***The other end of the Red tubing will be connected to Brass tap on the Duct Blaster fan (section 5.6.a).***

Channel B Reference tap should be connected to the space where the Duct Blaster fan is installed. If the fan and gauge are in the same space, leave the tap open.

5. **Connect** the other end of the **Green** pressure tube to the static pressure probe **and insert probe into a supply register** and re-tape to secure probe in place making sure to seal register. Take a picture of this location when possible.

6. **Connect** the other end of the **Red** pressure tube to the duct blaster fan.



7. **After making certain the fan controller is off,** connect the controller to the duct blaster fan by the female power receptacle and plug into power supply.

Performing Total Duct Leakage Pressurization Test

1. Turn on Duct blaster Fan and Pressure Gauge
2. Push **Mode** button to **PR/FL@25Pa**
3. Push the **Device** button until **DB B** is **displayed on the Channel A side**
4. Next push the **Config** button to select a flow ring **(Open = no ring, A1 = ring 1, B2 = ring 2, C3 = ring 3)** and install the matching flow ring onto the fan housing.
5. **Adjust** duct blaster fan speed control until **Channel A** reads as close as possible to **25 Pa;** if you're unable to reach 25 Pa, try another flow ring (remembering to reset the DG-700 accordingly).

Note: ***For extremely leaky duct work no adjustments to the test are necessary if you cannot reach 25 Pa. The DG700 gauge has the built in correction factor function when used in PR/FL@25 Pa Mode; it will automatically adjust the cfm leakage estimate for you.***

6. **Record pressure, flow, and time**

7. **Repeat steps 1-5 with duct blaster test pressure of 50 Pa**

8. **Record** values and **check** flow exponent. (To check each test, calculate flow exponent as for the blower door test (previous page). The flow exponent, $n, = \frac{\mathrm{Ln}\left(\frac{Q50}{Q25}\right)}{\ln\left(\frac{P50}{P25}\right)}$ where Q is flow rate and P is pressure. If flow exponent is not between 0.50 and 0.75, repeat the test.)

9. If flow exponent is within range, test is complete.

10. Note any unusual testing conditions (wind, etc.)

11. Calculate the total duct leakage at 25Pa as a percentage of nominal system airflow (400 cfm/ton of cooling). If leakage is less than 15% proceed to 0 (Building Shell Data Collection).

12. If leakage exceeds 15%, the duct system may still be Title-24-compliant; Title 24 allows either a) no more than 15% total duct leakage or b) no more than 10% leakage to outside. The team leader will make a judgment call whether to continue with leakage-to-outside testing based on the apparent distribution of ductwork between conditioned and unconditioned spaces.

    a. If most of the ductwork is in unconditioned space, there is a good chance that the bulk of total leakage is also leaking outside the envelope and the duct system will fail the 10% test as well. In this case the team leader may decide not to perform the leakage-to-outside test, but must document the reasons behind the decision not to test.

    b. If a large proportion of the ductwork is in conditioned space, much of the duct leakage may be into the envelope and the system could pass the 10% test. In this case the team should proceed with leakage-to-outside testing.

While good judgment is expected, the leakage-to-outside test is not optional. It's merely unnecessary if the outcome of the test appears clear to the team leader. If you have any doubt about whether to run the leakage-to-outside test, run it.

Infiltration and Duct Leakage-To-Outside Testing Protocol

Install Blower Door

1. Close all windows and doors to the outside.

2. Open all interior doors and supply registers.

3. Close all dampers and doors on wood stoves and fireplaces. Seal fireplace or woodstove as necessary.

4. Make certain furnace and water heater cannot come on during test.

5. Put water heater and/or gas fireplace on "pilot" setting (if equipped with a pilot light) or "off" (if equipped with electronic ignition).

6. Make certain all exhaust fans and clothes dryers are off.

7. Make certain any other combustion appliances will not be back-drafted by the blower door.

8. Make certain doors to interior furnace cabinets are closed.

9. Also make certain the crawlspace hatch is on, even if it is an outside access.

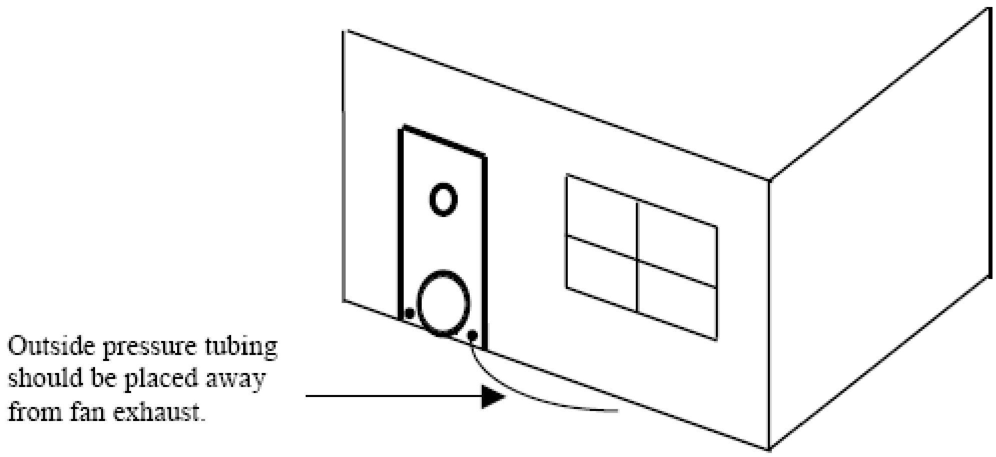
10. Check attic hatch position.

11. Put garage door in normal position.

12. If dryer is not installed, seal off dryer vent.

13. Setup and install Blower door frame in an exterior doorway – but do not put fan in opening yet.

14. Put the Green pressure tubing through one of the openings in the door, run it at least 5 feet to the side making sure that the end of the tubing is placed well away from the exhaust flow of the Blower Door fan. If it's windy, place the end of the tubing midway into an empty cup or bottle to reduce the direct effect of the wind.



15. Install the Blower door fan in the opening making certain the elastic band fits snugly around the fan with the collar resting in between the two sides of the electrical box.

16. Attach the fan to the cross bar with the Velcro strap. The fan should now be suspended in the door with the flow plate side facing towards you.

17. Attach DG-3 pressure gauge to mounting board and put on gauge hanger.

1

2

3

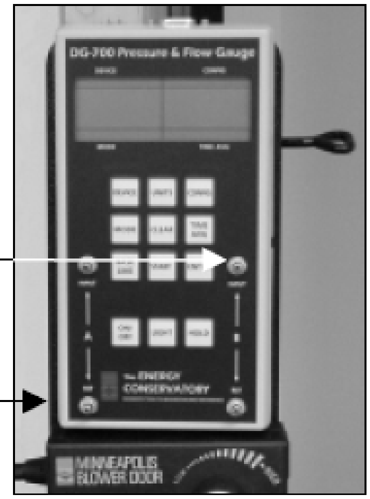
18. Connect the Red pressure tubing to the Channel B Input Tap and connect the other end to the pressure tap located on the blower door fan.

19. Connect the Green pressure tubing to the Channel A Reference Tap

3.5.a DG-700 Gauge:

Connect the **Red** tubing to the Channel B Input tap. ***Channel B is used to measure Fan pressure and flow.***

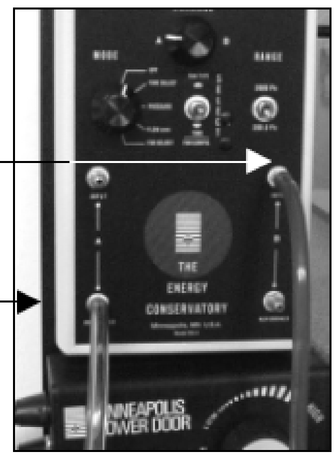
Connect the **Green** tubing to the Channel A Reference tap. ***Channel A is used to measure building pressure with reference to outside.***



3.5.b DG-3 Gauge:

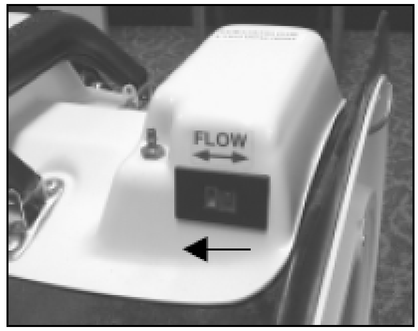
Connect the **Red** tubing to the Channel B Input tap. ***Channel B is used to measure Fan pressure and flow.***

Connect the **Green** tubing to the Channel A Reference tap. ***Channel A is used to measure building pressure with reference to outside.***



1. After making certain the fan speed controller is off, insert plug into blower door fan and connect to power supply.

2. Make certain fan direction switch is positioned towards the direction of airflow; air must flow into the house to pressurize it.



Exterior Duct Pressurization (Leakage to Outside) Test Procedures Using the DG700

1. Set Blower Door fan direction switch so airflow is directed into the home.
2. Turn on the Duct Blaster fan and the pressure gauge.
3. Push **Mode** button to **PR/FL**
4. Push the **Device** button until **DB B** is **displayed on the Channel A side**
5. Next push the **Config** button to select a flow ring **(Open= no ring, A1 = ring 1, B2 = ring 2,C3 = ring 3)** and install the matching flow ring onto the fan housing.
6. With all rings removed from the Blower Door fan, pressurize the house to 50 Pa.
7. **Adjust** duct blaster fan speed control until **Channel A** reads **0 Pa** or **as close as possible**
8. **Recheck** the Blower Door to make sure test pressure has been maintained.
9. **Recheck** duct blaster fan pressure and adjust if necessary and **record values**
10. **Repeat steps 1-8 with blower door test pressure at 25 Pa.**
11. Record values and check flow exponent**:** $n = \ln(Q_{NSOP}/Q_{NSOPH})/\ln(NSOP/NSOP_H)$. If flow exponent is not between 0.50 and 0.75, repeat the test**.**
12. If flow exponent is within range, the test is complete.
13. Uninstall the duct blaster fan, un-tape all supply and return registers, and replace the filter(s).
14. Note any unusual testing conditions (wind, etc.)

Perform Blower Door Depressurization Test

1. Replace the Blower Door fan's DG-3 with the DG-700 from the duct leakage tests. Turn it on and press the Mode button twice for PR/FL@50
2. If BD3 is not displayed on Channel A push Device until BD3 is displayed

3. Push the Configure button until the installed flow ring is displayed on Channel B. Typically you should start with ring B2 (Open= No Ring, A1= ring A, B1= ring B). The rings on the blower door fan are labeled as such.
4. If you cannot get an accurate flow you will need to add or remove flow rings on the blower door fan as well as change the Config setting for the appropriate ring. If LO appears in the Channel B window it means that the gauge cannot accurately calculate the flow, and a different flow ring should be used.
5. Change Blower Door fan direction switch so airflow is directed out of the home. Turn on the fan and increase the fan speed until you get a pressure reading on Channel A between -45 and -55 Pa. The gauge when in PR/FL@50 mode will automatically adjust, so don't worry about getting exactly to 50 Pa
6. Once you have reached a pressure that is acceptable press the Hold button
7. Record the BD ring used, House pressure near -50Pa on Channel A, and the BD cfm@50 value on Channel B.
8. Press the HOLD button again to release the hold and PRESS MODE button to PR/PR and record BD FAN PRESSURE value from CHANNEL B.
9. Repeat test at 25Pa and QC using the flow exponent equation* (make sure to set the Mode to PR/FL@25)
10. If Flow exponent checks out no further tests are required.

*To check test, calculate the flow exponent, n. Use the formula $\boldsymbol{n} = \frac{\boldsymbol{ln}\left(\frac{Q50}{Q25}\right)}{\boldsymbol{ln}\left(\frac{P50}{P25}\right)}$ where Q50 and Q25 are the flows through the blower door at the testing pressures (which are denoted P50 and P25). Depending on the test, you may not get the house to exactly –50 or –25 Pa WRT outside. Use the actual ΔP you measure when checking the flow exponent. For example, if the house gets to –48 Pa for the high ΔP, use this as the P50 in the equation. If the flow exponent is not between 0.50 and 0.75, repeat the test.

Building Shell Data Collection

Once the power logging equipment has been installed and QC'ed and airflow testing is complete, field staff should work together to complete the site survey.

- **Perform a complete takeoff of the zone served by the serviced HVAC system.** Typically this will be the entire residence. Unless plans are provided by the site contact, the engineer will manually survey the space using a walking wheel and sketch the results on graph paper.
    - Indicate the front orientation of the home
    - Indicate the total conditioned space of the zone served by the HVAC system
    - Indicate the total ceiling area of the zone served by the HVAC system

- All exterior walls will also be explicitly noted. Floor-to-ceiling heights will be recorded, as well as floor-to-floor (or floor-to-roof) heights
  - Framing type
  - Frame spacing
  - Wall cavity R-value
  - External wall R-value
- Exterior windows will also be measured and assigned to their respective walls. Identified window characteristics will be limited to:
  - Frame type
  - Number of panes
  - Tinted/Low-E coating.
  - Overhang and Sidefin Presence:
    - Distance from the top of the window
    - Horizontal projection
    - Left or right extension past the window
- Roof type and color will be recorded. Identified roof characteristics will be limited to:
  - Roofing Material
  - Vaulted/Flat
  - Insulation Type
  - Insulation Depth
  - Insulation R-value
- Floor types will be recorded. Identified floor characteristics will be limited to:
  - Square footage
  - Slab/Crawl/Over Conditioned Space/Over Unconditioned Basement/Other
  - Insulation Type
  - Insulation R-value
- Exterior shading by other buildings or trees should be recorded on both the site sketch and by taking pictures of elevations in each orientation
- All interior walls to adjacent spaces will be identified
- If air walls, then record tonnage of nearby units and register locations inside the common space

- **Record key space schedules.**
  - HVAC temperature set points for heating and cooling will be recorded from thermostats.

Cleanup and Teardown Checklist

1. Remove Watts-Up logger
2. Check all registers for tape and make sure they're open/closed as found
3. Re-enable exhaust fans, untape clothes dryer vents
4. Ensure filter(s) are reinstalled
5. Remove condensing unit logger and return air logger
6. Make sure HVAC system is operating properly and thermostat is controlling the unit as-found (e.g. cooling on, scheduled program being followed)
7. Give incentive gift card to resident and obtain signature on Incentive Verification Form

Tool Checklist

1. Duct Blaster and Blower Door equipment sets, register tape, blue painters' tape, duct tape, UL-Rated Metal Tape, "cruise control" cable to connect DG-700 to fan controller, serial/USB cable to connect DG-700 to computer
2. Amprobe and Watt's-Up for spot power readings
3. (1) Hobo Micro Station with two S-THB-M002 temp/RH sensors and serial/USB cable
4. Two digital pressure gauges (Crystal Engineering XP2i or equivalent) with all necessary hoses and couplings, +/-0.1% reading, 1000 psi model. One will be charged with R-22 and one with R-410a.
5. Infrared thermometer
6. 2 RTD surface probes Class B or better, +/- 1 °F @ 150 °F, and insulating tape
7. RTD ambient probe Class B or better, +/- 1 °F @ 150 °F
8. RTD bead probe Class B or better, +/- 1 °F @ 150 °F
9. 1-2 digital RTD thermometers
10. Humidity and temperature meter, +/- 1 °F, +/- 2% RH (Vaisala H41 or equivalent)
11. True Power meter, +/- 2% of reading for true RMS power, (Fluke 49 or equivalent)
12. Refrigerant Leak Detector, heated diode or infrared, 0.2 oz./year sensitivity or better, must detect R-410a
13. Schrader cores and repair tool
14. Service tool and Hex extension for back seated valves
15. Cell phone, camera, mini-first-aid kit, tape measure and walking wheel, 6-1 tool, small screwdriver, pliers, wire strippers, wire cutters, electrical safety gloves, safety glasses, ladder, low-e detector, screw drivers, gloves, steel wool and rags

APPENDIX N. COMPARISON OF RESULTS FOR HERS AND DNV GL FIELD TESTS

This section includes the HERS Raters' test results for each of the three compliance tests as well as the results of DNV GL's tests (performed according to HERS procedures).

Figure 64. Duct leakage results

HVAC6 ID	Duct test needed?	Correct duct form found?	HERS allowable duct leakage (cfm)	HERS duct leakage (cfm25)	DNVGL duct leakage (cfm25)
LCSZ9XX-233	Yes	Yes	300	260	325
SCSZ8XX-74	Yes	No form			161
PXSZ2XX-15	Yes	Yes	124	68	73
PPSZ3XX-91	Yes	Yes, but leakage null	NULL	NULL	147
SCSZ9C2-29	Yes	Incorrect form, should have been 08-T31-CF4R_MCH-20 and 6% leakage instead of existing duct form and 15% leakage	326	291	324
LCSZ9XX-149	Yes	Incorrect form, should have been 08-T31-CF4R_MCH-20 and 6% leakage instead of existing duct form and 15% leakage	244	164	161
PPDZ2XX-18	Yes	Yes	140	112	105
SXCZ15XX-8	Yes	Yes, but leakage null	NULL	NULL	147
PPSZ3XX-431	Yes	Yes, but leakage null	NULL	NULL	99
LCSZ9C2-3	Yes	Incorrect form, should have been 08-T31-CF4R_MCH-20 and 6% leakage instead of existing form and 15% leakage. Also, leakage test values missing on form.	NULL	NULL	694
PXSZ12XX-22	Yes	No form			47
SCSZ9XX-261	Yes	Yes	120	107	152
SCSZ9XX-110	Yes	Yes	84	43	114
PPSZ13C4-46	Yes	Incorrect form, but more stringent standard so OK	150	145	236
PPSZ12C3-171	Yes	Yes	120	104	96
PXSZ12C4-20	Yes	Yes, passed using smoke test.	150	211	296
DDSZ10XX-69	Yes	Yes, passed using smoke test.	180	540	266
PPDZ12C2-11	Yes	Yes	83	80	200
PPSZ12C2-99	Yes	Yes	210	89	48
PPSZ4XX-87	Yes	Yes	127	50	45
PXSZ12C2-26	Yes	No form			562
SCDZ15C2-2	Yes	No form			525
SCSZ10C2-98	Yes	Yes	240	131	dk

HVAC6 ID	Duct test needed?	Correct duct form found?	HERS allowable duct leakage (cfm)	HERS duct leakage (cfm25)	DNVGL duct leakage (cfm25)
SCSZ6XX-33	Yes	Yes, passed using smoke test.	180	540	372
SCSZ9C2-71	Yes	Yes	111	109	166
SCSZ9C3-46	Yes	Yes	240	109	66
SXSZ10XX-9	Yes	Yes	300	293	dk
SXSZ14C2-24	Yes	Yes	300	293	245

Figure 65. HVAC system airflow test results

HVAC6 ID	Site collected duct changes	Airflow test needed?	Correct airflow form found?	HERS fan flow (cfm)	DNV GLfan flow (cfm)
LCSZ9XX-233	None	No	N/A		1042
SCSZ8XX-74	All	Yes	No form		516
PXSZ2XX-15	All	Yes	No form		1150
PPSZ3XX-91	Over 40'	No	N/A		1236
SCSZ9C2-29	All	Yes	No form		1438
LCSZ9XX-149	All	Yes	No form		940
PPDZ2XX-18	None	No	N/A		dk
SXCZ15XX-8	None	No	N/A		4348
PPSZ3XX-431	None	No	N/A		dk
LCSZ9C2-3	All	Yes	No form		1174
PXSZ12XX-22	All	Yes	Yes	720	714
SCSZ9XX-261	40' or Less	No	N/A		1143
SCSZ9XX-110	All	Yes	No form		485
PPSZ13C4-46	None	No	N/A		1002
PPSZ12C3-171	None	No	N/A		756
PXSZ12C4-20	None	No	N/A		320
DDSZ10XX-69	None	No	N/A		dk
PPDZ12C2-11	40' or less	Yes	No form		
PPSZ12C2-99	40' or more	Yes	No form		1154
PPSZ4XX-87	40' or less	No	N/A		
PXSZ12C2-26	40' or more	Yes	No form		911
SCDZ15C2-2	40' or less	No	N/A		
SCSZ10C2-98	dk	No	N/A		dk
SCSZ6XX-33	None	No	N/A		
SCSZ9C2-71	40' or more	Yes	No form		838
SCSZ9C3-46	40' or more	Yes	No form		2202
SXSZ10XX-9	40' or less	No	N/A		
SXSZ14C2-24	dk	No	N/A		1124

Figure 66. Review of refrigerant charge test forms

HVAC6 ID	Standards year	Climate zone	Site collected HVAC change-out type	Cooling type	RCA test needed ?	Correct RCA form found?
LCSZ9XX-233	2008	9	Both	Split-system	Yes	Yes
SCSZ8XX-74	2013	8	Both	Split-system	Yes	Yes, but null
PXSZ2XX-15	2008	2	Furnace only	Forced Air Furnace	No	N/A
PPSZ3XX-91	2013	3	Both	Split-system	No	Yes, though not needed in CZ 3
SCSZ9C2-29	2008	9	Both	Split-system	Yes	Yes
LCSZ9XX-149	2008	2	Both	Split-system	Yes	No form
PPDZ2XX-18	2008	2	Furnace only	Forced Air Furnace	No	N/A
SXCZ15XX-8	2008	1	Both	Packaged Unit	No	N/A
PPSZ3XX-431	2013	3	Furnace only	Forced Air Furnace	No	N/A
LCSZ9C2-3	2008	9	Both	Split-system	Yes	No form
PXSZ12XX-22	2013	12	Both	Packaged Unit	No	N/A
SCSZ9XX-261	2008	9	Both	Split-system	Yes	No form
SCSZ9XX-110	2008	9	Both	Split-system	Yes	No form
PPSZ13C4-46	2008	13	Both	Packaged Heat Pump	No	N/A
PPSZ12C3-171	2013	12	Both	Packaged Unit	No	N/A
PXSZ12C4-20	2008	12	Both	Packaged Unit	No	N/A
DDSZ10XX-69	2013	10	Both	Split-system	Yes	Yes
PPDZ12C2-11	2013	12	Both	Split-system	Yes	No form
PPSZ12C2-99	2008	12	Cooling system	Split-system	Yes	Yes
PPSZ4XX-87	2013	4	Heating system	Forced Air Furnace	No	N/A
PXSZ12C2-26	2008	12	Both	Packaged Unit	No	Yes, though package unit not required
SCDZ15C2-2	2008	15	Both	Split-system	Yes	No form
SCSZ10C2-98	2008	10	Both	Split-system	Yes	Yes
SCSZ6XX-33	2013	6	Both	Split-system	No	N/A
SCSZ9C2-71	2013	9	Both	Split-system	Yes	Yes
SCSZ9C3-46	2013	9	Both	Split-system	Yes	Yes, but null
SXSZ10XX-9	2008	10	Both	Packaged Unit	No	N/A
SXSZ14C2-24	2008	14	Both	Split-system	Yes	Yes

Figure 67. Refrigerant charge test results

HVAC6 ID	HERS fan flow	System capacity [tons]	DNVGL airflow /ton	HERS actual SC-target SC	DNV GL actual SC - target SC	HERS target SC	DNV target SC	Notes
LCSZ9XX-233	"pass"	5.0	208	-1	-7.8	10	13	Target SC found on unit sticker.
SCSZ8XX-74	NULL	4.0	129	NULL	-5.4	NULL	8	
SCSZ9C2-29	"pass"	4.0	360	1.1	-2.0	10	10	Target SC found in installation manual
DDSZ10XX-69	"complies"	3.0	DK	3	3.0	10	10	Target SC not found, condenser nameplate model number not legible. Assumed target SC=10
PPSZ12C2-99	"pass"	4.0	289	0.8	7.7	6	9	Target SC found in technical manual, pg. 12
PXSZ12C2-26	"complies"	2.0	456	0	DK	10	N/A	SC performed by HERS Rater though not required on package unit and not appropriate for unit with piston metering device.
SCSZ10C2-98	"pass"	3.5	DK	3	14.4	10	7	Target SC found by calling manufacturer. Because the evaporator coil was non-Lennox the manufacturer does not publish SC values. However, tech support recommended 5-7 degrees SC.
SCSZ9C2-71	"complies"	4.0	210	-2.3	21.9	4	10	Target SC not found, model number not recorded by DNV GL team. Assumed target SC=10
SCSZ9C3-46	NULL	4.0	551	NULL	-3.7	NULL	10	
SXSZ14C2-24	"pass"	5.0	225	3	1.4	15	15	Target SC found on unit sticker

APPENDIX O. HERS RATER COMPLIANCE FORM (CF3R) TEMPLATES

This appendix presents the compliance form templates used in our analyses (Figure 22 through Figure 39). These include:

- 2008-CF4R_MEC-20, 2013-CF3R-MEC-20: Duct leakage diagnostic test for new or replaced ducts
- 2008-CF4R_MEC-21, 2013-CF3R-MEC-21: Duct leakage diagnostic test for existing ducts
- 2008 CF3R-MCH-22, 2013 CF3R-MCH-22: Air flow and fan power index
- 2008 CF4R-MCH-25, 2013 CF3R-MCH-25: Refrigerant charge verification

For the full set of 2013 compliance forms, please refer to Appendix A of the 2013 Standards (CEC, 2013) at http://www.energy.ca.gov/title24/2013standards/res_compliance_forms/2013_Appendix_A_Compliance_Forms_List.pdf.

Figure 68. Duct Leakage Diagnostic Test Form, 2013 Standards, CF3R-MCH-20a

STATE OF CALIFORNIA

DUCT LEAKAGE DIAGNOSTIC TEST 3006

CEC-CF3R-MCH-20-H (Revised 06/13)

CALIFORNIA ENERGY COMMISSION

CERTIFICATE OF VERIFICATION	CF3R-MCH-20-H
Duct Leakage Diagnostic Test	(Page 1 of 3)

Project Name:	Enforcement Agency:	Permit Number:
Dwelling Address:	City	Zip Code

A. System Information

01	Space Conditioning System Identification or Name:	1
02	Space Conditioning System Location or Area Served:	2
03	Building Type from CF1R	3
04	Verified Low Leakage Ducts in Conditioned Space (VLLDCS) Credit from CF1R?	4
05	Verified Low Leakage Air-handling Unit Credit from CF1R?	5
06	Duct System Compliance Category:	6

MCH-20a - Completely New Duct System 7

B. Duct Leakage Diagnostic Test

01	Condenser Nominal Cooling Capacity (ton)	12
02	Heating Capacity (kBtu/h)	13
03	Conditioned Floor Area Served by this HVAC System (ft2)	14
04	Duct Leakage Test Conditions	15
05	Duct Leakage Test Method?	16
06	LeakageFactor ( )	17
07	Air-Handling Unit Airflow (AHUAirflow) Determination Method	18
08	Measured AHUAirflow (cfm)	19
09	Calculated Target Allowable Duct Leakage Rate (cfm)	20
10	Actual duct leakage rate from leakage test measurement (cfm)	21
11	Compliance statement: 22	
12	Notes * the [illegible] allow [illegible] to provide different B1, B2 or B3 from 2R -- 33	

C. ADDITIONAL REQUIREMENTS FOR COMPLIANCE

01	System was tested in its normal operation condition. No temporary taping allowed.	
02	Outside air (OA) ducts for Central Fan Integrated (CFI) ventilation systems, shall not be sealed/taped off during duct leakage testing. CFI OA ducts that utilize controlled motorized dampers, that open only when OA ventilation is required to meet ASHRAE Standard 62.2, and close when OA ventilation is not required, may be configured to the closed position during duct leakage testing.	
03	All supply and return register boots were sealed to the drywall.	
04	Building cavities were not used as plenums or platform returns in lieu of ducts.	
05	If cloth backed tape was used it was covered with Mastic and draw bands.	
06	All connection points between the air handler and the supply and return plenums are completely sealed.	
	Visual Inspection at Final Construction Stage (applicable if system was tested at rough-in) After installing the interior finishing wall and verifying that the above rough-in tests was completed, the following procedure must be performed:	
07	For all supply and return registers, verify that the spaces between the register boot and the interior finishing wall are properly sealed.	
08	If the house rough-in duct leakage test was conducted without an air handler installed, inspect the connection points between the air handler and the supply and return plenums to verify that the connection points are properly sealed.	
09	Inspect all joints to ensure that no cloth backed rubber adhesive duct tape is used.	
10	Verification Status:	31
11	Correction Notes:	32

The responsible person's signature on this compliance document affirms that all applicable requirements in this table have been met unless otherwise noted in the Verification Status and the Corrections Notes in this table.

Registration Number: Registration Date/Time: HERS Provider:

CA Building Energy Efficiency Standards - 2013 Residential Compliance June 2013

Figure 69. Duct Leakage Diagnostic Test Form, 2013 Standards, CF3R-MCH-20b

STATE OF CALIFORNIA
DUCT LEAKAGE DIAGNOSTIC TEST 3000
CEC-CF3R-MCH-20-H (Revised 09/13) CALIFORNIA ENERGY COMMISSION

CERTIFICATE OF VERIFICATION		CF3R-MCH-20-H
Duct Leakage Diagnostic Test		(Page 1 of 2)
Project Name:	Enforcement Agency:	Permit Number:
Dwelling Address:	City	Zip Code

A. System Information		
01	Space Conditioning System Identification or Name:	1
02	Space Conditioning System Location or Area Served:	2
03	Building Type from CF1R	3
04	Verified Low Leakage Ducts in Conditioned Space (VLLDCS) Credit from CF1R?	4
05	Verified Low Leakage Air-handling Unit Credit from CF1R?	5
06	Duct System Compliance Category:	6

MCH-20b - Low Leakage Ducts in Conditioned Space 8

B. Duct Leakage Diagnostic Test		
01	System compliance with visual inspection per RA3.1.4.1.3? (registered MCH-21 is required)	23
02	Duct Leakage Test Conditions	15
03	Duct Leakage Test Method	16
04	Target Allowable Duct Leakage Rate (cfm)	24
05	Actual duct leakage rate from leakage test measurement (cfm)	21
06	Compliance statement: 25	

C. ADDITIONAL REQUIREMENTS FOR COMPLIANCE		
01	System was tested in its normal operation condition. No temporary taping allowed.	
02	Outside air (OA) ducts for Central Fan Integrated (CFI) ventilation systems, shall not be sealed/taped off during duct leakage testing. CFI OA ducts that utilize controlled motorized dampers, that open only when OA ventilation is required to meet ASHRAE Standard 62.2, and close when OA ventilation is not required, may be configured to the closed position during duct leakage testing.	
03	All supply and return register boots were sealed to the drywall.	
04	Building cavities were not used as plenums or platform returns in lieu of ducts.	
05	If cloth backed tape was used it was covered with Mastic and draw bands.	
06	All connection points between the air handler and the supply and return plenums are completely sealed.	
07	Verification Status:	31
08	Correction Notes:	32

The responsible person's signature on this compliance document affirms that all applicable requirements in this table have been met unless otherwise noted in the Verification Status and the Corrections Notes in this table.

D. Determination of HERS Verification Compliance	
All applicable sections of this document shall indicate compliance with the specified verification protocol requirements in order for this Certificate of Verification as a whole to be determined to be in compliance.	
01	3000

Registration Number: Registration Date/Time: HERS Provider:
CA Building Energy Efficiency Standards - 2013 Residential Compliance June 2013

Figure 70. Duct Leakage Diagnostic Test Form, 2013 Standards, CF3R-MCH-20c

~~STATE OF~~ CALIFORNIA
DUCT LEAKAGE DIAGNOSTIC TEST 3000
CEC-CF3R-MCH-20-H (Revised 06/13)
CALIFORNIA ENERGY COMMISSION

CERTIFICATE OF VERIFICATION	CF3R-MCH-20-H
Duct Leakage Diagnostic Test	(Page 1 of 3)

Project Name:	Enforcement Agency:	Permit Number:
Dwelling Address:	City	Zip Code

A. System Information		
01	Space Conditioning System Identification or Name:	1
02	Space Conditioning System Location or Area Served:	2
03	Building Type from CF1R	3
04	Verified Low Leakage Ducts in Conditioned Space (VLLDCS) Credit from CF1R?	4
05	Verified Low Leakage Air-handling Unit Credit from CF1R?	5
06	Duct System Compliance Category:	6

9

MCH-20c - Low Leakage Air-Handling Unit (LLAHU)

B. Duct Leakage Diagnostic Test		
01	Condenser Nominal Cooling Capacity (ton)	12
02	Heating Capacity (kBtu/h)	13
03	Conditioned Floor Area Served by this HVAC System (ft2)	14
04	Duct Leakage Test Conditions	15
05	Duct Leakage Test Method?	16
06	LeakageFactor ( )	17
07	Air-Handling Unit Airflow (AHUAirflow) Determination Method	18
08	Measured AHUAirflow (cfm)	19
09	Calculated Target Allowable Duct Leakage Rate (cfm)	20
10	Actual duct leakage rate from leakage test measurement (cfm)	21
11	Air-Handling Unit Manufacturer Name	26
12	Air-Handling Unit Model Number	27
13	Compliance statement: 28	
14	Notes: 33	

For information and data collection only. Not valid until registered with a HERS provider

Registration Number: Registration Date/Time: HERS Provider:
CA Building Energy Efficiency Standards - 2013 Residential Compliance June 2013

Figure 71. Duct Leakage Diagnostic Test Form, 2013 Standards, CF3R-MCH-20d

STATE OF CALIFORNIA
DUCT LEAKAGE DIAGNOSTIC TEST 3600
CEC-CF3R-MCH-20-H (Revised 06/13)
CALIFORNIA ENERGY COMMISSION

CERTIFICATE OF VERIFICATION		CF3R-MCH-20-H
Duct Leakage Diagnostic Test		(Page 1 of 2)
Project Name:	Enforcement Agency:	Permit Number:
Dwelling Address:	City	Zip Code

A. System Information		
01	Space Conditioning System Identification or Name:	1
02	Space Conditioning System Location or Area Served:	2
03	Building Type from CF1R	3
04	Verified Low Leakage Ducts in Conditioned Space (VLLDCS) Credit from CF1R?	4
05	Verified Low Leakage Air-handling Unit Credit from CF1R?	5
06	Duct System Compliance Category:	6

MCH-20d - Complete Replacement or Altered Duct System 10

B. Duct Leakage Diagnostic Test		
01	Condenser Nominal Cooling Capacity (ton)	12
02	Heating Capacity (kBtu/h)	13
03	Conditioned Floor Area Served by this HVAC System (ft2)	14
04	Duct Leakage Test Conditions	15
05	Duct Leakage Test Method?	16
06	LeakageFactor ( )	17
07	Air-Handler Unit Airflow (AHUAirflow) Determination Method	18
08	Measured AHUAirflow (cfm)	19
09	Calculated Target Allowable Duct Leakage Rate (cfm)	20
10	Actual duct leakage rate from leakage test measurement (cfm)	21
11	Compliance statement: 29	
12	Notes: * ~~See notes on 22a~~ 33	

C. ADDITIONAL REQUIREMENTS FOR COMPLIANCE		
01	System was tested in its normal operation condition. No temporary taping allowed.	
02	Outside air (OA) ducts for Central Fan Integrated (CFI) ventilation systems, shall not be sealed/taped off during duct leakage testing. CFI OA ducts that utilize controlled motorized dampers, that open only when OA ventilation is required to meet ASHRAE Standard 62.2, and close when OA ventilation is not required, may be configured to the closed position during duct leakage testing.	
03	All supply and return register boots were sealed to the drywall.	
04	Building cavities were not used as plenums or platform returns in lieu of ducts.	
05	If cloth backed tape was used it was covered with Mastic and draw bands.	
06	All connection points between the air handler and the supply and return plenums are completely sealed.	
07	If the system complies using the Smoke Test method, the smoke test was conducted in accordance with the requirements of Reference Residential Appendix RA3.1.4.3.6. Systems that comply using smoke test shall not be included in sample groups for HERS verification.	
08	Verification Status:	31
09	Correction Notes:	32

The responsible person's signature on this compliance document affirms that all applicable requirements in this table have been met unless otherwise noted in the Verification Status and the Corrections Notes in this table.

Registration Number: Registration Date/Time: HERS Provider:
CA Building Energy Efficiency Standards - 2013 Residential Compliance June 2013

Figure 72. Duct Leakage Diagnostic Test Form, 2013 Standards, CF3R-MCH-20e

STATE OF CALIFORNIA

DUCT LEAKAGE DIAGNOSTIC TEST 3000

CEC-CF3R-MCH-20-H (Revised 06/13)

CALIFORNIA ENERGY COMMISSION

CERTIFICATE OF VERIFICATION	CF3R-MCH-20-H
Duct Leakage Diagnostic Test	(Page 1 of 3)

Project Name:	Enforcement Agency:	Permit Number:
Dwelling Address:	City	Zip Code

A. System Information		
01	Space Conditioning System Identification or Name:	1
02	Space Conditioning System Location or Area Served:	2
03	Building Type from CF1R	3
04	Verified Low Leakage Ducts in Conditioned Space (VLLDCS) Credit from CF1R?	4
05	Verified Low Leakage Air-handling Unit Credit from CF1R?	5
06	Duct System Compliance Category:	6

11

MCH-20e - Sealing All Accessible Leaks using Smoke Test

B. Duct Leakage Diagnostic Test		
01	Condenser Nominal Cooling Capacity (ton)	12
02	Heating Capacity (kBtu/h)	13
03	Conditioned Floor Area Served by this HVAC System (ft2)	14
04	Duct Leakage Test Conditions	15
05	Duct Leakage Test Method	16
06	LeakageFactor ( )	17
07	Air-Handling Unit Airflow (AHUAirflow) Determination Method	18
08	Measured AHUAirflow (cfm)	19
09	Calculated Target Allowable Duct Leakage Rate (cfm)	20
10	Actual duct leakage rate from leakage test measurement (cfm)	21
11	Compliance statement:	30
12	Notes:	33

For information and data collection only. Not valid until registered with a HERS provider

Registration Number: Registration Date/Time: HERS Provider:

CA Building Energy Efficiency Standards - 2013 Residential Compliance June 2013

Figure 73. Duct Leakage Diagnostic Test Form, 2008 Standards, CF4R-MECH 20

STATE OF CALIFORNIA

DUCT LEAKAGE TEST – COMPLETELY NEW OR REPLACEMENT DUCT SYSTEM

CEC- CF-4R-MECH-20 (Revised 08/09) CALIFORNIA ENERGY COMMISSION

CERTIFICATE OF FIELD VERIFICATION AND DIAGNOSTIC TESTING		**CF-4R-MECH-20**
Duct Leakage Test – Completely New or Replacement Duct System		**(Page 1 of 3)**
Site Address:	**Enforcement Agency:**	**Permit Number:**

Enter the Duct System Name or Identification/Tag:	689
Enter the Duct System Location or Area Served:	690
Note: Submit one Installation Certificate for each duct system that must demonstrate compliance in the dwelling.	

This certificate is required for compliance for completely new duct systems installed in new dwelling construction, and also for completely new or replacement duct systems in existing dwellings. For existing dwellings, a completely new or replacement duct system can also include existing parts of the original duct system (e.g., register boots, air handler, coil, plenums, etc.) if those parts are accessible and they can be sealed.

SAMPLE FORM FOR INFORMATION ONLY NOT FOR SUBMITTAL

Duct Leakage Diagnostic Test – completely new or replacement duct system

Enter a value for the Allowed Leakage (CFM) for the duct system leakage verification. The value entered must be the Verified Low Leakage Ducts in Conditioned Space criteria or one of the three calculated leakage rates described below.	
Verified Low Leakage Ducts in Conditioned Space (VLLDCS) Compliance Credit – If compliance credit for verified low leakage ducts in conditioned space is shown in the special features section of the CF-1R, the leakage to outside test method must be used to verify duct leakage (refer to RA3.1.4.3.4), and 25 CFM must be entered for Allowed Leakage.	Allowed Leakage (CFM)
Allowed leakage calculation – (select one calculation method from this section). Use 6% (*leakage factor* = 0.06) for calculations. When utilizing Low Leakage Air Handler (LLAH) credit, the allowed duct leakage may be specified by the CF-1R to be less than 6%, in which case the user-specified leakage rate must be used in the calculations below. For example, if the user-specified leakage (specified as a percentage of fan airflow) is reported on the CF-1R as 3%, then use a *leakage factor* of 0.03 in the calculations below. 691 ☐ Cooling system method: Nominal capacity of condenser in Tons 692 x 400 x *leakage factor* = 693 (CFM) ☐ Heating system method: 21.7 x 694 Output Capacity in Thousands of Btu/hr x *leakage factor* = 695 (CFM) ☐ Measured airflow method (RA3.3): Enter measured fan flow in CFM here 696 x *leakage factor* = 697 (CFM)	
Enter value for **Actual** leakage (CFM) in the right column, from measurement using applicable duct leakage pressurization test procedure from Reference Residential Appendix RA3.1(CFM @ 25 Pa).	Actual Leakage (CFM)
List **Actual** Leakage from duct leakage test (CFM)	698
Pass if Actual Leakage is less than Allowed Leakage 699	☐ Pass ☐ Fail
For complete replacement of duct systems only, if the 6 percent leakage rate criteria cannot be met, a smoke test should be performed to verify that the excess leakage is coming only from the furnace cabinet (air handler cabinet), and not from other *accessible* portions of the duct system. A HERS rater must verify the installation (No sampling allowed). List **Actual** Leakage from smoke test(CFM)	700
Pass if all accessible leaks (except for existing air handler) are sealed using smoke 701	☐ Pass ☐ Fail

Registration Number: ______ *Registration Date/Time:* ______ *HERS Provider:* ______

2008 Residential Compliance Forms *August 2009*

Figure 74. Duct Leakage Diagnostic Test Form, 2008 Standards, CF4R-MECH 21

STATE OF CALIFORNIA
DUCT LEAKAGE TEST – EXISTING DUCT SYSTEM
CEC-CF-4R-MECH-21 (Revised 03/10) CALIFORNIA ENERGY COMMISSION

CERTIFICATE OF FIELD VERIFICATION AND DIAGNOSTIC TESTING		**CF-4R-MECH-21**
Duct Leakage Test – Existing Duct System		**(Page 1 of 3)**
Site Address:	**Enforcement Agency:**	**Permit Number:**

Enter the Duct System Name or Identification/Tag:	710
Enter the Duct System Location or Area Served:	711
Note: Submit one Installation Certificate for each duct system that must demonstrate compliance in the dwelling.	

This installation certificate is required for compliance for alterations and additions in existing dwellings to space conditioning systems and duct systems.

Note: For existing dwellings, a completely new or replacement duct system can also include existing parts of the original duct system (e.g., register boots, air handler, coil, plenums, etc.) if those parts are accessible and they can be sealed. For a completely new or replacement duct system installed in an existing dwelling, use the Installation Certificate titled "Duct Leakage Test – Completely New or Replacement Duct System."

SAMPLE FORM FOR INFORMATION ONLY NOT FOR SUBMITTAL

Duct Leakage Diagnostic Test – existing duct system

Select one compliance method from the following four choices.

712
- ☐ Option 1. Measured leakage less than 15% of Fan Airflow.
- ☐ Option 2. Measured leakage to outside less than 10% of Fan Airflow.
- ☐ Option 3. Reduce leakage by 60% or more, and conduct smoke test to seal all accessible leaks.
- ☐ Option 4. Fix all accessible leaks using smoke test, and HERS rater must verify.

Note: (One of Options 1, 2, or 3 must be attempted before utilizing Option 4.)

Determine nominal **Fan Airflow** using one of the following three calculation methods.

713
- ☐ Cooling system method: Size of condenser in Tons 714 x 400 = 715 CFM
- ☐ Heating system method: 21.7 x ___ Heating Output Capacity (kBtuh) 717 CFM
- ☐ Measured system airflow using RA3.3 airflow test procedures: 718 CFM

1	**Option 1** used then: Allowed leakage = Fan Airflow 719 x 0.15 = 720 CFM Actual leakage = 721 CFM **Pass if Actual leakage is less than Allowed leakage**	722 ☐ Pass ☐ Fail
2	**Option 2** used then: Allowed leakage = Fan Airflow 723 x 0.10 = 724 CFM Actual leakage to outside = 726 CFM **Pass if Actual leakage to outside is less than Allowed leakage**	727 ☐ Pass ☐ Fail
3	**Option 3** used then: Initial leakage prior to start of work= 728 CFM Final leakage after sealing all accessible leaks using smoke test = 729 CFM Initial leakage 730 - Final leakage 731 = Leakage reduction 732 CFM (Leakage reduction 733 / Initial leakage 730) x 100% = 734 % Reduction **Pass if % Reduction ≥ 60%**	736 ☐ Pass ☐ Fail

Registration Number: ___ *Registration Date/Time:* ___ *HERS Provider:* ___
2008 Residential Compliance Forms *March 2010*

Figure 75. Duct Leakage Diagnostic Test Form, 2013 Standards, CF4R-MECH 21-H

STATE OF CALIFORNIA
DUCT LOCATION
CEC-CF3R-MCH-21-H (Revised 06/13)

5000

CALIFORNIA ENERGY COMMISSION

CERTIFICATE OF INSTALLATION		CF3R-MCH-21-H
Duct Location		(Page 1 of 2)
Project Name:	Enforcement Agency:	Permit Number:
Dwelling Address:	City	Zip Code

A. General Information

Note: Submit one Installation Certificate for each duct system that is taking credit for duct location.

01	SC System Identification or Name	1
02	SC System Location or Area Served	2
03	Status - Less than 12 ft Ducts in Conditioned Space Performance Credit:	3
04	Status - Ducts Located In Conditioned Space Performance Credit:	4
05	Status – All Ducts Entirely in Directly Conditioned Space R-value Exception	5

B. 12 Linear Feet or Less of Supply Duct Located Outside of Conditioned Space - RA3.1.4.1.2		
01	A visual inspection shall confirm space conditioning systems with air handlers located outside the conditioned space have 12 linear feet or less of duct located outside the conditioned space including air handler and plenum.	
02	Verification Status:	9
03	Correction Notes:	10
The responsible person's signature on this compliance document affirms that all applicable requirements in this table have been met unless otherwise noted in the Verification Status and the Corrections Notes in this table.		

C. Ducts Located In Conditioned Space - RA3.1.4.1.3		
01	A visual inspection shall confirm the space conditioning system is located entirely in conditioned space.	
02	Verification Status:	11
03	Correction Notes:	12
The responsible person's signature on this compliance document affirms that all applicable requirements in this table have been met unless otherwise noted in the Verification Status and the Corrections Notes in this table.		

D. All Ducts Located Entirely in Directly Conditioned Space R-Value Exception - RA3.1.4.3.8		
01	A visual inspection shall confirm the space conditioning system location:	6
02	Actual system duct leakage rate (cfm) measured using RA3.1.4.3.4 Duct Leakage to Outside from Fan Pressurization of Ducts	7
03	Compliance Statement:	8

E. Determination of HERS Verification Compliance	
All applicable sections of this document shall indicate compliance with the specified verification protocol requirements in order for this Certificate of Verification as a whole to be determined to be in compliance.	
01	5000

For information and data collection only. Not valid until registered with a HERS provider.

Registration Number: Registration Date/Time: HERS Provider:
CA Building Energy Efficiency Standards - 2013 Residential Compliance June 2013

Figure 76. Airflow and Fan power index Test Form, 2008 Standards, CF4R-MCH-22

STATE OF CALIFORNIA
HSPP/PSPP INSTALLATION; COOLING COIL AIRFLOW & FAN WATT DRAW TEST
CEC- CF-4R-MECH-22 (Revised 03/10) CALIFORNIA ENERGY COMMISSION

CERTIFICATE OF FIELD VERIFICATION AND DIAGNOSTIC TESTING		**CF-4R-MECH-22**
HSPP/PSPP Installation; Cooling Coil Airflow & Fan Watt Draw Test		**(Page 1 of 3)**
Site Address:	**Enforcement Agency:**	**Permit Number:**

As many as 4 systems in the dwelling can be documented for compliance using this form. Attach an additional form(s) for any additional systems in the dwelling as applicable.

Hole for the placement of a Static Pressure Probe (HSPP), and Permanently installed Static Pressure Probe (PSPP) in the supply plenum

When the Certificate of Compliance (CF1R)indicates Cooling Coil Airflow or Fan Watt Draw verification are required, HSPP or PSPP are required to be installed in each air handler in the dwelling. Procedures for installing HSPP and PSPP are described in Reference Residential Appendix RA3.3. This measure requires verification by a HERS rater.

742

Select one method from the two choices below for compliance with the HSPP/PSPP requirement for this dwelling.				
☐ HSPP	1/4 inch (6 mm) hole labeled and located downstream of the evaporator coil in the supply plenum as shown in the figure in Section RA3.3.1.1.			
☐ PSPP	1/4 inch (6 mm) hole equipped with a permanently installed pressure probe, labeled and located downstream of the evaporator coil in the supply plenum as shown in the figure in Section RA3.3.1.1.			
System Name or Identification/Tag	743			
System Location or Area Served	744			
Confirm that a HSPP or PSPP has been installed on the air handler per the requirements of RA3.3.1.1. **Enter Pass or Fail**	745			

Cooling Coil Airflow Verification

When the Certificate of Compliance indicates Cooling Coil Airflow verification is required, the procedures for measuring the cooling coil airflow must be performed as specified in Reference Residential Appendix RA3:3. Results of the cooling coil airflow diagnostic test must be entered in the table below. This measure requires verification by a HERS rater.

746

Select one method from the three choices below for compliance with the Cooling Coil Airflow test requirement for this dwelling.				
☐ Diagnostic Fan Flow Using Plenum Pressure Matching according to the procedures in RA3.3.3.1.1				
☐ Diagnostic Fan Flow Using Flow Grid Measurement according to the procedures in RA3.3.3.1.2				
☐ Diagnostic Fan Flow Using Flow Capture Hood according to the procedures in RA3.3.3.1.3				
System Name or Identification/Tag	747			
System Location or Area Served	748			
Nominal Cooling Capacity (ton) of the outdoor unit.	749			
Enter the minimum airflow requirement from the CF-1R (CFM/ton).	750			
Calculate the target minimum airflow for the test by multiplying the CFM/ton criteria specified on the CF-1R by the nominal cooling capacity of the outdoor unit (ton). **Target (CFM)**	751			
Enter the diagnostically tested airflow (CFM). **Tested (CFM)**	752			
The system complies if Tested (CFM) is equal or greater than Target (CFM). **Enter Pass or Fail**	753			

FOR SAMPLE FORM INFORMATION ONLY
NOT FOR SUBMITTAL

Registration Number: ______ *Registration Date/Time:* ______ *HERS Provider:* ______
2008 Residential Compliance Forms *March 2010*

Figure 77. Airflow and Fan power index Test Form, 2013 Standards, CF3R-MCH-22-a, pg.1

STATE OF CALIFORNIA
SPACE CONDITIONING SYSTEM FAN EFFICACY 6000
CEC-CF3R-MCH-22-H (Revised 06/13)
CALIFORNIA ENERGY COMMISSION

CERTIFICATE OF VERIFICATION		CF3R-MCH-22-H
Space Conditioning System Fan Efficacy		(Page 1 of 1)
Project Name:	Enforcement Agency:	Permit Number:
Dwelling Address:	City	Zip Code

A. Ducted Cooling System Information		
01	System Identification or Name	1
02	System Location or Area Served	2
03	System Installation Type	3
04	Nominal Cooling Capacity (tons) of Condenser	4
05	Condenser Speed Type	5
06	Cooling System Zonal Control Type	6
07	Central Fan Integrated (CFI) Ventilation System Status	7
08	System Bypass Duct Status	8
09	Date of System Airflow Rate Measurement	9
~~10~~	~~Certificate of Compliance Type~~	~~30~~
11	Airflow Rate Protocol utilized	10

B. Fan Watt Measurement Apparatus and Procedure Information		
Instrument Specifications are given in RA3.3.1, and system fan watt measurement apparatus information is given in RA3.3.2.2.		
01	Fan Watt Verification Device Used.	13

21
MCH-22a Forced Air System Fan Watt Measurement – Newly Installed Non-Zoned Systems or Zoned Multi-Speed Compressor

C. Forced Air System Airflow Rate Measurement		
The procedures for System Fan Watt Verification are specified in Reference Residential Appendix RA3.3.X.X		
01	Actual Tested Watts	14
02	Actual Tested Airflow from MCH-23 (cfm)	15
03	Required Fan Efficacy (watts/cfm)	16
04	Actual Fan Efficacy (watts/cfm)	17
05	Compliance Statement:	18

D. Additional Requirements		
01	All registers were fully open during the diagnostic test.	
02	System fan was set at maximum speed during the diagnostic test.	
03	If fresh air duct is part of the HVAC system it was not closed during the diagnostic test.	
04	Airflow rate and fan watt draw shall be simultaneous measurements when used to calculate the Fan Efficacy tested value.	
05	Multi-speed compressor space cooling systems or variable speed compressor systems shall verify air flow (cfm/ton) and fan efficacy (Watt/cfm) with system operating in cooling mode at the maximum compressor speed and the maximum air handler fan speed.	
06	Zoned cooling air distribution systems with single speed compressors shall meet both the airflow (cfm/ton) and fan efficacy (Watt/cfm) criteria in every zonal control mode.	
07	Verification Status:	31
08	Correction Notes:	32
The responsible person's signature on this compliance document affirms that all applicable requirements in this table have been met.		

Registration Number: Registration Date/Time: HERS Provider:
CA Building Energy Efficiency Standards - 2013 Residential Compliance June 2013

Figure 78. Airflow and Fan power index Test Form, 2013 Standards, CF3R-MCH-22-b, pg.2

6000 B

CERTIFICATE OF VERIFICATION – USER INSTRUCTIONS	CF3R-MCH-22-H
Space Conditioning System Fan Efficacy	(Page 1 of 3)

A. Ducted Cooling System Information		
01	System Identification or Name	1
02	System Location or Area Served	2
03	System Installation Type	3
04	Nominal Cooling Capacity (tons) of Condenser	4
05	Condenser Speed Type	5
06	Cooling System Zonal Control Type	6
07	Central Fan Integrated (CFI) Ventilation System Status	7
08	System Bypass Duct Status	8
09	Date of System Airflow Rate Measurement	9
10	Airflow Rate Protocol utilized	10

B. Fan Watt Measurement Apparatus and Procedure Information

Instrument Specifications are given in RA3.3.1, and system fan watt measurement apparatus information is given in RA3.3.2.2.

01	Fan Watt Verification Device Used.	13

MCH-22b Forced Air System Fan Efficacy Measurement – Newly Installed Zoned Single-Speed Compressor Systems

C. Forced Air System Fan Efficacy Measurement – All Zones Calling

The procedures for System Fan Watt Verification are specified in Reference Residential Appendix RA3.3.3.2

01	Actual Tested Watts	14
02	Actual Tested Airflow from MCH-23 (cfm)	15
03	Required Fan Efficacy (watts/cfm)	16
04	Actual Fan Efficacy (watts/cfm)	17
05	Compliance Statement:	18

D. Forced Air System Fan Efficacy Measurement – All Zonal Control Modes

The procedures for System Fan Efficacy Verification are specified in Reference Residential Appendix RA3.3.

Note: For compliance with verification in all zonal control modes, it is sufficient to verify fan efficacy for operation of each individual zone when the individual zone is the sole zone calling for conditioning. It is not necessary to verify fan efficacy for combinations of 2 or more zones that are less than all zones calling (e.g., 2 out of three zones calling).

01	Number of independently controlled zones (i.e., number of thermostats or temperature sensors that independently control one or more dampers.)	19
02	Required Fan Efficacy in all Zonal Control Modes(watt/cfm)	20

03	04	05	06	07	08
Zone Name	Zone Description	Measured Watt Draw with all other zones off	Measured Airflow with all other zones off (cfm)	Calculated Fan Efficacy (W/cfm)	Zone Compliance Status
23	24	25	26	27	28

09	Compliance Statement:	29

CA Building Energy Efficiency Standards - 2013 Residential Compliance June 2013

Figure 79. Refrigerant Charge Test Form, 2008 Standards, CF4R-MECH-25

STATE OF CALIFORNIA
CERTIFICATE OF FIELD VERIFICATION AND DIAGNOSTIC TESTING
CEC- CF-4R-MECH-25 (Revised 03/13) CALIFORNIA ENERGY COMMISSION

CERTIFICATE OF FIELD VERIFICATION AND DIAGNOSTIC TESTING		**CF-4R-MECH-25**
Refrigerant Charge Verification – Standard Measurement Procedure		**(Page 1 of 6)**
Site Address:	**Enforcement Agency:**	**Permit Number:**

Note: If installation of a Charge Indicator Display (CID) is utilized as an alternative to refrigerant charge verification for compliance, a MECH-24 Certificate (instead of this MECH-25 Certificate) should be used to demonstrate compliance with the refrigerant charge verification requirement. TMAH and STMS are not required for compliance, when a CID is utilized for compliance.

As many as 4 systems in the dwelling can be documented for compliance using this form. Attach an additional form(s) for any additional systems in the dwelling as applicable.

Temperature Measurement Access Holes (TMAH) and Saturation Temperature Measurement Sensors (STMS)
Procedures for installing TMAH are specified in Reference Residential Appendix RA3.2. If refrigerant charge verification is required for compliance, TMAH are also required for compliance, unless the TMAH Compliance Option is chosen.

STMS are only required for completely new or replacement space-conditioning systems that utilize prescriptive compliance method.

TMAH - Access Holes in Supply and Return Plenums of Air Handler

System Name or Identification/Tag		827			
System Location or Area Served		828			
1	5/16 inch (8 mm) access hole upstream of evaporative coil in the return plenum and labeled according to Figure in Section RA3.2.2.2.2.	829 ☐Yes ☐No	☐Yes ☐No	☐Yes ☐No	☐Yes ☐No
1a	Return side of the duct system is located entirely within conditioned space and return airflow temperature to be measured at the return grille.	1095 ☐Yes ☐No	☐Yes ☐No	☐Yes ☐No	☐Yes ☐No
2	5/16 inch (8 mm) access hole downstream of evaporative coil in the supply plenum and labeled according to Figure in Section RA3.2.2.2.2.	830 ☐Yes ☐No	☐Yes ☐No	☐Yes ☐No	☐Yes ☐No
The TMAH Compliance Option should be checked *only* if the HERS Rater is able to confirm that it was physically impossible for the HVAC Installer to drill the TMAH as required by Section RA3.2.2.2.2. Using this Compliance Option requires the HVAC installer to annotate on the HERS Provider's data registry an explanation as to why the TMAH cannot be installed on the system, and photographs of the equipment on which the TMAH cannot be installed. Use of this Compliance Option also requires minimum airflow verification through the direct measurement of airflow per RA3.3. For more information see http://www.energy.ca.gov/title24/2008standards/special_case_appliance/					
TMAH Compliance Option		1092 ☐	☐	☐	☐
Yes to 1 *and* 2, *or* Yes to 1a *and* 2, *or* checking the TMAH Compliance Option, is a pass. Enter Pass or Fail		920 ☐ Pass ☐ Fail	☐ Pass ☐ Fail	☐ Pass ☐ Fail	☐ Pass ☐ Fail

Registration Number: *Registration Date/Time:* *HERS Provider:*
2008 Residential Compliance Forms *March 2013*

Figure 80. Refrigerant Charge Test Form, 2013 Standards, CF3R-MECH-25a

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STATE OF CALIFORNIA
REFRIGERANT CHARGE VERIFICATION
CEC-CF3R-MCH-25-H (Revised 06/13)

CALIFORNIA ENERGY COMMISSION

CERTIFICATE OF VERIFICATION		CF3R-MCH-25
Refrigerant Charge Verification		(Page 1 of 3)
Project Name:	Enforcement Agency:	Permit Number:
Dwelling Address:	City	Zip Code

A. System Information HERS Rater to field-verify all system information, discrepancies to be noted by overwriting entry.		
01	System Identification or Name	1
02	System Location or Area Served	2
03	Condenser (or package unit) make or brand	3
04	Condenser (or package unit) model number	4
05	Nominal Cooling Capacity (tons) of Condenser	5
06	Condenser (or package unit) serial number	6
07	Refrigerant Type	7
08	Other Refrigerant Type (if applicable)	8
09	System Installation Type	9
10	Charge Indicator Display (CID) Status (Note: Even systems with a CID must have refrigerant charge verified by installer)	10
11	Is the system of a type that the minimum airflow can be verified using an approved measurement procedure (RA3.3 or RA3.2.2.7)?	11
12	Is the system of a type that approved refrigerant charge verification procedures can be used to verify compliance with the refrigerant charge verification requirements when temperatures are ≥ 55°F (RA3.2.2, or RA1)?	12
13	Date of HERS Rater Refrigerant Charge Verification for this system	13
14	Refrigerant charge verification method used by installer.	14
15	Person who performed the Refrigerant Charge Verification reported on the Certificate of Installation:	15
16	HERS Verification Compliance Requirement Status	16
17	Refrigerant charge verification method used by HERS Rater.	82

17

Standard Charge Verification Procedure – CF3R-MCH-25a - Superheat Method

B. Metering Device Verification – HERS Rater is required to visually field verify all information from CF2R Superheat Method can only be used on systems that do not have a variable metering device.		
01	Refrigerant metering device	22
02	Superheat Method applicability status	23

C. Instrument Calibration – HERS Raters are required to calibrate their diagnostic tools. Procedures for instrument calibration are given in Reference Residential Appendix RA3.2.2 and RA3.2.2.2		
01	Date of Digital Refrigerant Gauge Calibration	24
02	Date of Digital Thermocouple Calibration	25
03	Digital Refrigerant Gauge Calibration Status	26
04	Digital Thermocouple Calibration Status	27

D. Measurement Access Hole (MAH) Verification – HERS Raters are required to visually field verify MAH *Procedures for installing MAH are specified in Reference Residential Appendix RA3.2.2.3*		
01	Method used to demonstrate compliance with the Measurement Access Hole (MAH) requirement	28

Registration Number: Registration Date/Time: HERS Provider:
CA Building Energy Efficiency Standards - 2013 Residential Compliance June 2013

Figure 81. Refrigerant Charge Test Form, 2013 Standards, CF3R-MECH-25b

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B

STATE OF CALIFORNIA

REFRIGERANT CHARGE VERIFICATION

CEC-CF3R-MCH-25-H (Revised 06/13)

CALIFORNIA ENERGY COMMISSION

CERTIFICATE OF VERIFICATION	CF3R-MCH-25-H
Refrigerant Charge Verification	(Page 1 of 3)

Project Name:	Enforcement Agency:	Permit Number:
Dwelling Address:	City	Zip Code

A. System Information

HERS Rater to field-verify all system information, discrepancies to be noted by overwriting entry.

01	System Identification or Name	1
02	System Location or Area Served	2
03	Condenser (or package unit) make or brand	3
04	Condenser (or package unit) model number	4
05	Nominal Cooling Capacity (tons) of Condenser	5
06	Condenser (or package unit) serial number	6
07	Refrigerant Type	7
08	Other Refrigerant Type (if applicable)	8
09	System Installation Type	9
10	Charge Indicator Display (CID) Status (Note: Even systems with a CID must have refrigerant charge verified by installer)	10
11	Is the system of a type that the minimum airflow can be verified using an approved measurement procedure (RA3.3 or RA3.2.2.7)?	11
12	Is the system of a type that approved refrigerant charge verification procedures can be used to verify compliance with the refrigerant charge verification requirements when temperatures are ≥ 55°F (RA3.2.2, or RA1)?	12
13	Date of HERS Rater Refrigerant Charge Verification for this system	13
14	Refrigerant charge verification method used by installer.	14
15	Person who performed the Refrigerant Charge Verification reported on the Certificate of Installation:	15
16	HERS Verification Compliance Requirement Status	16
17	Refrigerant charge verification method used by HERS Rater.	82

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Standard Charge Verification Procedure - MCH25b - Subcooling Method

CEC information and data collection only. Not valid until registered with a HERS provider

B. Metering Device Verification – HERS Rater is required to visually field verify all information from C2R Subcooling Method can only be used on systems that have a variable metering device.

01	Refrigerant metering device	22
02	Subcooling Method applicability status	47

C. Instrument Calibration – HERS Raters are required to calibrate their diagnostic tools.

Procedures for instrument calibration are given in Reference Residential Appendix RA3.2.2 and RA3.2.2.2

01	Date of Digital Refrigerant Gauge Calibration	24
02	Date of Digital Thermocouple Calibration	25
03	Digital Refrigerant Gauge Calibration Status	26
04	Digital Thermocouple Calibration Status	27

Registration Number: Registration Date/Time: HERS Provider:

CA Building Energy Efficiency Standards - 2013 Residential Compliance June 2013

Figure 82. Refrigerant Charge Test Form, 2013 Standards, CF3R-MECH-25c

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STATE OF CALIFORNIA
REFRIGERANT CHARGE VERIFICATION
CEC-CF3R-MCH-25-H (Revised 06/13)
CALIFORNIA ENERGY COMMISSION

CERTIFICATE OF VERIFICATION		CF3R-MCH-25-H
Refrigerant Charge Verification		(Page 1 of 4)
Project Name:	Enforcement Agency:	Permit Number:
Dwelling Address:	City	Zip Code

A. System Information

HERS Rater to field-verify all system information, discrepancies to be noted by overwriting entry.

01	System Identification or Name	1
02	System Location or Area Served	2
03	Condenser (or package unit) make or brand	3
04	Condenser (or package unit) model number	4
05	Nominal Cooling Capacity (tons) of Condenser	5
06	Condenser (or package unit) serial number	6
07	Refrigerant Type	7
08	Other Refrigerant Type (if applicable)	8
09	System Installation Type	9
10	Charge Indicator Display (CID) Status (Note: Even systems with a CID must have refrigerant charge verified by installer)	10
11	Is the system of a type that the minimum airflow can be verified using an approved measurement procedure (RA3.3 or RA3.2.2.7)?	11
12	Is the system of a type that approved refrigerant charge verification procedures can be used to verify compliance with the refrigerant charge verification requirements when temperatures are ≥ 55°F (RA3.2.2, or RA1)?	12
13	Date of HERS Rater Refrigerant Charge Verification for this system	13
14	Refrigerant charge verification method used by installer.	14
15	Person who performed the Refrigerant Charge Verification reported on the Certificate of Installation:	15
16	HERS Verification Compliance Requirement Status	16
17	Refrigerant charge verification method used by HERS Rater.	82

For information and data collection only. Not valid until registered with a HERS provider

Weigh In Charging Procedure HERS Rater Observation- MCH25c	19

Registration Number: Registration Date/Time: HERS Provider:
CA Building Energy Efficiency Standards - 2013 Residential Compliance June 2013

Figure 83. Refrigerant Charge Test Form, 2013 Standards, CF3R-MECH-25d

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STATE OF CALIFORNIA

REFRIGERANT CHARGE VERIFICATION

CEC-CF3R-MCH-25-H (Revised 06/13) CALIFORNIA ENERGY COMMISSION

CERTIFICATE OF VERIFICATION		CF3R-MCH-25
Refrigerant Charge Verification		(Page 1 of 3)
Project Name:	Enforcement Agency:	Permit Number:
Dwelling Address:	City	Zip Code

A. System Information
HERS Rater to field-verify all system information, discrepancies to be noted by overwriting entry.

01	System Identification or Name	1
02	System Location or Area Served	2
03	Condenser (or package unit) make or brand	3
04	Condenser (or package unit) model number	4
05	Nominal Cooling Capacity (tons) of Condenser	5
06	Condenser (or package unit) serial number	6
07	Refrigerant Type	7
08	Other Refrigerant Type (if applicable)	8
09	System Installation Type	9
10	Charge Indicator Display (CID) Status (Note: Even systems with a CID must have refrigerant charge verified by installer)	10
11	Is the system of a type that the minimum airflow can be verified using an approved measurement procedure (RA3.3 or RA3.2.2.7)?	11
12	Is the system of a type that approved refrigerant charge verification procedures can be used to verify compliance with the refrigerant charge verification requirements when temperatures are ≥ 55°F (RA3.2.2, or RA1)?	12
13	Date of HERS Rater Refrigerant Charge Verification for this system	13
14	Refrigerant charge verification method used by installer.	14
15	Person who performed the Refrigerant Charge Verification reported on the Certificate of Installation:	15
16	HERS Verification Compliance Requirement Status	16
17	Refrigerant charge verification method used by HERS Rater.	82

Verification of Charge Indicator Display – CF2R-MCH-25d – CID ~~80~~ 81

B. Charge Indicator Display Verification Applicability

01	Measured Condenser air entering dry-bulb temperature ($T_{condenser, db}$) (degreeF)	32
02	Outdoor Temperature Qualification Status	33
03	Self Diagnostic Reporting (SDR)	85 ~~85~~
04	Charge Indicator Display Verification Applicability	86 ~~86~~

C. Measurement Access Hole (MAH) Verification – HERS Raters are required to visually field verify MAH
Procedures for installing MAH are specified in Reference Residential Appendix RA3.2.2.3

01	Method used to demonstrate compliance with the Measurement Access Hole (MAH) requirement	28

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Registration Number: Registration Date/Time: HERS Provider:
CA Building Energy Efficiency Standards - 2013 Residential Compliance June 2013

Figure 84. Refrigerant Charge Test Form, 2013 Standards, CF3R-MECH-25e

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STATE OF CALIFORNIA
REFRIGERANT CHARGE VERIFICATION
CEC-CF3R-MCH-25-H (Revised 06/13)

CALIFORNIA ENERGY COMMISSION

CERTIFICATE OF VERIFICATION		CF3R-MCH-25-H
Refrigerant Charge Verification		(Page 1 of 4)
Project Name:	Enforcement Agency:	Permit Number:
Dwelling Address:	City	Zip Code

A. System Information HERS Rater to field-verify all system information, discrepancies to be noted by overwriting entry.		
01	System Identification or Name	1
02	System Location or Area Served	2
03	Condenser (or package unit) make or brand	3
04	Condenser (or package unit) model number	4
05	Nominal Cooling Capacity (tons) of Condenser	5
06	Condenser (or package unit) serial number	6
07	Refrigerant Type	7
08	Other Refrigerant Type (if applicable)	8
09	System Installation Type	9
10	Charge Indicator Display (CID) Status (Note: Even systems with a CID must have refrigerant charge verified by installer)	10
11	Is the system of a type that the minimum airflow can be verified using an approved measurement procedure (RA3.3 or RA3.2.2.7)?	11
12	Is the system of a type that approved refrigerant charge verification procedures can be used to verify compliance with the refrigerant charge verification requirements when temperatures are ≥ 55°F (RA3.2.2, or RA1)?	12
13	Date of HERS Rater Refrigerant Charge Verification for this system	13
14	Refrigerant charge verification method used by installer.	14
15	Person who performed the Refrigerant Charge Verification reported on the Certificate of Installation:	15
16	HERS Verification Compliance Requirement Status	16
17	Refrigerant charge verification method used by HERS Rater.	82

Winter Setup Charge Verification Procedure - MCH25e – 20
Winter Setup for the Standard Charge Verification Procedure is specified in Reference Residential Appendix RA1.2.Procedures for determining Refrigerant Charge using the Standard Charge Verification Procedure are given in Reference Residential Appendix RA3.2.2.

B. System Model Applicability for Winter Setup Method – HERS Rater must verify applicability of Winter Setup Method		
01	Refrigerant metering device	69
02	Winter Setup Method applicability status	70
03	**The responsible person's signature on this document indicates confirmation that the installed model number is currently listed as approved for Winter Setup Method on the Energy Commission website:** http://www.energy.ca.gov/title24/2008standards/special_case_appliance/	

Registration Number: Registration Date/Time: HERS Provider:
CA Building Energy Efficiency Standards - 2013 Residential Compliance June 2013

Figure 85. Refrigerant Charge Test Form, 2013 Standards, CF2R-MECH-25e

STATE OF CALIFORNIA
REFRIGERANT CHARGE VERIFICATION
CEC-CF2R-MCH-25f-F (Revised 06/14)

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CALIFORNIA ENERGY COMMISSION

CERTIFICATE OF INSTALLATION		CF2R-MCH-25-E
Refrigerant Charge Verification – Packaged System		(Page 1 of 3)
Project Name:	Enforcement Agency:	Permit Number:
Dwelling Address:	City	Zip Code

A. System Information

Each system requiring refrigerant charge verification will be documented on a separate certificate.

01	System Identification or Name	1
02	System Location or Area Served	2
03	Condenser (or package unit) make or brand	3
04	Condenser (or package unit) model number	4
05	Nominal Cooling Capacity (tons) of Condenser	5
06	Condenser (or package unit) serial number	6
07	Refrigerant Type	7
08	Other Refrigerant Type (if applicable)	8
09	System Installation Type	9
10	Charge Indicator Display (CID) Status (Note: Even systems with a CID must have refrigerant charge verified by installer)	10
11	Is the system of a type that the minimum airflow can be verified using an approved measurement procedure (RA3.3 or RA3.2.2.7)?	11
12	Is the system of a type that approved refrigerant charge verification procedures can be used to verify compliance with the refrigerant charge verification requirements when temperatures are ≥ 55°F (RA3.2.2, or RA1)?	12
13	Date of Refrigerant Charge Verification for this system	13
14	Refrigerant charge verification method used.	14
15	Person who performed the Refrigerant Charge Verification reported on this Certificate of Installation:	15
16	HERS Verification Compliance Requirement Status	16

For informational and data collection only. Not valid until registered with a HERS provider

Registration Number: Registration Date/Time: HERS Provider:
CA Building Energy Efficiency Standards - 2013 Residential Compliance June 2014

APPENDIX P. HERS TESTING REQUIREMENTS

Figure 86 presents the "trigger" list for the test installation conditions that would one or more HERS tests. The remainder of this appendix presents the complete trigger sheet for residential HVAC installations per the 2013 Standards.

Figure 86. Scope of the installation that would trigger a HERS test

Scope of Work	Duct Sealing (Code-2013 all CZ; Code-2008 only in CZ 2, 8—15)	Refrigerant Charge (CZ 2, 8—15)	Cooling Coil Airflow and Fan Efficacy (all CZ)
New System (equipment and ducts)	≤ 6%	≥ 350 cfm[1]/ton and w/target superheat or subcool[2]	≥ 350 cfm/ton[2] and 0.58 Watts/cfm
New Duct System, >75% and all accessible	≤ 6%	N/A	≥ 350 cfm/ton[2] and 0.58 Watts/cfm
Altered Duct System, >40' in unconditioned	≤ 15%	N/A	N/A
Altered Furnace/Forced Air Unit	≤ 15%	N/A	N/A
Altered Condenser or Coil	≤ 15%	≥ 300 cfm/ton and w/in target superheat or subcool[3]	N/A
Altered Refrigerant Containing Component	N/A	≥ 300 cfm/ton and within target superheat or subcool[3]	N/A

1 Cubic feet per minute
2 Or return sizing per Table 150.0-C/D.
3 Package HVAC systems were exempt from the 2008 standard.

Figure 87. HERS Trigger Sheet for 2013 Standards, Source Energy Code Ave, pg. 1 of 2

Ace Resources — Title 24 Part 6 Residential Triggers Sheet

HVAC Alterations

Split Systems and Packaged Systems	Mandatory Measures					Prescriptive Requirements	
	Setback Thermostat	Cooling Load Calcs	Heating Load Calcs	HERS: Duct Seal and Test	HERS: Cooling Coil Airflow and Fan Watt Draw	Duct Insulation	HERS: Refrigerant Charge
Change this (and nothing else)	§110.2(c) §150.2(b)F	§150.0(h), §150.2(b)1C	§150.0(h), §150.2(b)1C	§150.0 (m)1-3 & 11 §150.2(b)1C,D, & E	§150.0(m)12, 13 & 15 §150.2 (b)1C, D	§150.1(c)9 §150.2(b)1D	§150.1(c)7 A §150.2(b)1 F
Whole split or packaged system (no ducts added or replaced)	YES	no	no A	YES B	no	no	YES C, D
Evaporator coil (cooling coil), condenser coil, or outdoor condensing unit	YES	no	no A	YES B	no	no	YES C, D
Furnace (air handler)	YES	no	no A	YES B	no	no	YES C, D
Compressor, refrigerant metering device	YES	no	no A	no	no	no	YES C, D
Some ducts	no	maybe E	maybe A, E	YES B	no	YES F	no
"All new" ducts G	no	maybe E	maybe A, E	YES H	YES I	YES F	no
Whole split or packaged system and all new ducts	YES	YES E	YES A, E	YES H	YES I	YES F	YES C, D

NOTE:
- + Replacing the blower wheel fan is considered a repair and does NOT trigger the Standards.
- + All new HVAC equipment must meet minimum federal efficiency requirements
- + Cooling line insulation is triggered if the line set (cooling system, suction line) is replaced or repaired. Line sets ≤1.5" in diameter must have 0.5" thick insulation.

A Heating equipment must meet CBC minimum capacity requirements.

B Unless exceptions apply, duct systems must be sealed and verified if >40 feet of ducts in unconditioned space. Duct system leakage must be ≤15% in total, or ≤10% to the outside. Or, if unable to meet the sealing requirements, all accessible leaks must be sealed and verified by a HERS rater.

C HERS verification of refrigerant charge is required in **climate zones 2 and 8–15 only** when a refrigerant containing component of an air conditioner or heat pump is replaced or installed in an existing building.

D Although there are no commercially available HVAC systems with approved Charge Indicator Display (CID) devices at the time of publication (July 2014) the Standards do allow use of a CEC-approved CID should such equipment become available during the 2013 code cycle.

E Cooling and heating load calculations are required when ducts are added to **serve new conditioned space**, such as an addition.

F When adding or replacing >40 feet of ducts in unconditioned space: CZ 1-10 and 12-13: R-6; CZ 11 and 14-16: R-8. HERS verification is required for insulated ducts in conditioned space. Mandatory duct insulation requirements (R-6) apply to all new or replacement ducts (not existing or unaltered ducts).

G The system is considered to have "all new" ducts when 75% or more of the ducts are new material and up to 25% reused parts from the existing duct system (e.g., registers, grilles, boots, air handler, coil, plenums, duct material) if the reused parts are accessible and can be sealed to prevent leakage.

H In all climate zones, when new duct systems are installed in unconditioned space, leakage must be ≤8% of the air handler airflow.

I When new duct systems are installed, cooling coil airflow must be >350 CFM per ton, and fan watt draw must be ≤0.58W/CFM. Alternatively, the system can meet the requirements in Table 150.0-C or Table 150.0-D (Return Duct Sizing and Filter Sizing).

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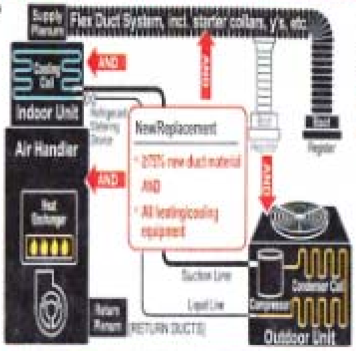
DOCUMENT 2014-07-29

Figure 88. HERS Trigger Sheet for 2013 Standards, Source Energy Code Ave, pg. 2 of 2

60

Title 24 Part 6 Essentials for Residential AC Quality Installation Contractors

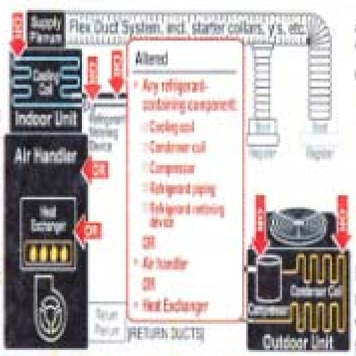
2013 Entirely New or Complete Replacement Space-Conditioning System §150.2(b)1C



A space-conditioning system is considered entirely new or a complete replacement when all of the following are installed or replaced:

- All the system heating/cooling equipment
- ≥75% new duct material G

2013 Altered Space-Conditioning System §150.2(b)1E, F



A space-conditioning system is considered altered when it is not a new or replacement system and any of the following components is installed or replaced:

- Any refrigerant-containing component, including:
  - Cooling coil
  - Condenser coil
  - Compressor
  - Refrigerant piping
  - Refrigerant metering device
- Air handler
- Heat exchanger

Replacing other components is considered a repair — not an alteration. For example, replacing the blower wheel fan, but not the heat exchanger or air handler in the furnace, is a repair.

2013 Altered or Replaced Duct Systems (Duct Sealing) §150.2(b)1D

Entirely New or Complete Replacement Ducts

Entirely new or complete replacement duct systems are those that contain at least 75% new duct material. Existing duct system components (up to 25%) may be reused if they are accessible and can be sealed.G

The Duct Sealing and Testing HERS measure must demonstrate a leakage rate less than or equal to 6% of the system air handler airflow. In addition, verification of Cooling Coil Airflow and Fan Watt Draw (HERS measure) is required. The system must have airflow >350 CFM per ton of nominal cooling capacity through the return grilles, and an air-handling unit fan efficacy ≤0.58 W/CFM.

Alteration or Extension of Existing Ducts

In all climate zones when more than 40 feet of new or replacement system ducts are installed as an extension of an existing duct system, Duct Sealing and Testing (HERS measure) is required, and the measured leakage shall be equal to or less than 15% of system air handler air flow.

(There are alternatives to meeting the maximum 15% leakage. Consult your Building Department or §150.2(b)1Diib in the Standards.)

Required Documentation

For All HVAC Alterations

All HVAC alterations require:

- Permit — for all HVAC changeouts
- CF1R: Certificate of Compliance: Alteration to an HVAC System (CF1R-ALT-02*-E, or CF1R-ALT-03-E or CF1R-ALT-04-E)

  Submitted to the building department by the contractor or the home owner
- CF2R-MCH-01-H: Certificate of Installation for Space Conditioning Systems, Ducts and Fans

  Completed and signed by the installing contractor and made available for final inspection by building department

For HERS Measures

Projects with HERS measures require:

- Registration of the CF1R, via HERS Provider
- CF2R-MCH...H: Certificates of Installation for mechanical system with HERS measures

  Completed and signed by the installing contractor, must be submitted to a HERS Provider Registry after the contractor has signed it, and made available for inspection by the building department
- CF3R-MCH...H: Certificates of Field Verification for mechanical system with HERS measures

  Completed and registered by a HERS Rater for each CF2R-H; the HERS Rater or contractor ensures the relevant CF3Rs are available for final inspection by the building department.
- HERS: Duct Leakage Diagnostic Test
  - CF2R-MCH-20*-H and CF3R-MCH-20*-H
- HERS: Fan Efficacy (Fan Watt Draw)
  - CF2R-MCH-22-H and CF3R-MCH-22-H

  and

  HERS: Space Conditioning System Airflow Rate
  - CF2R-MCH-23*-H and CF3R-MCH-23*-H
- HERS: Refrigerant Charge Verification
  - CF2R-MCH-25*-H and CF3R-MCH-25*-H

  or
  - CF2R-MCH-25f-E (for packaged systems with refrigerant charge certified by manufacturer)

* *Correct version (e.g., "a" or "b" or "c") varies depending upon the project scope and approach used to demonstrate compliance*

For Projects with New or Replacement Duct Systems using Duct and Filter Sizing

Projects that use Duct and Filter Sizing instead of the Cooling Coil Airflow and Fan Watt Draw HERS Measure require:

- CF2R-MCH-28-H and CF3R-MCH-28-H

SDG&E · SoCalGas · Southern California EDISON · Pacific Gas and Electric Company

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2013 Residential Appendices *RA2-17*

The Third Party Quality Control Program shall meet the requirements imposed on a HERS Rater specified in the Commission's HERS Program regulations (California Code of Regulations, Title 20, Division 2, Chapter 4, Article 8, Sections 1670 -1675), including the requirement to be an independent entity from the builder, the HERS Rater that provides independent field verifications, and the subcontractor installer as specified by Section 1673(j). However, a Third Party Quality Control Program may have business relationships with installers participating in the program to advocate or promote the program and an installer's participation in the program, and to advocate or promote products that the Third Party Quality Control Program sells to installers as part of the Program.

Prior to approval by the Commission, the Third Party Quality Control Program shall provide a detailed explanation to the Commission of 1) the data that is to be collected from the installers, 2) the data checking process that will be used to evaluate the validity and accuracy of the data, 3) the justification for why this data checking process will provide strong assurance that the installation actually complies, and 4) the format for the database that will be maintained and the functionality that will allow Energy Commission staff to query retained data or documents. The Third Party Quality Control Program may apply for a confidential designation of this information as specified in the Commission's Administrative Regulations (California Code of Regulations, Title 20, Division 2, Chapter 7, Article 2, Section 2505). The Third Party Quality Control Program shall also provide a detailed explanation of the training that will be provided to installers, and the procedures that it will follow to complete independent field verifications.

The Third Party Quality Control Program certified installing contractor and the installing contractor's responsible installing technicians shall be required to be trained in quality installation procedures; the requirements of this Appendix RA2; and any other applicable specialized Third Party Quality Control Program-specific procedures as a condition to participation in the program. The training requirements also apply to the installing contractor's specialty subcontractors who provide Third Party Quality Control Program services. All installation verification and diagnostic work performed in the program shall be subject to the same quality assurance procedures as required by the Energy Commission's HERS program regulations.

The Third Party Quality Control Program shall be considered for approval as part of the rating system of a HERS Provider, which is certified as specified in the Commission's HERS Program regulations, Section 1674. A Third Party Quality Control Program can be added to the rating system through the recertification of a certified HERS Provider as specified by Title 20, Division 2, Chapter 4, Article 8, Section 1674(e).

RA2.8 Installer Requirements and HERS Procedures for Alterations

This section on alterations describes the differences that apply to alterations. Otherwise the procedures and requirements detailed in previous sections of Appendix RA2 shall also apply to alterations. For alterations, building owners or their agents may carry out the actions that are assigned to builders in previous sections of AppendixRA2.

Applicable procedures for registration of compliance documents described in Appendix RA2 shall also apply to alterations.

When compliance for an alteration requires field verification and diagnostic testing, the building owner may choose for the field verification and diagnostic testing to be completed for the dwelling unit individually, or alternatively, as part of a designated sample group of dwelling units for which the same installing company has completed work that requires HERS verification for compliance.

When sampling is utilized for HERS verification compliance for alterations, the dwelling units in a designated sample group are not required to be located within the same enforcement agency jurisdiction. However, to enable the enforcement agency to schedule testing to accomplish the corroboration of field verification and diagnostic testing procedures performed by the building owner, subcontractors, or certified HERS Rater as described in Section RA2.4.4, the enforcement agency may require that a separate dwelling unit from the sample group that is located within its jurisdiction be tested.

The building owner or agent of the building owner shall submit, or make arrangements for submittal of the required Certificate of Compliance information to the HERS Provider data registry to complete the applicable Certificate of Compliance documentation in accordance with the requirements in Standards Section 10-103(a)1 and 10-103(a)2.

APPENDIX Q. LIMITATIONS OF HERS DATA ACQUISITION

DNV GL sought compliance form (CF) data to measure how well HERS Raters perform field inspections. However, the evaluation has data limitations given that the CEC-approved HERS Registries retain the CFs, and Registry data is not publicly available. Additionally, building departments rarely (if ever) retain CFs. Over a period of six months, DNV GL repeatedly requested cooperation from both HERS Providers (CalCERTS and USERA) with minimal success. Ultimately, with assistance from the CEC, several of the requests were fulfilled by CalCERTS; however, a lack of data in some cases required us to modify our original scope.

The original research plan intended to evaluate a two years' worth of Providers' quality assurance (QA) test results to measure the frequency of errors found. We then intended to extrapolate the frequency of errors to the population of unaudited units to estimate the overall share of projects that may be non-compliant. However, it was necessary for us to reframe the scope of these analyses because we were unable to obtain this data from the Providers.

Although CalCERTS provided site-level data, they had limitations regarding the data they were willing to provide. For the installations where we were able to obtain site-level data, CalCERTS declined CPUC requests for the complete set of CFs. In particular, CalCERTS declined to provide the CF1R and CF2R forms. Additionally, due to contracting and cost, we were able to obtain and review only 80% of the sampled CF3Rs. Additionally, because we were only able to obtain CFs from CalCERTS and not USERA, it is possible that USERA held a subset of the permitted installations in their Registry. Unfortunately, there is no way to know the extent to which this occurred.

The overall impact of the incomplete CF data is as follows:

- 1) we had to rely on customer self-report of the equipment installed in addition to our onsite observations, as opposed to HERS and contractor data description of the project scope
- 2) the CF3R does not address many compliance requirements, thus we did not have access to data such as the equipment type, efficiency, ducting plenums, or confirmation of a setback thermostat
- 3) we were unable to verify CFs for the complete sample because USERA did not cooperate with the study and CalCERTS did not fulfill the entire request

APPENDIX R. HERS RATER SURVEY METHODOLOGY

Below we provide details regarding the HERS Rater survey design, survey implementation, and the weighting approach. Recall that the HERS Rater survey effort involved two stages:

- **Screener telephone survey.** The purpose of the screener survey was to identify a list of Raters with experience performing HVAC inspections to participate in the more extensive (full-length) survey. For the screener survey, we asked respondents a series of questions about themselves and their companies, including job titles, geographic range of service, and number and types of inspections performed. We also asked several questions relating to their experience with and knowledge of the HERS process.
- **Full-length online survey.** The purpose of the full-length survey was to identify and assess the prevalence of systematic issues, knowledge gaps, and barriers to HERS inspections on HVAC installations producing a HERS-compliant installation. To qualify for the online survey, Raters had to have personally completed at least one HVAC inspection in a residential dwelling in California within the 12 months prior to the screener survey. We offered each eligible screener survey participant a $50 incentive to complete the online survey.

Sample design

Currently there is no comprehensive public repository to identify HERS Raters. At the time we conducted the surveys, only two of the three HERS Providers were approved to process compliance forms for HVAC changeouts (CALCERTS and USERA). CalCERTS maintains a Directory of HERS Raters while USERA does not. DNV GL submitted a data request to both Providers (CalCERTS and USERA) to obtain information necessary to develop a sample of HERS Raters that performed HVAC alteration (changeout) inspection services, including:

- Total number of HERS Raters performing changeouts
- Rater company information and employee names
- Estimate on volume of HVAC changeout inspections performed in a given year for each company
- Regions in which the Raters were located

Neither CalCERTS nor USERA fulfilled the data requests. Instead, we obtained data from the CalCERTS publicly-available online Rater Directory;[15] however, this data was limited. From the CalCERTS Rater Directory, we filtered from the class of certification “Residential Alteration” with the expectation that the results would yield only Raters in this class that actively performed inspections. The downloaded information contained a list of HERS Rater company names along with the individual HERS Raters associated with each company in November 2015. At that time, the Rater Directory contained 528 companies employing a total of 653 individual HERS Raters listed as certified in performing residential alterations for the 2013 Standards (current energy code). A total of 508 unique phone numbers, one per company, was available after we removed the duplicates and removed companies for which we could not find phone numbers. Removing five Raters affiliated with companies without phone numbers left 648 Raters in the sample frame for the screener survey.

DNV GL wanted to collect data from companies and Raters representing various levels of annual activity in HVAC changeouts. Higher activity levels were assumed to be associated with companies having a larger

[15] https://www.calcerts.com/RaterSearch.php

number of Raters, and with Raters being affiliated with more companies. Since no activity or volume information was available within the information downloaded from the CalCERTS Rater Directory, we conducted some exploratory analysis to characterize the Rater companies and Raters to the extent possible. This characterization provided the basis for streamlining contact with HERS Raters so that only one Rater completed a survey representing a company.

DNV GL categorized the companies by the number of Raters they employed, which includes all employees listed for each company and includes multiple entries for Raters listed for more than one company. We also categorized the Raters by the number of companies that listed them as employees. Figure 89 shows that the majority of companies employ only one HERS Rater (86%). Figure 90 shows that a similar proportion of the HERS Raters were listed as affiliated with only one company (89%).

Figure 89: Number of HERS companies by Raters employed

Number of Raters Employed	Number of Companies	Percent of Total Companies
1	452	86%
2	44	8%
3 or more	32	6%
Total	**528**	**100%**

*Total includes each Rater listed as employee. Raters employed by more than one company are listed multiple times.

Figure 90. Number of HERS Raters by companies affiliated

Number of Companies Affiliated with Rater	Number of Raters	Percent of Total Raters
1	573	89%
2	67	10%
3	8	1%
Total	**648**	**100%**

Although only 11% of Raters are listed in the CalCERTS Rater Directory as affiliated with multiple companies, it is possible that any of the Raters are also employed by other companies that are not listed in this registry (e.g., USERA), or companies electing not to be listed in the CalCERTS directory. Therefore, we included questions in the screener survey to capture HVAC alterations services performed by a single Rater for multiple companies.

To further understand the relationship of Raters to companies within the sample frame, we investigated the distribution of companies by the number of Raters they listed, and whether their Raters were only listed with the single company, or with multiple companies. This analysis produced the general framework for the sample design.

Figure 91 presents a complete breakdown of the companies that employ Raters who are listed with a single company, versus companies that employ one or more Raters who are listed with multiple companies. Of the 432 companies employing one Rater, 358 of the companies are the only company listed with the individual Rater (83%). The remaining 74 companies employ only one Rater, but the Rater is listed with multiple companies. Seventy-nine percent of the companies listed in the CalCERTS Registry are companies employing

Raters who are listed with only one company and 75% of the Raters are listed as employees of only one company. The remaining 25% of Raters, or 162 individuals, are listed as working for companies that employ one or more Raters that are listed with multiple companies.

Figure 91. Companies with Raters listed with a single company and companies with Raters listed with multiple companies

Number of Raters listed with Company	Companies with Raters Only Listed with One Company		Companies with Raters Listed with More than One Company		Total Raters	Total Companies
	Number of Raters	Number of Companies	Number of Raters	Number of Companies		
1	358	358	74	74	432	432
2	58	29	30	15	88	44
3	18	6	18	6	36	12
4	20	5	0	0	20	5
5	5	1	15	3	20	4
6	6	1	6	1	12	2
8	0	0	24	3	24	3
9	9	1	9	1	18	2
12	12	1	12	1	24	2
19	0	0	19	1	19	1
21	0	0	21	1	21	1
Total	**486**	**402**	**162***	**106**	**648**	**508**
Percent of Total	**75%**	**79%**	**25%**	**21%**	**100%**	**100%**

* Note: Some Raters listed more than once

Based on the insights above, DNV GL organized the sample of HERS Rater companies by:

- If a company was associated with Raters listed with a single company or multiple companies
- Number of Raters per company
- For companies associated with multiple Raters, if the company owner's name was identifiable in the data or not (we assumed the Rater to be the owner of the company if the Rater's name matched the company's name)

Figure 92 presents the final sample characterization that supported the survey implementation.

Figure 92. Sample characterization for screener survey

Category ID	Company Categories	Number of Raters	Owner Identified	Number of Companies	Subtotal Number of Companies
1	Companies with Raters listed only with One Company	One Rater	Yes	358	402
2		2+ Raters	Yes	11	
3			No	33	
4	Companies with Raters from Multiple Companies	One Rater	Yes	74	106
5		2+ Raters	Yes	4	
6			No	28	
Total					**508**

In early 2015 during the research planning phase, DNV GL estimated the study population of 650 HERS Raters and established a goal of 57 completed full-length surveys to achieve a coefficient variation of 0.5 and 90% confidence-interval with precision at 10%. We rounded the goal of 57 up to 60 in the approved Research Plan. During the sample design phase, the information downloaded from the CalCERTS Rater Directory included 648 HERS Raters, which was very similar to the planning population, but the Raters only represented 508 Rater companies. Having decided to interview only one HERS Rater per company, we maintained the goal of completing 60 full-length interviews, recognizing it as an ambitious goal with the smaller population of 508 companies.

Survey implementation

DNV GL contracted with a reputable computer-assisted telephone interviewing (CATI) firm to conduct the screener surveys in January, 2016. The CATI firm attempted to contact the full population of 508 HERS Rater companies in the sample frame, to ensure a sufficient sample of qualified companies to invite to participate the full-length survey. DNV GL staff developed and issued an online survey using the Forms.com tool and implemented the survey during February and March 2016. We emailed Raters with an invitation to the survey, and Raters completed it on their own time.

Starting from a sample frame of 508 Rater companies, a total of 122 Rater companies participated in the screener survey and 57 participated in the full-length survey, although only 50 of the 57 completed every question (Figure 93). The results presented include both the complete and partial survey responses. Note that 57 respondents participated in the full length-survey from 56 companies; it was later found that one company had a second respondent. Figure 93 summarizes the number of screener surveys and full-length surveys completed by the sample characterization categories.

Figure 93. Sample characterization with survey completes

Category ID	Company Categories	Number of Raters	Owner Identified	Number of Raters	Number of Companies	Completed Surveys	
						Screener	Full Survey
1	Companies with Raters listed with only One Company	One Rater	Yes	358	402	87	36
2		2+ Raters	Yes	11		3	2
3			No	33		5	6
4	Companies with Raters from Multiple Companies	One Rater	Yes	74	106	22	12
5		2+ Raters	Yes	4		1	0
6			No	28		4	1
Total					**508**	**122**	**57**

Figure 94 reflects response rates for the two surveys.[16] We established limited eligibility requirements for the surveys, which resulted in 45 companies dropped from the screener survey because no one at their company had completed a HERS inspection of any kind in the last 12 months and 5 companies dropped because no one at their company had completed a HVAC HERS inspection in the last 12 months. Some 28%

[16] DNV GL uses APPOR response rate calculator 3 to estimate response rates: https://www.aapor.org/AAPOR_Main/media/MainSiteFiles/Standard-Definitions2015_8thEd.pdf

of Raters refused to participate in the full-length survey; the most frequently cited reason was "too long of a time commitment".

Figure 94. Screener and full-length survey response rates

	Screener Survey	Full-length Survey
Sample Size	508	122
Complete	26%	49%
Refused	4%	28%
Not Completed - Eligible	70%	23%

DNV GL compared the key characteristics of the HERS Rater companies that were qualified to participate in the full-length survey to assess bias between the ones that completed only the screener survey (61) and the ones that completed the full-length survey (57). This analysis used unweighted data from the screener survey. We had two primary findings. First, both groups had similar distributions across the categories of the number of HVAC residential alteration inspections completed in California during 2015. We grouped the number of inspections completed by a company into four categories: fewer than 20 inspections, 20-99 inspections, 100-199 inspections, and 200 or more inspections.

Second, raters reported the climate zones they most often conduct HERS inspections, and geographic coverage was similar for both groups for the south coast, north inland, and central inland regions in California. A higher proportion of companies completing the full-length survey reported covering the north coast region, but a lower proportion reported covering the south inland region compared with the coverage reported by companies completing only the screener survey. Figure 95 summarizes the geographic regions in which respondents reported that they conduct HVAC alteration inspections.

Figure 95. Geographic coverage reported by survey respondents (HERS Rater screener survey, 2016, unweighted)

Climate Region	Completed only the Screener Survey	Completed the Full-length Survey	Overall
North Coast	20%	41%	30%
North Inland	31%	34%	32%
Central Inland	43%	48%	45%
South Inland	43%	34%	38%
South Coast	21%	21%	21%
Total Sample Size	**61**	**57**	**117**

Note that 57 respondents participated in the full length-survey from 56 companies; one company had a second respondent.

Weighting approach

The analyses presented in subsequent sections cover topics relevant to characteristics of Raters and Rater firms, and areas relevant to the population of HVAC alteration inspections. DNV GL developed sample weights for the 57 Raters who completed the full-length survey, to use for the analyses that covered topics relevant to the population of inspections. Developing the weights involved several steps:

1. **Estimating the total number of inspections completed in a typical year by firms represented in the screener survey**. The screener survey asked Raters to provide an estimate of the number of inspections their company completed in the previous year, to indicate whether that number reflected a typical year, and to revise their estimate accordingly. We summed the number of inspections reported by all 122 of the screener survey respondents for a typical year, totaling to 19,440 inspections.
1. **Extrapolating the rate of inspections estimated from the screener survey to the population of Raters to calculate the population of inspections.** The 122 respondents to the screener survey represented approximately one-quarter of the population of 500+ HERS Raters. We assumed the three-quarters of Raters that did not complete the screener survey completed inspections at the same annual rate as the Raters who completed the screener survey, and extrapolated the number of inspections to the population of Raters. This approach yielded an estimate of 81,000 total HERS inspections in California for one year.
2. **Calculating weights proportionately for the 57 Raters to represent the population of inspections.** We multiplied the proportion of inspections of the total for the 57 Raters by the estimated 81,000 estimated total inspections per year to calculate the Rater-level weights. Most of the analyses in this report used these weights. Results are presented as "Raters accounting for X% of projects" to reflect the percentage (X%) relative to the population of projects, not of the population of Raters. Results reported as means represent survey responses weighted to the population of projects.

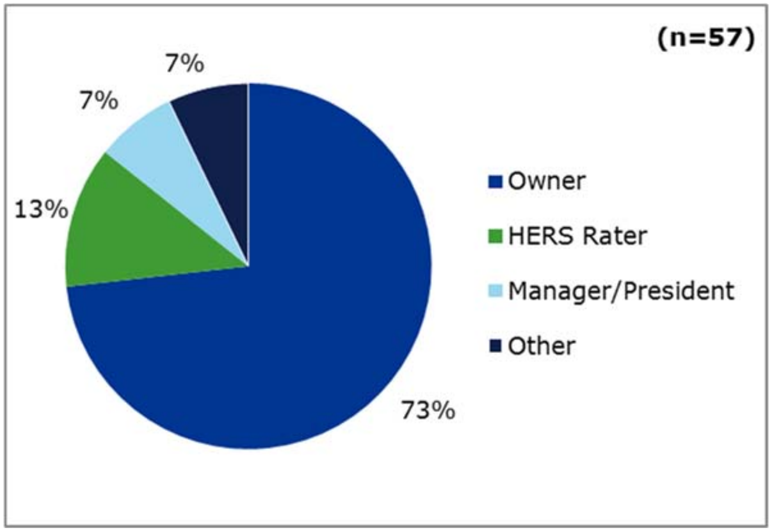
Ideally, we would have calculated the weights from the HERS Provider registry as opposed to Raters' estimates. However, these data are not publicly available, and the HERS Providers denied the CPUC's requests for this information and cited no reasons for declining

APPENDIX S. DETAILED RESULTS: HERS RATER SCREENER SURVEYS (TELEPHONE SURVEY)

This appendix summarizes screener survey results for the 57 HERS Raters who completed the full-length surveys. We provide more details on these results below. As a reminder, these results are unweighted.

We first asked respondents about their positions or job titles. As Figure 96 shows, more than 70% said they owned their company, with most of the remaining respondents saying they were a HERS Rater. This affirms that most of the people we spoke to were in the right positions to provide useful insight regarding conditions in the HVAC project industry.

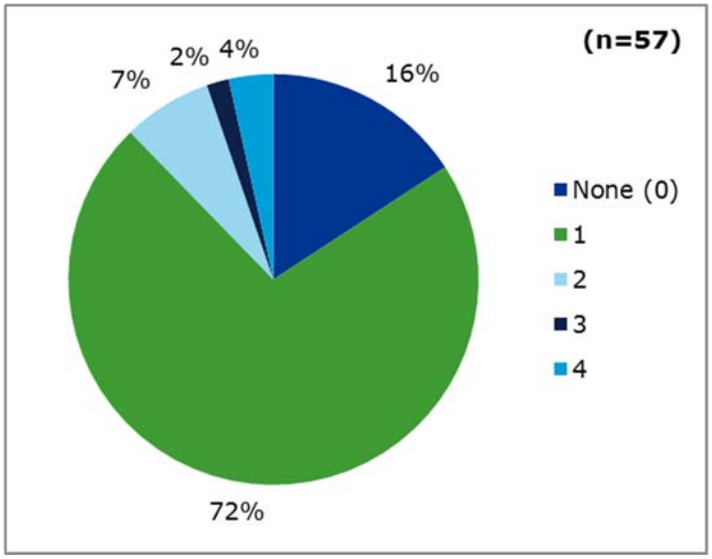
Figure 96. HERS Rater job titles (HERS Rater screener survey, 2016)



We also identified how many HERS Raters worked full-time for respondents' companies (Figure 97). The majority (72%) of respondents said that their company had one full-time HERS Rater, while a combined 13% said their company had between two and four Raters. The average number of employed HERS Raters was 1.1. Taken along with the previous question, this means that the majority of respondents were single-proprietor HERS Rater company owners.

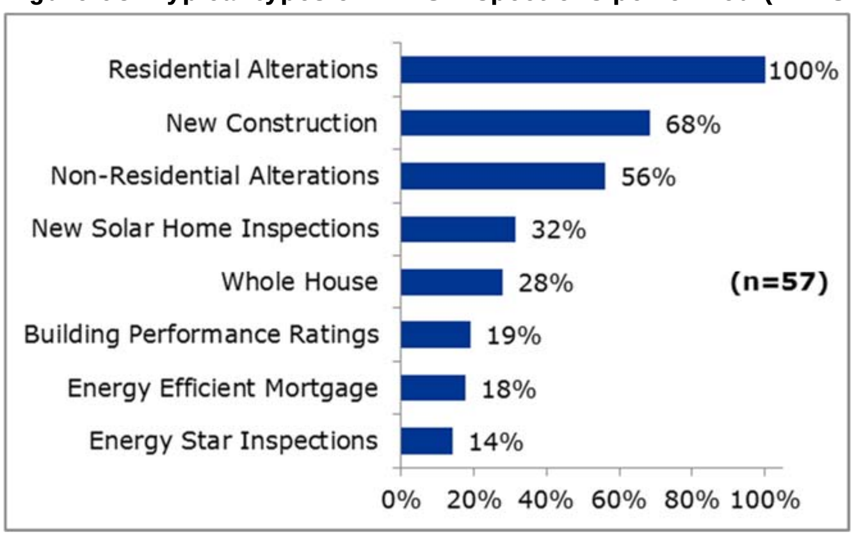
The 16% that said they employed zero Raters are likely cases in which part-time Raters are employed or situations in which respondents interpreted the question to mean how many Raters their company employs in addition to the respondent.

Figure 97. Number of full-time HERS Raters employed (HERS Rater screener survey, 2016)



We then asked the respondents the type of HERS inspections they performed (Figure 98). As mentioned previously, to prequalify for the full-length survey they had to have performed Residential Alterations. Additionally, roughly two-thirds said they performed inspections on New Construction, and more than half performed Non-Residential Alterations. About a third said they perform New Solar Home Inspections (32%) and over a quarter said they performed Whole House inspections (28%).

Figure 98. Typical types of HERS inspections performed (HERS Rater screener survey, 2016)



Note: These totals exceed 100% due to multiple responses.

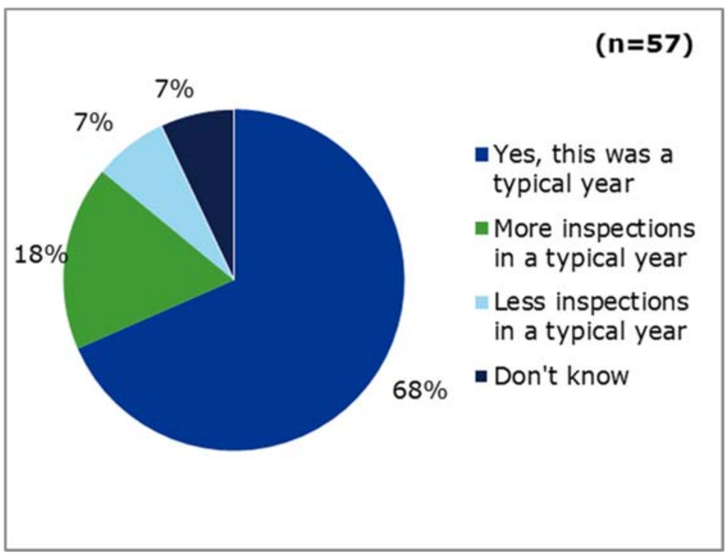
We then asked respondents how many HERS Inspections of all types their companies performed in California in 2015 and followed up by asking how many of those inspections were related to residential HVAC alterations. Figure 99 shows that, in 2015, more than half of respondents' companies (54%) completed 100 or more inspections of all types but only 40% completed 100 or more residential HVAC alteration inspections. On average, respondents' companies completed 226 inspections of all types and 159 inspections related to residential HVAC alterations.

Figure 99. Estimated number of HERS Inspections completed by company in 2015 (HERS Rater screener survey, 2016)

Total Number of Inspections (n=57)	% of Inspections	% of Inspections Related to Residential HVAC Alterations
200+	32%	19%
100-199	23%	21%
20-99	30%	35%
<20	16%	25%
Total	**100%**	**100%**

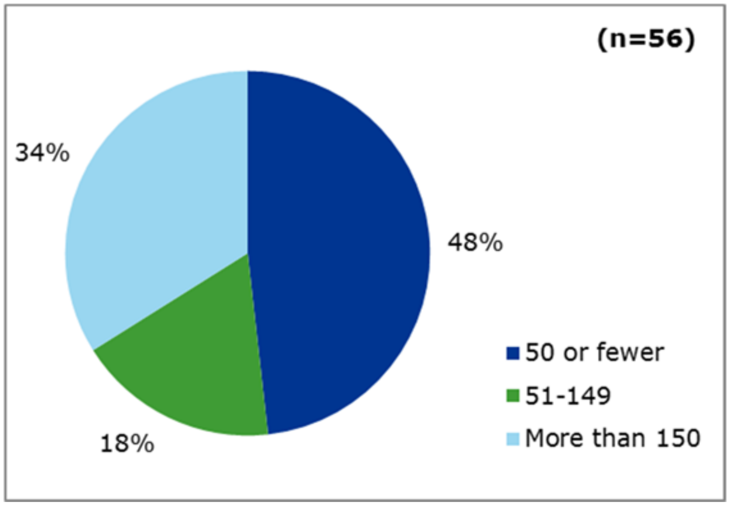
Since these were estimates for the calendar year 2015, we also wanted to know whether their estimates of inspections, related to residential HVAC alterations, represented a *typical year* for their companies (Figure 100). Slightly more than two-thirds of respondents said that 2015 was a typical year for these types of inspections (68%). However, more than double as many respondents said that a typical year contained more inspections (18% of respondents) than said a typical year contained less inspections (7%), meaning that 2015 may have been a lower year than usual for these types of inspections, at least for this population.

Figure 100. Whether 2015 represented a typical year for HERS Inspections (HERS Rater screener survey, 2016)



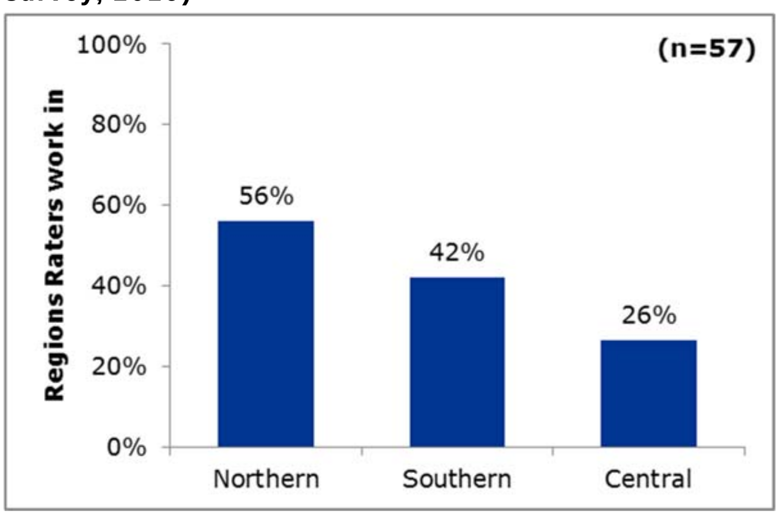
Lastly in terms of inspection numbers, we asked respondents how many HVAC alteration inspections they personally completed in 2015. The results are shown in Figure 101. Roughly one-third of respondents (34%) said they personally completed more than 150 such inspections. Again, this affirms that respondents are able to provide useful insight regarding conditions in the HVAC industry.

Figure 101. Estimated number of HVAC alteration inspections completed by respondents in 2015 (HERS Rater screener survey, 2016)



Next, to identify whether the respondents geographically covered the state, we asked which of the three regions in California (Northern, Southern, or Central) in which they often work. Multiple responses were allowed. As Figure 102 shows, the majority of respondents said they work in Northern California (56%), and about a quarter of them said they work in Central California (26%).

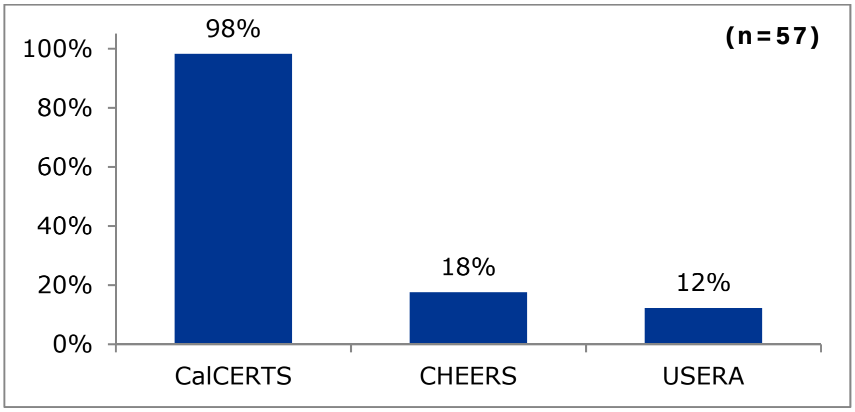
Figure 102. Regions of California in which respondents most often work (HERS Rater screener survey, 2016)



Note: These totals exceed 100% due to multiple responses.

We asked the respondents which HERS Providers they were registered with (Figure 103). All but one of the 57 respondents said they were registered with CalCERTS, Inc., which was unsurprising given that our sample frame for the survey was taken from the CalCERTS website. Fewer than one in five respondents said they were registered with ConSol Home Energy Efficiency Rating Services, Inc. (CHEERS); and/or USERA (18% and 12%, respectively). Almost three-quarters of respondents (72%) said they were registered with only CalCERTS. Just one respondent said they were registered with all three Providers, and one respondent said they were only registered with USERA. When asked which Provider they worked with most often (for those who worked with multiple providers), the majority (73%) worked primarily with CalCERTS, with the remaining 27% saying they worked primarily with USERA.

Figure 103. HERS Providers with which survey respondents were registered (HERS Rater screener survey, 2016)

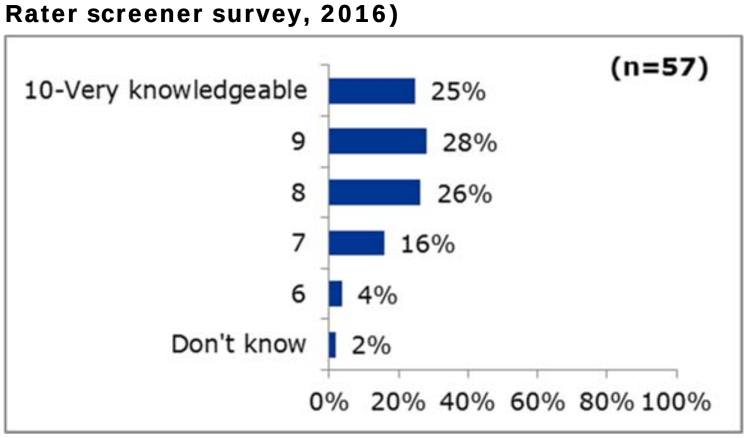


Note: These totals exceed 100% due to multiple responses.

The survey also asked the respondents a couple of questions regarding their background and experience. Slightly more than half of respondents (58%) said they had worked as a HERS Rater for less than five years, and about half of respondents (51%) said they had a background as an HVAC contractor or technician.

The final screener survey question asked survey respondents how knowledgeable they were regarding the Title 24 2013 code for HVAC systems in residential dwellings. Respondents used a 10-point scale in which 10 meant 'very knowledgeable' and 1 meant 'not at all knowledgeable.' All respondents rated their level of knowledge at a 6 or higher, and most respondents (79%) rated their level of knowledge as an 8 or higher. The full spectrum of results can be seen in Figure 49.

Figure 104. Respondents' self-reported knowledge about residential Title 24 HVAC code (HERS Rater screener survey, 2016)



APPENDIX T. DETAILED HERS SURVEY FINDINGS

RESEARCH QUESTION 1: WHAT ARE THE KEY BARRIERS ASSOCIATED WITH TRAINING FOR HERS RATERS?

Of the 57 online survey respondents, 55 participated in a HERS Rater certification or re-certification training course for the 2013 Title 24 Energy Code that went into effect in July of 2014 and accounted for 97% of projects. We asked these respondents to share their experiences with the HERS Registry training (n=55).

Raters (accounting for 84% of projects) most recently participated in the training, offered by HERS Registry certification offered by CalCERTS, which is not surprising given the source of our sample frame (the CalCERTS Registry). For most of the remainder, Raters (accounting for 14% of projects) most recently participated in the training offered by USERA. Raters accounting for the final 2% of projects participated in HERS Rater certification training from other entities such as the Center for Sustainable Energy.

Field training

One aspect of the research theory mentioned above is that HERS Rater training does not include enough field training. When we asked whether their most recent HERS Registry training took place in a classroom setting, a field setting (with HVAC equipment), or a combination of both, respondents accounting for two-thirds of projects said the training took place in a classroom only (66%). Respondents accounting for the remaining 34% said the training was based in a combination of classroom and field training. A significantly greater proportion of respondents with more than five years of experience said that their most recent training only took place in a classroom setting than those with less than five years of experience (accounting for 94% of projects versus 34% of projects). The likely explanation is, the training programs have begun to offer a field component, but only to new Raters; Raters who participate in the new code refresh-only courses are not offered a field component.

Usefulness of training

To probe further on the effectiveness of the HERS Registry certification or re-certification training, we asked respondents how useful the training had been in helping them with a variety aspects of the HERS process. Respondents used a 10-point scale in which 10 indicated "very useful" and 1 indicated "not at all useful." We asked about elements of training that general fell into two categories: (1) testing and verification procedures; and (2) other elements of the training. Figure 105 shows the mean rating across respondents and the ratings grouped into three categories: high usefulness (ratings of 8 to10); moderate usefulness (ratings of 4 to 7); and low usefulness (ratings of 1 to 3). We weighted survey responses up to the population of projects as described in Section 2.5, so the percentages represent the proportion of projects the Raters account for, in each category.

Figure 105 shows that the training was generally useful in helping Raters apply proper testing or verification procedures, particularly with regard to procedures for duct testing and blower door testing (average ratings of 8.3 and 7.7, respectively). Results suggest that Raters perceived the training as relatively useful with regard to helping participants apply proper verification of mandatory and prescriptive measures (7.1), applying proper testing procedures for measuring refrigerant charge levels (6.9), and measuring airflow and fan power index (6.7). The lowest ratings were with regard to the training's usefulness in helping Raters apply proper testing or verification procedures was for fog testing using a theatrical fog machine (6.3).

Figure 105 also shows that there was a considerable range in how useful respondents thought the other elements of training were. Respondents rated the usefulness of these other elements of training highest in terms of helping them to obtain relevant information on Title 24 requirements for HVAC inspections and in terms of learning which compliance forms apply for various HVAC changeout scenarios (average ratings of 8.3 and 7.7, respectively). According to respondents, the training was somewhat useful in terms of helping to make the HERS Rater manual easy to use and in terms of communicating test results to installation contractors (average ratings of 7.0 and 6.6, respectively). Lastly, respondents thought the training was least useful in terms of helping them to become familiar with the CF submission process for the HERS Provider's Registry (4.7). Nearly half of the respondents rated that aspect of the training as a 3 or lower.

Figure 105. Usefulness of HERS Rater training in helping with specific elements of HERS rating activities (HERS Rater online survey, 2016)

Training Element	Usefulness Rating* (n = 55)				
	Mean	High (8 to 10)	Moderate (4 to 7)	Low (1 to 3)	Don't know
Testing and verification procedures					
Apply proper testing procedures for duct testing	8.3	57%	42%	1%	-
Apply proper testing procedures for blower door testing	7.7	49%	43%	8%	-
Apply proper verification of mandatory and prescriptive measures	7.1	47%	35%	17%	-
Apply proper testing procedures for measuring refrigerant charge level	6.9	44%	36%	20%	-
Apply proper testing procedures for measuring airflow and fan power index	6.7	39%	43%	18%	-
Apply proper testing procedures for fog testing (using a theatrical fog machine)	6.3	38%	34%	28%	-
Other elements of training					
Obtain relevant information on Title 24 requirements for HVAC inspections	8.3	60%	39%	1%	-
Learn which compliance forms apply for various HVAC changeout scenarios	7.7	59%	32%	9%	-
Ease of use with the HERS Rater manual	7.0	46%	35%	19%	<1%
Communicate test results to installation contractors	6.6	45%	30%	24%	2%
Become familiar with the form submission process for the HERS Provider's Registry	4.7	33%	19%	49%	-

* Respondents provided ratings on a 10-point scale where 1 means "not at all useful" and 10 means "very useful." Percentages represent the proportion of projects the Raters account for, in each category.

There were some statistically significant differences between certain groups of respondents in terms of how useful they thought the training was. Overall, Raters with five or fewer years of experience were more positive about the usefulness of the training than Raters with more than five years of experience. These differences could indicate either that more experienced Raters already knew this information or that more experienced Raters are more set in their ways and more resistant to changes in the HERS process. Or it may be the case the training program has improved within the last five years. It was also the case that Raters with more than 150 residential HVAC alteration inspections done in 2015 were more positive in their assessment of how useful the training was than Raters with fewer jobs completed. APPENDIX U provides more information on the full set of statistically significant differences between certain groups of respondents for all research theories.

Satisfaction with training

We also probed respondents' satisfaction with various aspects of the training, using the 10-point scale again. A rating of 10 indicated "very satisfied" and 1 indicated "not at all satisfied." We grouped the elements of training into three categories: (1) hands-on experience; (2) training logistics; and (3) other elements of the training. For each of these, we present the mean rating across respondents and the ratings grouped into three categories: high satisfaction (ratings of 8 to 10); moderate satisfaction (ratings of 4 to 7); and low satisfaction (ratings of 1 to 3). The analyses weighted the survey responses up to the population of projects, as described in Section 2.5

Hands-on experience. Figure 106 shows training participant satisfaction with the hands-on experience offered in the trainings. Satisfaction was relatively low with the four aspects related to hands-on experience addressed in the online survey. Respondents were least satisfied with the level of hands-on experience that the training provided as far as using the certification forms (average rating of 5.3) and only somewhat satisfied with the other three elements of hands-on training we addressed in the survey (average ratings of 6.5 to 6.6 each). We elicited specific feedback from participants with regard to the hands-on elements of training, and responses included the following:

- "I feel more hands-on training is needed to truly understand how to use the instruments we use for testing, but also an explanation of the how's and whys. One of the problems is once a newly licensed HERS Rater is in the field, if he/she does not understand AC, system design, static pressure, they can't adequately teach...and ultimately I feel the HERS program and HERS Raters should be above all else, teachers in the field. We would be more widely accepted, and less feared if installers felt we were there to work with them and help them achieve better system design."
- "When my employees come back from training and they have passed their certification test, I expect them to be trained. This has NEVER been the case. Perfect example; HERS verifications of hot water heaters/plumbing. There was one black and white picture and NO hands-on examples of the parts of a system they would need to inspect."
- "Coming from a person in the HVAC trade, the training offered by rating organizations needs to be more in-depth with hands-on tools. I have had to buy special equipment that I had to learn on my own trying to follow compliance procedures."

Additionally, although the online survey did not specifically ask about training with regard to the HERS Rater Registry participants accounting for more than 10 percent of projects offered unsolicited perspectives regarding the need for hands-on training regarding the CalCERTS Registry. Specific comments included:

- "A little bit of training on the CalCERTS Registry would have been nice."
- "There was no training on how to use the Registry for the 2013 Standards. I had to figure it out on my own. It is a convoluted process and was very confusing for the first few weeks."
- "The CalCERTS training does not cover using the CalCERTS database/web form data entry. It would be a great help if they did."

APPENDIX T provides more detail on training participants' open-ended comments with regard to the HERS Rater training.

Figure 106. Satisfaction with hands-on experience provided in the HERS Rater training among training participants (HERS Rater online survey, 2016)

Hands-On Experience	Satisfaction Rating* (n = 55)				
	Mean	High (8 to 10)	Moderate (4 to 7)	Low (1 to 3)	Don't Know
Hands-on experience visually verifying mandatory and prescriptive measures	6.6	37%	43%	20%	<1%
Hands-on experience using testing equipment	6.5	39%	40%	21%	-
The training support HERS Raters receive while in the field or on the job	6.5	42%	33%	25%	-
Hands-on experience using certification forms	5.3	19%	51%	30%	-

* Respondents used a 10-point scale where 1 means "not at all satisfied" and 10 means "very satisfied." Percentages represent the proportion of projects the Raters account for, in each category.

Training logistics. As far as the training logistics, respondents were relatively satisfied (Figure 107). Respondents provided moderately high ratings with regard to the length of the training course, geographic location, and frequency of training offered (mean ratings of 7.1 to 7.4 across all respondents). Satisfaction with the cost of the training was slightly lower but still moderate (average rating of 6.6).

Figure 107. Satisfaction with training logistics among HERS Rater training participants (HERS Rater online survey, 2016)

Training Logistics	Satisfaction Rating* (n = 55)				
	Mean	High (8 to 10)	Moderate (4 to 7)	Low (1 to 3)	Don't Know
Course length	7.4	44%	53%	3%	-
Course location	7.3	50%	35%	15%	-
Course frequency	7.1	40%	56%	4%	1%
Course cost	6.6	34%	44%	22%	<1%

* Respondents used a 10-point scale where 1 means "not at all satisfied" and 10 means "very satisfied." Percentages represent the proportion of projects the Raters account for, in each category.

Other elements of training. Respondents were very satisfied with the instructors' technical knowledge of HVAC systems (average rating of 8.1), as presented in Figure 108. Training participants also provided mean satisfaction ratings of 7 or higher with regard to the relevance of the material presented, the ease of working with the training manual, and the content of the training course.

Despite these relatively high satisfaction ratings, some training participants offered specific feedback regarding the manual. For example:

- "When I was in my training there were several times where we had to cross something out of the manual because it was either the wrong information or no longer applicable. The manual also contradicted itself a few times. While learning this proved to be very confusing because in one chapter you learn something then in the next one it tells you something completely different or I would have to go back to the last chapter and cross out what I had just learned."

- "Regarding the 2013 classroom update course from CalCERTS I pointed out 3 'errors' they made regarding code… I had anticipated CalCERTS would have sent out an 'update' style email to all the Raters who took that course so there would be no confusion in the field of applying the code correctly but sadly nothing was ever done."

APPENDIX T provides more detail on training participants' open-ended comments.

Figure 108. Satisfaction with other elements of training among HERS Rater training participants (HERS Rater online survey, 2016)

Other Elements of Training	Satisfaction Rating* (n = 55)				
	Mean	High (8 to 10)	Moderate (4 to 7)	Low (1 to 3)	Don't Know
The instructors' technical knowledge of HVAC systems	8.1	59%	40%	2%	-
The relevance of the material presented	7.7	48%	51%	0%	-
The ease of working with the training manual	7.5	47%	47%	6%	-
The content of the training course	7.2	48%	40%	12%	-

* Respondents used a 10-point scale where 1 means "not at all satisfied" and 10 means "very satisfied." Percentages represent the proportion of projects the Raters account for, in each category.

RESEARCH QUESTION 2: WHAT IS THE LEVEL OF COMPETENCY AMONG HERS RATERS IN COMPLETING ACCURATE INSPECTIONS?

Field diagnostic testing procedures

The three most common field diagnostic tests HERS Raters perform when evaluating an installation are duct leakage, refrigerant charge and system air flow with fan power index. The survey addressed the following tests and the tests involve:

- **Duct leakage**[17] is the volume of air over time, measured in cubic feet per minute (cfm), that leaks out of the ducts due to improper sealing and/or holes within the duct line. Reducing duct leakage is one of the most important energy efficiency code requirements. Since July 1, 2014, duct testing has been required in all climate zones (CZs) whenever an existing duct system is altered or replaced.

There are four ways to comply with Title 24 duct leakage requirements for an altered duct system. Most Raters begin with the first one, the total duct leakage (TDL) test: a system is compliant if the total leakage is no more than fifteen percent of total system airflow. The second is the leakage-to-outside (LTO) test: a system is compliant if leakage outside the conditioned envelope - into a vented attic containing the ducting, for example - is no more than ten percent of total system airflow. This test requires more equipment and more time to set up than the TDL test and is not usually performed unless

[17] Duct testing is applicable to packaged and split systems only

the TDL test fails. A system can also be deemed compliant if the Rater determines by inspection that all accessible ducts are sealed OR the Rater performs an inspection and "smoke" test using a chemical fog.

- **Refrigerant charge**[18] determines if the system has the proper amount of refrigerant. Under- or over-charged systems operate less efficiently than those that are properly charged. In the case of split systems, Title 24 requires that the refrigerant charge be verified. The Rater measures the pressures and temperatures of the refrigerant at specified points in the system and uses these values to consult lookup tables to verify proper charge. (Package systems are properly charged at the factory and do not need charge adjustment or verification at installation.)
- **System airflow and fan power index**[19] is the volume of air that moves through the system. The test measures the total volume of air that is moved by the forced-air system and the amount of electrical power the fan draws to move that volume of air. Title 24 requires that system airflow in an altered system be at least 300 cubic feet per minute (cfm per ton of cooling capacity. The acceptable methods for measuring system airflow are specified in Title 24 and are required to be accurate within ± 7 percent.

We asked HERS Raters a series of questions about FV/DT procedures to assess (1) their level of knowledge of Title 24 requirements, (2) the completeness of their HVAC inspection work, and (3) standard practices. We presented a residential changeout scenario and asked them to identify which of the Title 24 prescriptive measures they would typically verify and what tests they would typically perform in this specific scenario.

It is worth noting that for the majority of "field verification" Title 24 requirements, it is the contractor's responsibility to report compliance on the CF1R and the enforcement agency's responsibility to verify compliance. Additionally, several Title 24 requirements are activated only when a substantial portion of, or complete replacement of, the ducting is replaced. We were interested in assessing the accuracy of the HERS inspections, so included the comprehensive set of requirements on the survey (e.g. both requirements under the purview of the contractor and the HERS Raters).

Since some requirements are activated relative to the climate zone, we incorporated the Raters' self-reported climate zone in which they most often worked into the scenario. The scenario thus read as follows:

"This week you secured a HERS inspection at a single-family residential dwelling in climate zone [x]. The HVAC contractor replaced the central heating and cooling unit at the same time. The existing duct work is located in the attic and the house is 1,700 square feet."

Only the climate zone in the scenario varied from respondent to respondent. The scenario involved replacement of both the furnace and condensing unit but the duct work was not changed.

Figure 109 lists the Title 24 prescriptive requirements that are activated for this scenario. The table presents each requirement and its applicable climate zones, target or threshold values, and response results. We weighted survey responses up to the population of projects as described in Section 2.5, so the percentages represent the proportion of projects the Raters account for, in each category. The results are presented as three different percentages, representing:

- Percent of ALL Raters who would perform the FV/DT: This percentage represents all Raters who would have performed the test whether it was required in their climate zone or not.

[18] Refrigerant charge test is applicable to split system only

[19] System air flow and fan power index is applicable complete system changeout with new ducts

- Percent of ALL Raters who would perform the FV/DT in compliance with the requirement: This percentage represents two sets of Raters: those who would have performed the test AND the test applied to their climate zone, and secondly, Raters who would NOT have performed the test AND the test did not apply to their climate zone.
- Percent of Raters an applicable CZs who would perform the FV/DT: This data, the most relevant of the three, represents the percentage of Raters who work within those climate zones that require the test and who would have performed the test. It does not include Raters who work within climate zones where the requirement is not applicable.

Figure 108 illustrates that for the HVAC changeout scenario, inconsistencies in FV/DT performed by HERS Raters and possibly a gap in Raters' awareness of FV/DT requirements. Fortunately, in the climate zones where requirements are applicable, (Re: Percent of Raters In applicable CZs who would perform the FV/DT), there is a relatively high percent of Raters performing the FV/DT applicable to that climate zone (accounting for 71%, 97% & 94% of projects). The one exception is duct testing, Raters accounting for more than ¼ of projects claim they would not perform the duct leakage test; this test came into effective on July 1, 2014 in all climate zones.

Figure 109: HERS FV/DT requirements for a furnace and AC changeout with existing ducts (HERS Rater online survey, 2016)

Requirement	Applicability	Threshold	Method to Evaluate (FV or DT)	Percent of ALL Raters who would perform the FV/DT	Percent of ALL Raters who would perform the FV/DT in compliance with the requirement	Percent of Raters in applicable CZs who would perform the FV/DT
Duct Leakage at 15%	Mandatory, All Climate Zones	15% total leakage (changeout)	Diagnostic Test	71% (n=52)	71% (n=52)	71% (n=52)
Refrigerant Charge	Prescriptive, CZ 2 and CZs 8-15	Diagnostic within tolerance of target	Diagnostic Test	78% (n=52)	91% (n=50)	97% (n=35)
Verify Measurement Access (HSPP & PPSP)	Prescriptive CZs 10-15, Temperature and Pressure	Yes/No	Field Verification	84% (n=51)	59% (n=43)	94% (n=34)

Duct leakage number of respondents, (n=52), refrigerant charge number of respondents, (n=52, n=50, n=35), verify measurement access number of respondents, (n=51, n=43, n=34). Percentages represent the proportion of projects the Raters account for, in each category.

Figure 110 presents additional Title 24 requirements for HVAC changeouts; however, these requirements have applicability limits. The following limits apply and are described in the table under the column "Applicability to Changeout Scenario & Verification Delegation." These limits are in the following categories:

- The Title 24 requirement is not the responsibility of HERS Raters to verify but rather the responsibility of the contractor and the code enforcement agency. Most of these requirements are reported on the CF1R form.
- The Title 24 requirement is not required because existing ducts are largely unchanged (if there are no significant changes to the duct work many requirements are not triggered).

In general, it is useful to observe how many requirements are either not triggered or are not the Rater's responsibility. These results also illustrate some percent of Raters, depending on the requirement, are performing FV/DT that do not apply (between 2% and 63%). This is similar to the findings from Figure 109 that shows gaps in Raters' knowledge of their FV/DT requirements.

Figure 110. HERS FV/DT requirements for a furnace and AC changeout without new ducts, (HERS Rater online survey, 2016)

Requirement	Applicability	Threshold	Method to Evaluate FV or DT	Applicability to Changeout Scenario & Delegation	Percent of ALL Raters who would have performed the FV/DT requirement (n=51)
Minimum efficiency, split systems (n=51)	Mandatory, All Climate Zones	After 01/01/2015 SEER 14, AFUE 80, HSPF 8.2	AHRI Certification and Field Verification	Not applicable, contractor's responsible to report on CF1R form	63%
Set-back programmable thermostat (n=51)	Mandatory, All Climate Zones	It is mandatory for heating equipment and Heat Pump with electric resistance Yes/No	Field Verification	Not applicable, contractor responsible to report on CF1R form	14%
Additional duct insulation (n=51)	Prescriptive, varies by CZ from 6.0 to 8.0, only when ducts are new	R-value from 6.0 to 8.0 (requirements is 6.0 to 8.0)	Field Verification	Not applicable for this changeout scenario, because ducts are existing	15%
Refrigerant Suction line insulation (n=51)	Mandatory, All Climate Zones	(I think 1" suction line insulation is mandatory) Insulation thickness based on pipe diameter	Field Verification	Not applicable, contractor is responsible to report on CF1R form	23%
Duct insulation (n=51)	Mandatory, All Climate Zones	R-6.0 (requirements is 6.0)	Field Verification	Not applicable, contractor is responsible	15%

Requirement	Applicability	Threshold	Method to Evaluate FV or DT	Applicability to Changeout Scenario & Delegation	Percent of ALL Raters who would have performed the FV / DT requirement (n=51)
Fan power index consumption (n=52)	Prescriptive, CZ 10-15 applicable to complete system changeout with new ducts.	(New system equipment & ducts or New duct system > 75%) ≤0.58 W/cfmcfm	Diagnostic Test	Not applicable for this changeout scenario, because ducts are existing	10%
Duck leakage at 6% (n=52)	Applicable to complete system changeout with new ducts.	6% total leakage (entire system replacement including ducts)	Diagnostic Test	Not applicable for this changeout scenario, because not a complete system changeout	2%
Measure leakage to the outside (n=52)	Not a requirement unless duct leakage test doesn't pass	Not a requirement unless system doesn't pass	Diagnostic Test	Not applicable for this changeout scenario, system passes on first set of tests	13%
Manual J load calculations	Mandatory, All Climate Zones	Yes/No (no sizing requirement based on load calculations)	Calculation	Not applicable, contractor responsible to calculate and present to building department upon request	2%

Percentages represent the proportion of projects the Raters account for, in each category.

Standard practices when compliance tests fail

The primary role of a HERS Rater is to perform diagnostic tests on newly installed HVAC units. The most common tests are described above in Field Diagnostic Testing Procedures. We designed the standard practice questions to identify when diagnostic tests fail:

- Would Raters re-test or apply alternate test methods: what are their practices?
- How well do Raters communicate these results to contractors, customers, and to the HERS Registry?

Raters with no experience with a one of the failed tests were excluded from the questions on standard practice.

Duct test practices

The first standard practice question was on duct testing. The question asks:

"Consider the [climate zone # 1-16] installation scenario: The duct leakage test does not pass the first test and the contractor attempts to repair it but still does not pass. In this situation, what other test(s), if any, would you perform as part of your standard practice?"

Raters were asked to consider what they would do in this duct leakage scenario. Figure 111 presents the range of responses for this multiple response question. In this scenario, all Raters would perform a smoke leakage test to demonstrate whether accessible leaks have been sealed. This is an acceptable alternative to the total duct leakage test. Raters accounting for only 17% of projects would perform an LTO test - another acceptable alternative - if the total leakage test failed, and Raters accounting for 4% of projects would never perform an LTO test at all. To measure LTO, Raters must perform a separate Blower Door Test; it's possible that few Raters are performing LTO tests because of the added expense of the additional equipment and because the size and weight of the equipment is rather burdensome to carry from job to job.

Figure 111. Tests Raters would perform in hypothetical scenario when the duct test fails (HERS Rater online survey, 2016)

Test	Percent of Respondents (n=49)
Smoke test	100%
Repeat total leakage test	29%
Leakage to the outside test	17%
Inspect the system with contractor	16%
Seal ducts	12%
Visual inspection	6%
Would not perform leakage to outside test	4%
Other	<1%

Note: These totals exceed 100% due to multiple responses. Percentages represent the proportion of projects the Raters account for, in each category.

The next question in the duct leakage series asks about frequency in which Raters perform test. Respondents were asked:

"When your residential HVAC inspections fail the duct leakage tests, how often do you perform the following (3) tests?" The survey presented them with five response options: always, often, sometimes, rarely, or never.

The results in Figure 112 slightly contradict those presented above in the hypothetical scenario (Figure 111). Raters accounting for 87% of projects said they always or often repeat the total leakage test, in comparison to the Raters accounting for 100% of projects said that said they would perform that test as reflected in the above responses.

Figure 112. Frequency with which Raters perform standard tests when duct tests fail (HERS Rater online survey, 2016)

Test	Always / Often	Sometimes	Rarely / Never	Total
Repeat total leakage test	94%	5%	1%	100%
Perform smoke test	87%	11%	2%	100%
Perform leakage to the outside test	6%	13%	81%	100%

Percentages represent the proportion of projects the Raters account for, in each category.

Airflow and fan power index test practices

As described above, these two tests measure the volume of air moving through the system and the electrical power needed to push that volume of air. Failure to properly size the system (whether too large or too small) can lead to comfort issues, excessive power usage, and early burnout of equipment. These tests apply in all climate zones but only when there is a complete system changeout with new ducts or when 75% of the ducts have been replaced.

HERS Raters accounting for only 84% of projects overall claimed to have experience with HVAC alterations that did not pass the airflow and fan power index tests. Respondents with less than 5 years' experience in the field and fewer than 50 tests in a typical year were the least likely to experience these situations (accounting for 73% and 72% of projects, respectively).

After first screening out the respondents who had no experience with fan power index and airflow tests, the survey asked Raters:

"If an airflow test does not pass, what do you typically do?"

Figure 113 presents the range of responses. It's interesting to note there are few options for Raters beyond contacting the contractor (97% of projects) and repeating the tests (61% of projects). Additionally, we note while the Standards state a system must be properly sized there is no compliance form designed to capture and illustrate the results as such it is likely the contractors do not perform the calculations but rather perform rough estimates based on total house square footage.

Figure 113. Actions taken when airflow / fan power index tests fail (HERS Rater online survey, 2016)

Action	Percent of Respondents (n=41)
Contact the installation contractor	97%
Repeat test	61%
Perform static pressure test	11%
Check fan speed	4%
Other	5%

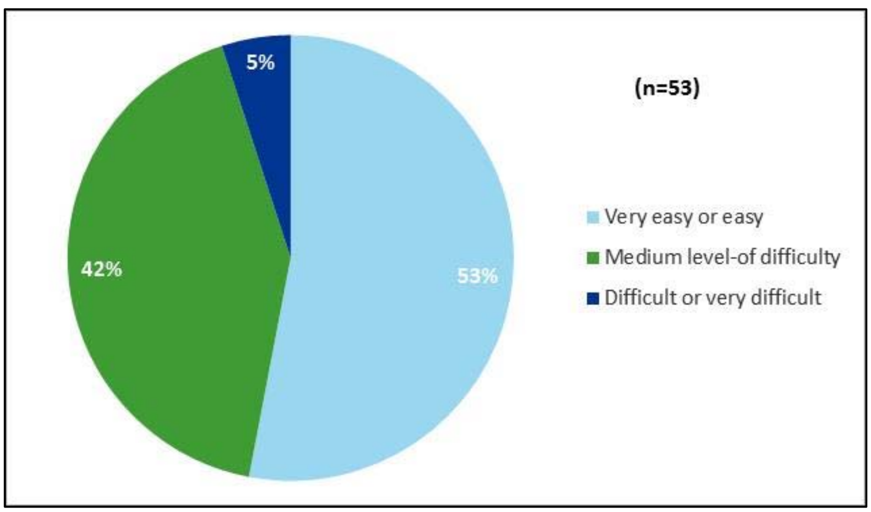
Note: These totals exceed 100% due to multiple responses. Percentages represent the proportion of projects the Raters account for, in each category.

Communication with contractors when tests fail HERS inspection

DNV GL conducted a small-scale pilot phase of the full-length survey. This process revealed that HERS Raters find it challenging to communicate failed test results to contractors. Challenges may exist because Raters are most often informed of job opportunities by the installing contractor, and a failed test may result in additional time and expense for the contractor, to get the job to comply. Conflicts of interest may result when rest results are unfavorable to the contractor. To avoid the additional time and expense to get the job to comply, we hypothesize that unethical Raters may not actually perform all the required tests and some may not accurately report test results. Raters who accurately report failed tests run the risk of not being hired, or informed of future jobs, by the contractor when another HERS inspection is needed. HERS Raters may perceive a lack of tools to communicate test results to contractors as a barrier to the successful execution of their work. To address this barrier DNV GL developed questions to identify whether adequate communications tools do exist and/or whether additional tools would benefit HERS Raters.

First, we asked Raters if they give advice to contractors when the duct or airflow test fails, by in large Raters accounting for the majority of projects (96%) provide some level of advice. We then asked Raters to use a 5-point scale "1" means "very easy" and "5" means "very difficult," *how easy or difficult is it to convey failed test or verification measure results to installation contractors?* The results mostly agree with pilot test respondents that there are some barriers. As illustrated in Figure 114, Raters accounting for a slight majority of projects at 53% found it to be very easy or easy while the remaining 47% found some level of difficulty.

Figure 114. Ease in communicating failed test results to installing contractors (HERS Rater online survey, 2016)



Percentages represent the proportion of projects the Raters account for, in each category.

The current ways in which Raters convey test results are presented in Figure 115. For this multiple-choice question, the results show Raters most often call or email the installer. It is interesting to note that Raters accounting for 2% of projects contact the installer at their own company indicating the companies hire both installers and Raters. Surprisingly, Raters accounting for only 19% of projects are informing the end user and very few (6% of projects) submit the results these first set of results to the HERS Registry. Among the large majority of the Raters accounting for 30% of projects who stated "something else," many cited they are "trying to find the problem, then re-inspecting the system with the contractor, or check for obstructions, or repeat tests before communicating failed test results."

Figure 115. How Raters typically communicate failed test results to contractors (HERS Rater online survey, 2016)

Communication method	(n=52)
Telephone or email the installer that is with another company	73%
Inform the end user where the unit is installed	19%
Submit the "no pass" test on the compliance form	6%
Have installer present during inspection	6%
Inform the installer at my company	2%
Something else	30%

Note: These totals exceed 100% due to multiple responses. Percentages represent the proportion of projects the Raters account for, in each category.

Raters were presented with a list of communication tools that could help alleviate the challenges in conveying failed test results. Specifically, they were asked

> *"What communication tools, if any, would you like to have available to more effectively convey failed test results? (Check all that apply.)*

As previously reported, not all Raters agree that tools are needed; 19 of 52 respondents (representing 36% of projects inspected) indicated no tools were needed, while the majority (33 respondents, representing 62% of projects) would like to additional tools. Among those, the top interests were a mobile telephone application, a standardized form or template, a dedicated website to upload images and notes, and hands-on-training to communicate the results in a prescriptive manner (Figure 116).

Figure 116. Communication tools to more efectively convey failed test results (HERS Rater online survey, 2016)

Communication tool	Percent of Respondents (n=52)
No tools are needed	51%
Mobile telephone application	27%
Standardized form or template	24%
Dedicated website to upload images and notes	21%
Hands-on training	19%
Dedicated job call line	7%
Flowchart	5%
Other	9%

Note: These totals exceed 100% due to multiple responses. Percentages represent the proportion of projects the Raters account for, in each category.

Lastly, Raters were asked an open-ended question on whether they had any comments to offer on the issues of HVAC changeout inspections at residential homes. Raters accounting for more than half at 55% of projects had suggestions, and the post-coded range of responses is presented in Figure 117. The most commonly-cited response at was Raters ought to offer guidance to contractors to help improve the installation and contractors need to be better educated about HERS.

Figure 117. Comments on changeout inspection at residential homes (HERS Rater online survey, 2016)

Post-coded category	Percent of Respondents (n=29)
Raters offer guidance to contractors	46%
Contractors need to be more educated/trained about HERS	23%
Code enforcement is too low	7%
Permits not being pulled	6%
Homeowners need to be better educated about HERS	5%
Difficulties with existing registry	5%
Contractors struggle with refrigerant charge	4%
Contractors should have Title 24 certification	3%
Other	18%

Note: These totals exceed 100% due to multiple responses. Percentages represent the proportion of projects the Raters account for, in each category.

RESEARCH QUESTION 3: WHAT ARE THE KEY BARRIERS TO TITLE 24 COMPLIANCE AMONG HERS RATERS?

Detailed findings

To investigate the key barriers to compliance, we asked respondents about a list of potential barriers, or reasons why some Raters may not fully comply with the Title 24 requirements. Respondents used a 10-point scale in which 10 indicated that the respondent "strongly agreed" that the item was a barrier and 1 indicated that they "strongly disagreed." We grouped the potential barriers into four categories: Rater preparedness, lack of enforcement, job security concerns, and other factors.

Figure 118 shows the mean rating across respondents and the ratings grouped into three categories: high agreement (ratings of 8 to 10); moderate agreement (ratings of 4 to 7); and low agreement (ratings of 1 to 3). We weighted survey responses up to the population of projects as described in Section 2.5, so the percentages represent the proportion of projects the Raters account for, in each category. In some cases, survey participants offered specific feedback on these issues through open-ended survey questions; we provide representative responses below, but more detail can be found in APPENDIX T.

First, in terms of Rater preparedness, respondents overwhelmingly agreed that some HERS Raters may not have enough technical experience to perform quality installations, with an average agreement rating of 8.9 on the ten-point scale. This was the strongest barrier identified, echoing the findings from theory one regarding a lack of field experience component in the training. HERS Raters accounting for approximately 46% of projects had additional comments in the online survey specifically regarding this issue, including:

- "Most of the HERS Raters when starting up… honestly need more in-the-field training. If you don't have a little bit of installing experience it can be tough to get answers from CalCERTS and especially USERA. Just recently I attended a CalCERTS class and had a newly certified HERS Rater with no field experience call me upwards of 10 times a day and is still doing so to get answers for simple field testing issues."

- "HERS Raters lack the training for specific brand[s] of equipment."
- "If [HERS Raters] don't have the technical ability to perform some of the testing, the ability to get training should be made much easier."

Many respondents also agreed that a lack of enforcement by local jurisdictions presented a barrier (average agreement rating of 8.1 out of 10). Specifically, some jurisdictions enforce only some of the required testing and verification, leading to Raters not complying with Title 24. HERS Raters accounting for approximately 25% of projects had additional comments in the online survey specifically regarding this issue, including:

- "The building department agency does not know exactly what forms/tests are required; therefore they are not requiring that the contractor have those specific tests done."
- "The biggest is the building departments… most of the time the building department doesn't ask, so I'm not going to waste money and time unless they call me on it. [It's] very common for the building departments to ignore [enforcement] so the contractor saves money."
- "Some report false results without testing at all. I have reported them as I have found them, and no action has been taken [by the local building departments]. So there are no repercussions."

Respondents expressed moderately high levels of agreement with the ideas that some raters:

- Do not have the right equipment to perform all the required tests (average rating of 7.5)
- May not have the desire to perform quality inspections (average agreement rating of 7.1)
- May not understand which Title 24 measures apply to their jobs (6.6)
- Some HERS Raters may not correctly report all test results because of concerns regarding job security (6.5)

Agreement was relatively low with the idea that Raters may not perform all the required testing and verification if they think it will fail (average agreement rating of 3.6 out of 10) or that the time required to complete quality inspections is not a major barrier (average agreement of 3.1).

Figure 118. Level of agreement with potential barriers to Title 24 compliance among HERS Raters (HERS Rater online survey, 2016)

Potential Barrier	Agreement Rating* (n=52)				
	Mean	High (8 to 10)	Moderate (4 to 7)	Low (1 to 3)	Don't Know
Rater preparedness					
Raters may not have enough technical experience to perform a quality inspection	8.9	75%	10%	5%	10%
Raters may not have all the right equipment to perform all the required tests	7.5	59%	10%	19%	13%
Raters may not understand which Title 24 mandatory and prescriptive measures apply to their jobs	6.6	45%	16%	24%	15%
Lack of enforcement					
Raters may work in local jurisdictions that enforce only some of the required tests and verification requirements	8.1	54%	18%	6%	23%
Job security concerns					
Raters may not correctly report all the test results for job security	6.5	40%	13%	22%	25%
Raters may not perform all the required tests and verification requirements if they think they will fail	3.6	15%	14%	46%	26%
Other factors					
Raters may not have the desire to do a quality inspection	7.1	52%	19%	19%	11%
Raters may not have enough time to do a quality inspection	3.1	18%	10%	58%	14%

* Respondents used a 10-point scale where 1 means "strongly disagree" and 10 means "strongly agree." Percentages represent the proportion of projects the Raters account for, in each category.

In addition to asking HERS Raters to rate their level of agreement or disagreement with potential barriers, the online survey also provided respondents with the opportunity to voice any other comments they may have regarding barriers to HERS Raters in complying with Title 24 requirements. These responses provided further nuance regarding several of the issues addressed above and also included issues such as fraudulent Raters with cut-rate services not failing installations when a failure is appropriate, rating firm owners manipulating testing results to maintain business (related to the job security concerns described above), and low frequency of contractors obtaining the appropriate permits.

RESEARCH QUESTION 4: WHAT ARE THE KEY BARRIERS TO TITLE 24 COMPLIANCE AMONG CONTRACTORS?

To investigate HERS Raters' perspectives regarding the key barriers to compliance among contractors, we asked respondents to provide their level of agreement or disagreement with a list of potential barriers, or reasons why some contractors may not fully comply with the Title 24 requirements). Respondents used a 10-point scale in which 10 indicated "strongly agree" and 1 indicated "strongly disagree." We grouped these potential barriers into categories including systemic barriers, contractor shortcomings, and motivational barriers. Note that the survey included no open-ended questions with regard to this research question.

Figure 119 shows the mean rating across respondents and the ratings grouped into three categories: high agreement (ratings of 8 to10); moderate agreement (ratings of 4 to 7); and low agreement (ratings of 1 to 3). We weighted survey responses up to the population of projects as described in Section 2.5, so the percentages represent the proportion of projects the Raters account for, in each category. Results suggest that HERS Raters agreed that most of the potential barriers we laid out were in fact barriers to contractors complying with Title 24 requirements.

In terms of the systemic issues at play, HERS Raters agreed most strongly that there are barriers related to contractors not obtaining permits if they think their installations will not comply and local jurisdictions only enforcing some of the required testing and verification (average agreement ratings of 8.5 and 8.3 out of 10, respectively). However, much like the potential barriers for HERS Raters, respondents overall did not think that not having enough time to do quality installations was a barrier for HVAC contractors (average rating of 4.0).

Some of these barriers had to do with contractor shortcomings, such as not understanding which Title 24 measures apply to their installations and not knowing how to repair the installation if it fails HERS tests (ratings of 8.4 and 8.2, respectively). HERS Raters also exhibited fairly strong agreement that contractors lack the right equipment and/or that contractors lack the technical experience to complete a quality installation (average ratings of 7.1 for each).

Some of the potential motivational barriers to contractors also resonated with the HERS Rater respondents, such as the perception that contractor do not believe that they need a HERS Rater to tell them if their installation was done correctly and/or that contractors simply may not have the desire to perform a quality installation (agreement ratings of 8.4 and 8.0, respectively). HERS Raters' level of agreement with the idea that contractors do not believe that HERS inspections are needed was lower, averaging 5.9 out of 10.

Figure 119. HERS Raters' level of agreement or disagreement with barriers to Title 24 compliance among contractors (HERS Rater online survey, 2016)

Potential Barrier	Agreement Rating* (n=52)				
	Mean	High (8 to 10)	Moderate (4 to 7)	Low (1 to 3)	Don't Know
Systemic barriers					
Contractors may not pull a permit if they think their installation will not comply with Title 24	8.5	70%	12%	8%	11%
Contractors may work in local jurisdictions that enforce only some of the required test and verification requirements	8.3	72%	15%	12%	1%
Contractors may not have enough time to do a quality installation	4.0	26%	15%	53%	6%
Contractor shortcomings					
Contractors may not understand which Title 24 mandatory and prescriptive measures apply to their installations	8.4	78%	11%	11%	-
Contractors may not know how to repair the installation when it fails the HERS tests	8.2	71%	23%	6%	-
Contractors may not have the right equipment to do a quality installation	7.1	48%	18%	20%	15%
Contractors may not have enough technical experience to complete a quality installation	7.1	55%	27%	18%	-
Motivational barriers					
Contractors may not believe they need a HERS Rater to tell them if their installation is correct	8.4	77%	12%	10%	2%
Contractors may not have the desire to do a quality installation	8.0	68%	19%	13%	-
Contractors may not believe the HERS inspections are needed	5.9	45%	18%	37%	-

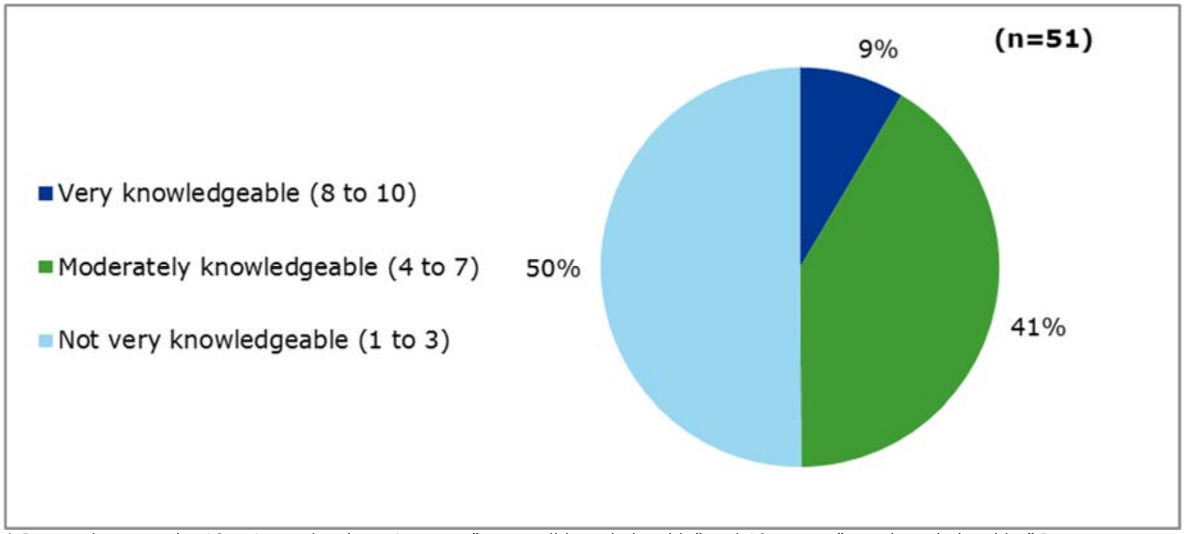
* Respondents used a 10-point scale where 1 means "strongly disagree" and 10 means "strongly agree." Percentages represent the proportion of projects the Raters account for, in each category.

RESEARCH QUESTION 5: TO WHAT EXTENT ARE CONTRACTORS AWARE OF THE CURRENT REQUIREMENTS FOR HERS TESTS AND INSPECTIONS IN TITLE 24?

Contractor knowledge of Title 24

First, we asked the respondents to provide their perspectives regarding HVAC contractors' general knowledge regarding the 2013 residential code requirements for HVAC changeouts. Respondents used a 10-point scale in which 10 indicated "very knowledgeable" and 1 indicated "not at all knowledgeable." As Figure 120 shows, respondents accounting for half of all projects rated HVAC contractor knowledge as low (ratings of 3 or lower) and Raters accounting for only 9% of projects rated contractor knowledge as high (ratings of 8 or higher). The average rating was 3.9, and no respondents gave a response of 10 ("very knowledgeable"). We weighted survey responses up to the population of projects as described in Section 2.5, so the percentages represent the proportion of projects the Raters account for, in each category.

Figure 120. HERS Rater perspectives on HVAC contractors knowledge regarding 2013 residential code requirements for HVAC changeouts* (HERS Rater online survey, 2016)



* Respondents used a 10-point scale where 1 means "not at all knowledgeable" and 10 means "very knowledgeable." Percentages represent the proportion of projects the Raters account for, in each category.

We then asked the respondents for their perspectives regarding HVAC contractor knowledge regarding six specific Title 24 requirements, including:

- Permit requirements for different types of installations
- Duct sealing requirements for new versus existing ducts
- Air flow and fan power index requirements
- Compliance form requirements for residential HVAC alterations
- Difference in Title 24 prescriptive and mandatory compliance requirements for different types of installations (e.g., packaged unit versus split systems)
- Difference in Title 24 prescriptive and mandatory compliance requirements by climate zones

As in the last question, respondents used a 10-point scale in which 10 indicated "very knowledgeable" and 1 indicated "not at all knowledgeable." Figure 121 shows the mean rating across respondents and the ratings grouped into three categories: highly knowledgeable (ratings of 8 to10); moderately knowledgeable (ratings of 4 to 7); and low knowledge (ratings of 1 to 3).

Overall, respondents were pessimistic about HVAC contractors' knowledge of Title 24 requirements. Each of the six specific Title 24 requirements received average scores lower than 5 on the 10-point knowledge level scale described above. The highest-rated aspects, permit requirements for different types of installations and duct sealing requirements for new versus existing ducts, only received averages of 4.8 and 4.2 on the 10-point scale, respectively. Respondents accounting for just 6% or fewer of projects said that HVAC contractors were knowledgeable (8 or higher) with airflow and fan power index requirements, compliance form requirements, and difference in Title 24 prescriptive and mandatory requirements for different types of installations and across climate zones (Figure 121).

Figure 121. HERS Rater perspectives on HVAC contractor knowledgeable regarding specific Title 24 requirements (HERS Rater online survey, 2016)

Element of Title 24	Knowledge Rating* (n=50)				
	Mean	High (8 to 10)	Moderate (4 to 7)	Low (1 to 3)	Don't Know
Permit requirements for different types of installations	4.8	28%	16%	43%	13%
Duct sealing requirements for new versus existing ducts	4.2	16%	38%	46%	-
Air flow and fan power index requirements	3.3	5%	47%	49%	<1%
Compliance form requirements for residential HVAC alterations	3.3	6%	37%	57%	-
Difference in Title 24 prescriptive and mandatory compliance requirements for different types of installations. e.g. packaged unit vs. split systems	3.0	5%	32%	61%	1%
Difference in Title 24 prescriptive and mandatory compliance requirements by climate zones	3.0	3%	30%	67%	1%

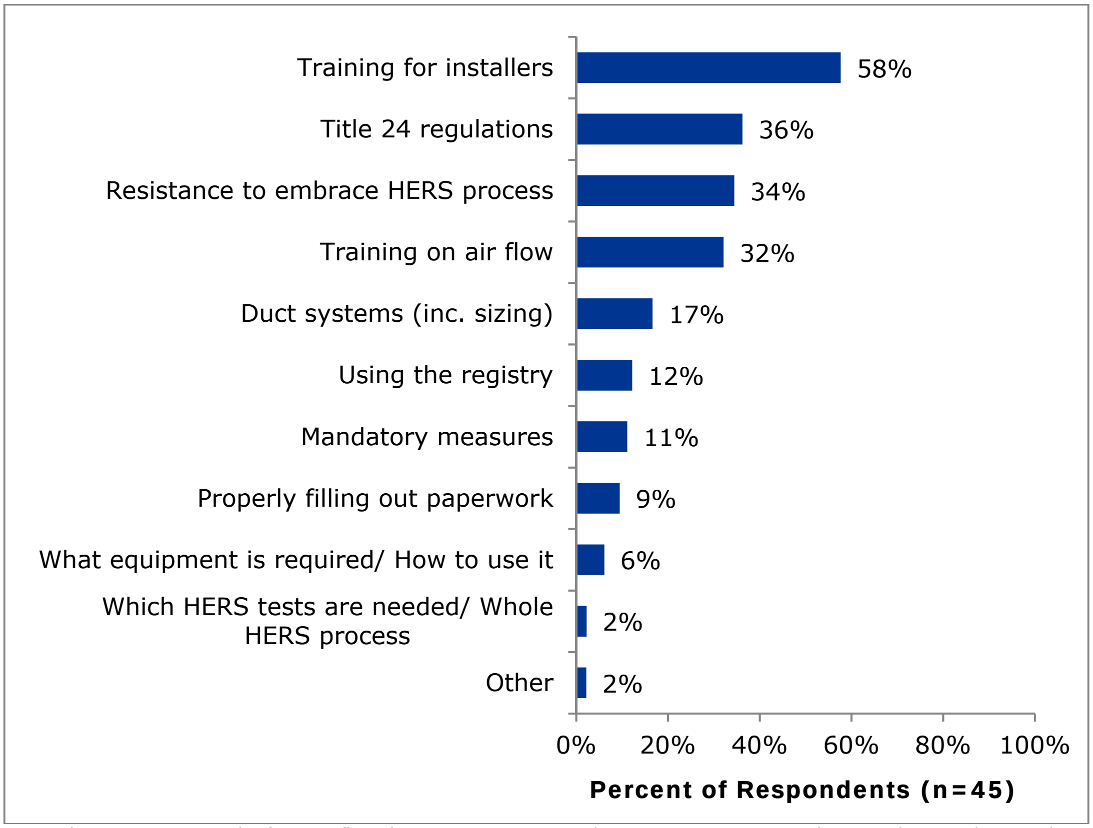
* Respondents used a 10-point scale where 1 means "not at all knowledgeable" and 10 means "very knowledgeable." Percentages represent the proportion of projects the Raters account for, in each category.

Continuing in the same vein, we asked respondents an open-ended question: what are the most common knowledge gaps you have observed among HVAC installation contractors? When we grouped these responses, the prevalent gaps were:

- Lack of training for this group (accounting for 58% of projects)
- Lack of knowledge regarding Title 24 in general (36%)
- Contractor resistance to embrace the HERS process (34%).

In terms of specific knowledge gaps, respondents most frequently cited training on airflow (accounting for 32% of projects), duct systems (17%), and using the Registry (12%). Figure 122 provides further detail below, and APPENDIX T provides verbatim survey responses.

Figure 122. HERS Raters' perspectives regarding gaps in HVAC contractor knowledge of Title 24 (HERS Rater online survey, 2016)



Note: The percentages in the figure reflect the percentage among those giving a response. These totals exceed 100% due to multiple responses. Percentages represent the proportion of projects the Raters account for, in each category.

While there were few statistically significant differences in responses based on respondent group, we did find that a higher proportion of Raters with more than five years of experience suggested that contractors have resisted HERS process (accounting for 57% of projects versus 9%). One theory for the difference by years of experience, is contractors may becoming less resistant to the HERS process now that the majority of installations requires a HERS inspection. Additionally, Raters who worked primarily in coastal climate zones were significantly more likely than those working mainly inland to say that duct systems were a knowledge gap for HVAC contractors (accounting for 67% projects versus 12%). One theory for this difference by climate zone, is contractors performing work in coastal zones haven't been required to perform duct testing on all ducted system until the recent Title 24 2013 code change came into effect on July 1, 2014 and this contributes to poor-quality installations in those regions.

Research question five suggests that a lack of contractor knowledge regarding Title 24 requirements could lead to poor-quality installations. In the online survey, we asked Raters to indicate whether any one or more of the following six issues contribute to poor quality installations among installation contractors:

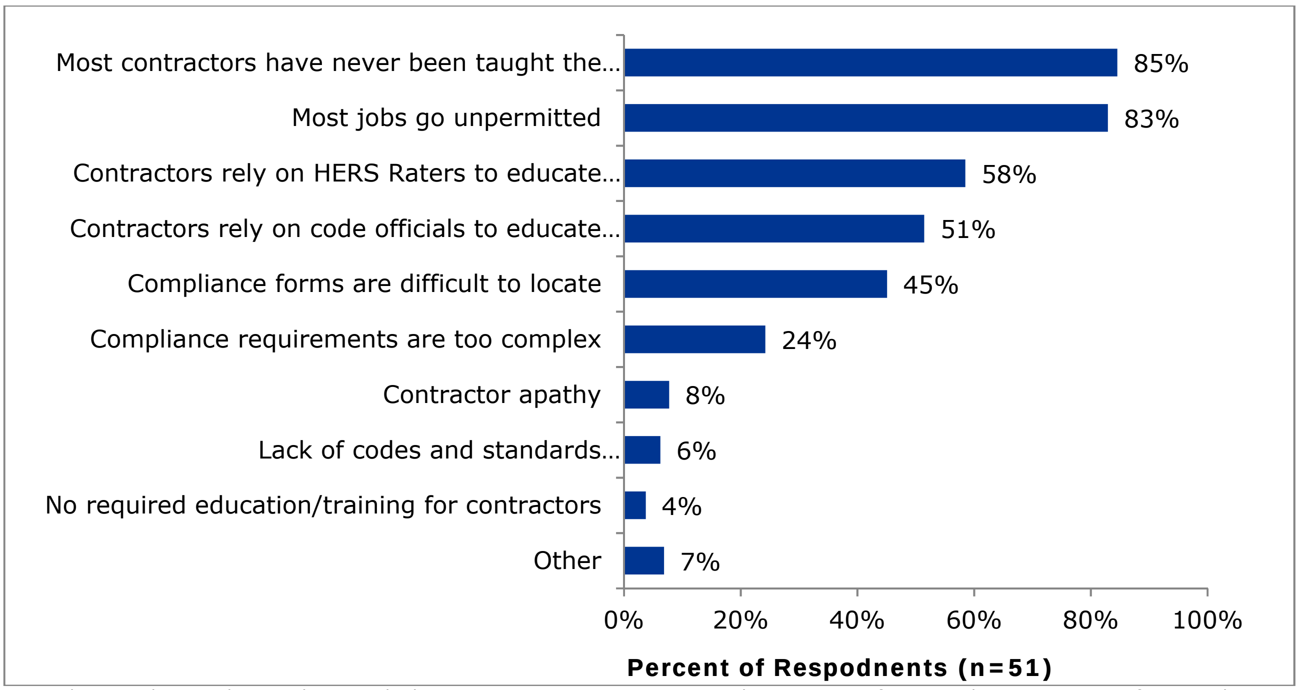
- Most jobs go unpermitted
- Compliance requirements are too complex
- Compliance forms are difficult to locate

- Most contractors have never been taught the Title 24 regulations
- Contractors rely on HERS Raters to educate them
- Contractors rely on code officials to educate them

We also allowed respondents to fill in their own answers (which included contractor apathy, lack of contractor knowledge/awareness of codes and standards, no required education/training for contractors, and a handful of other responses).

Figure 123 shows that most HERS Raters agreed that the fact that most contractors never having been taught the Title 24 regulations contributed to poor-quality installations (accounting for 85% of projects). A similar proportion said that most jobs going unpermitted led to poor-quality installations (83%). On the contrary, Raters accounting for just 24% of projects suggested that complex compliance requirements contributed to poor-quality installations.

Figure 123. Contributors to poor quality installations among contractors (HERS Rater online survey, 2016)



Note: These totals exceed 100% due to multiple responses. Percentages represent the proportion of projects the Raters account for, in each category.

One interesting finding was that significantly higher proportions of Raters with more than 150 residential HVAC alteration inspection jobs in 2015 (who are able to base their assessments on many data points) than those with fewer jobs cited that most contractors have never been taught the Title 24 regulations, that most jobs are/were going unpermitted, and/or that contractors rely on code officials to educate them.

As noted above, HERS Raters noted a lack of contractor training as strong factor contributing to poor-quality installations. A dozen respondents provided specific feedback on this issue, including:

- "Continuing education for all contractors. Mandatory!"

- “They should have Registry training. They don't know what to do when they get on the CalCERTS or USERA registry.”
- “The real issue is education. I am preparing presentations to take to the distributors of HVAC systems of present and past tests to show them, step by step, what we are looking for.”
- “Code changes need to be better explained and several different ways to get the message across. Special inexpensive training seminars targeted to the contractor. Perhaps have an online open book exam for new changes, which require contractors to watch a training video, prior to answering exam questions.”

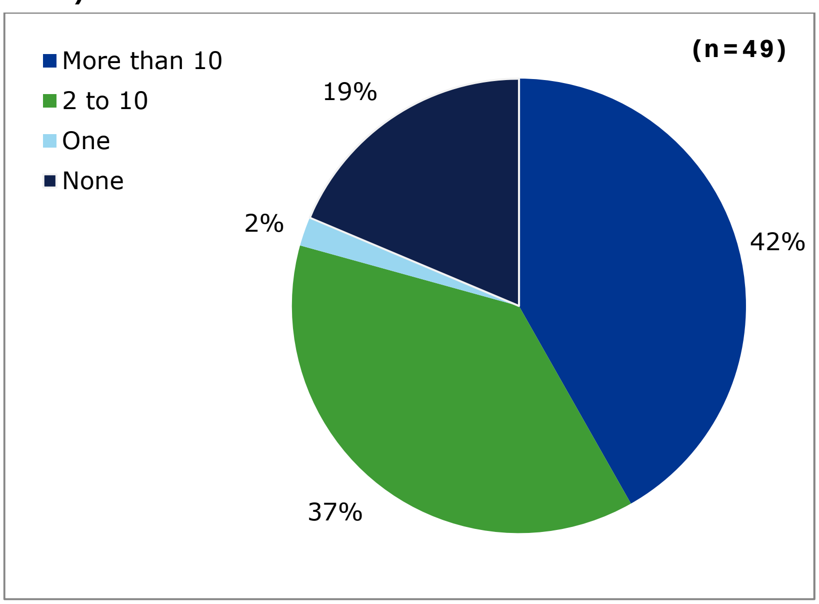
Other open-ended comments were scattered among various topics; APPENDIX T provides more detail.

RESEARCH QUESTION 6: HOW CONSISTENTLY DO LOCAL BUILDING DEPARTMENTS ENFORCE TITLE 24 REQUIREMENTS THROUGHOUT THE STATE?

HERS Raters accounting for 79% of projects said they work with more than one building department, with Raters accounting for 42% of projects saying they work with more than 10 building departments (Figure 124). We believed these respondents would have a good perspective regarding the potential inconsistencies in code enforcement across local jurisdictions, and thus focused the remaining questions on this topic to these 41 respondents.

One interesting finding from the online survey is that HERS Raters accounting for about one-fifth of the projects said that they do not deal with any building departments directly. The likely explanation is that, in those situations, the contractor has all of the interaction with building officials.

Figure 124. Number of jurisdictions with which HERS Raters work (HERS Rater online survey, 2016)



Percentages represent the proportion of projects the Raters account for, in each category.

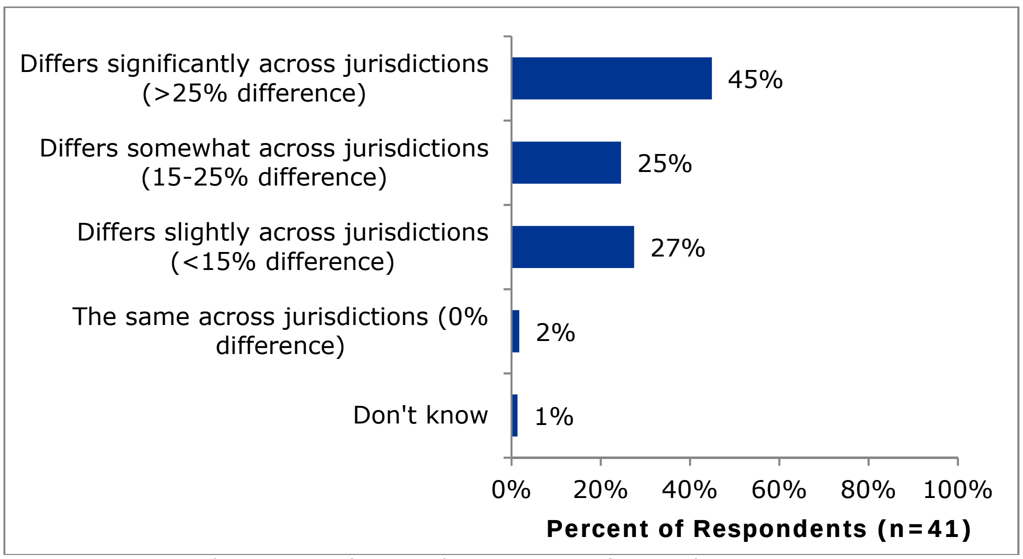
Consistency across building departments

We asked the 41 respondents who reported that they work with more than one building department whether they have observed differences in the way different building departments carry out enforcement of the Title 24 requirements for HVAC alterations or if enforcement was fairly consistent across jurisdictions. Respondents could choose among four options:

- The same across jurisdictions (0%)
- Differs slightly across jurisdictions (<15% difference)
- Differs somewhat across jurisdictions (15-25% difference)
- Differs significantly across jurisdictions (>25% difference)

Raters accounting for almost half of projects said that jurisdictions differ significantly (>25% difference; 45%), and Raters accounting for another 25% of projects said that jurisdictions differ somewhat (15-25% difference (Figure 125). Raters accounting for just 2% of projects said that enforcement is the same across jurisdictions.

Figure 125. HERS Rater perspectives on the extent to which jurisdictions differ in their enforcement of Title 24 requirements for HVAC alterations (HERS Rater online survey, 2016)

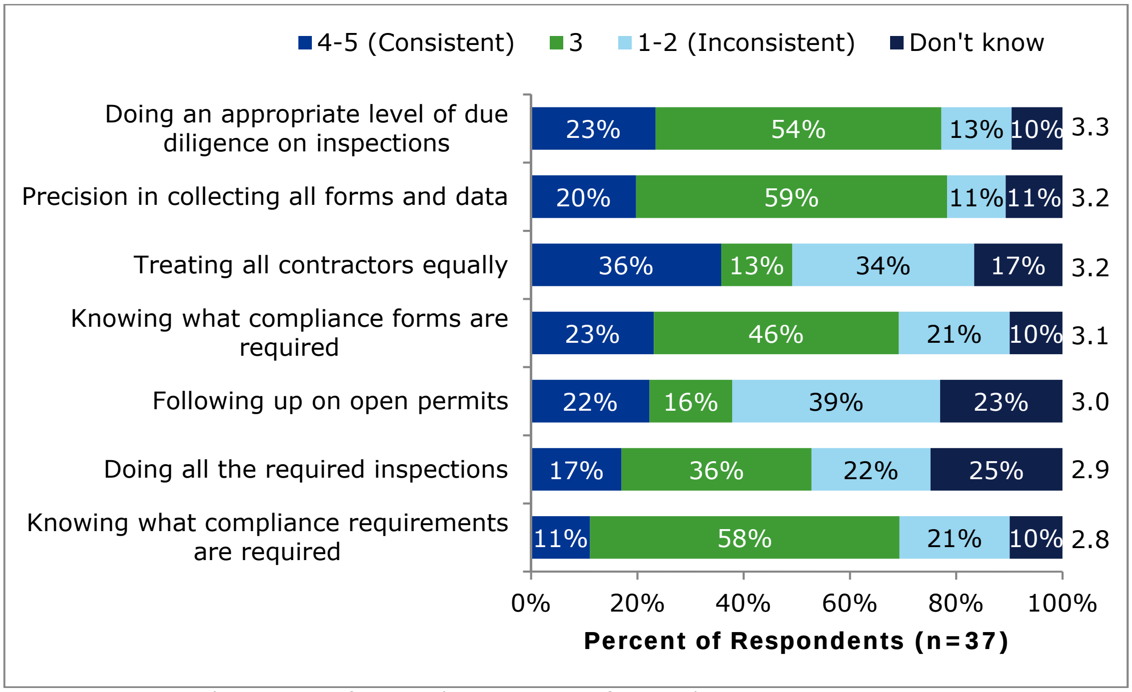


Percentages represent the proportion of projects the Raters account for, in each category.

In addition to the overall assessment described above, we also asked HERS Raters how consistently they thought the different building departments enforced seven specific elements of the Title 24 code for HVAC alterations. Respondents used a five-point scale where 5 meant "always consistent" and a 1 meant "never consistent." Figure 126 shows the results arranged from most to least consistent.

Respondents accounting for over one-third of projects stated that enforcement is rarely or never consistent in terms of following up on open permits and treating all contractors equally (39% and 34% of projects, respectively). The latter was a polarizing statement, however, with a roughly equal proportion stating building departments are often or always consistent in treating contractors fairly (accounting for 36% of projects). Raters representing less than one-fourth of the projects indicated a high level of consistency in enforcement for all of the remaining statements. One especially troubling result was that Raters accounting for over half of projects (58%) said that the foundational aspect of knowing what is required for compliance is only "sometimes" consistent.

Figure 126. Consistency of code enforcement across jurisdictions (HERS Rater online survey, 2016)



Percentages represent the proportion of projects the Raters account for, in each category.

Open-ended comments

Anticipating differences in enforcement across building departments, we gave respondents the opportunity to cite what they found to be best practices in building department enforcement of Title 24 HVAC alterations. Three practices emerged (in order of frequency cited):

- Requiring CF1R and/or CF3R forms at the time permits are pulled (8 respondents)
- Stamping permits with "HERS Required" (2 respondents)
- Paperless processes (2 respondents)

Lastly, we asked respondents to provide any other comments regarding Title 24 enforcement across jurisdictions. These comments very wide-ranging and difficult to categorize, including:

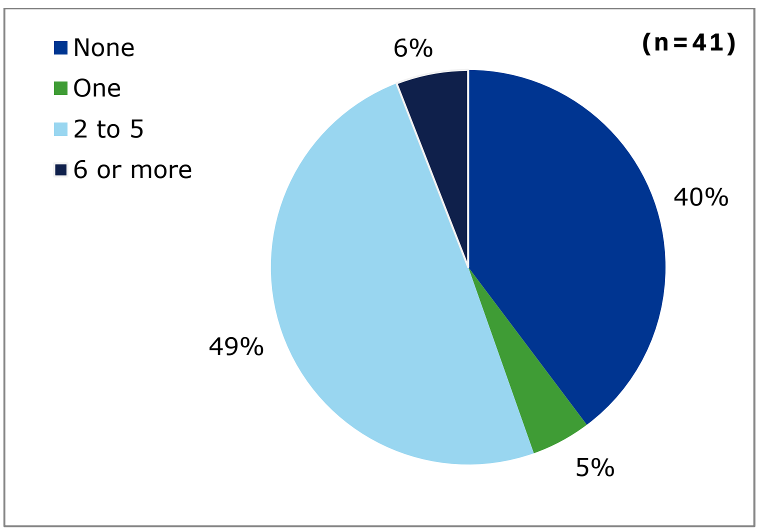
- "Quite often I am specifically told not to perform required tests. The building [department] won't look for it so they don't want to waste money testing and perhaps fixing their HVAC systems. I hear often, all these guys look for is the duct test, so I don't want anything else done. Also they only call me in if the HERS certification is asked for because more often than not it will be overlooked so why bother paying if it's not required by the building [department]."
- "The building [departments] seem to randomly enforce code. I don't have proof, but it seems that way."
- "Each department should have a database where HERS Rater or contractors could upload PDF files for each address so inspectors could find it at any time."

- "Again, educating the building departments on HERS verifications and on how to read the CF1R would be greatly beneficial. However, the only way to ensure that they are reading and actually verifying that all the information on the Tile 24 report would be some form they would need to fill out via a HERS Provider just as HERS Raters have to do. They could have a CF-1.5 form where they would verify that the CF1R forms are accurate to what work was actually done since they are the ones who are going out to the job sites and inspecting."
- "I once had a head building official tell me that they didn't really enforce energy code. I received the impression that if it was not health or safety it was superfluous. He even stated 'go ahead and turn me in. 'My question is, to whom? [The] CEC has not pursued these jurisdictions.'"
- "Building departments should allow the HERS Rater to email the documents. Quite often 30 pages per system."

RESEARCH QUESTION 7: HOW CONSISTENTLY ARE TITLE 24 REQUIREMENTS ENFORCED BY DIFFERENT OFFICIALS WITHIN A LOCAL BUILDING DEPARTMENT?

To identify HERS Raters who could provide perspectives on the consistency with which different officials within a local building department enforce Title 24, we first asked respondents to identify the number of officials with whom they work within the building department at the jurisdiction in which they most often work. As Figure 127 shows, Raters accounting for more than half of projects reported that they worked with 2 or more building officials within the same building department (55% of projects). The vast majority said they worked with between 2 and 5 officials (49% of projects).

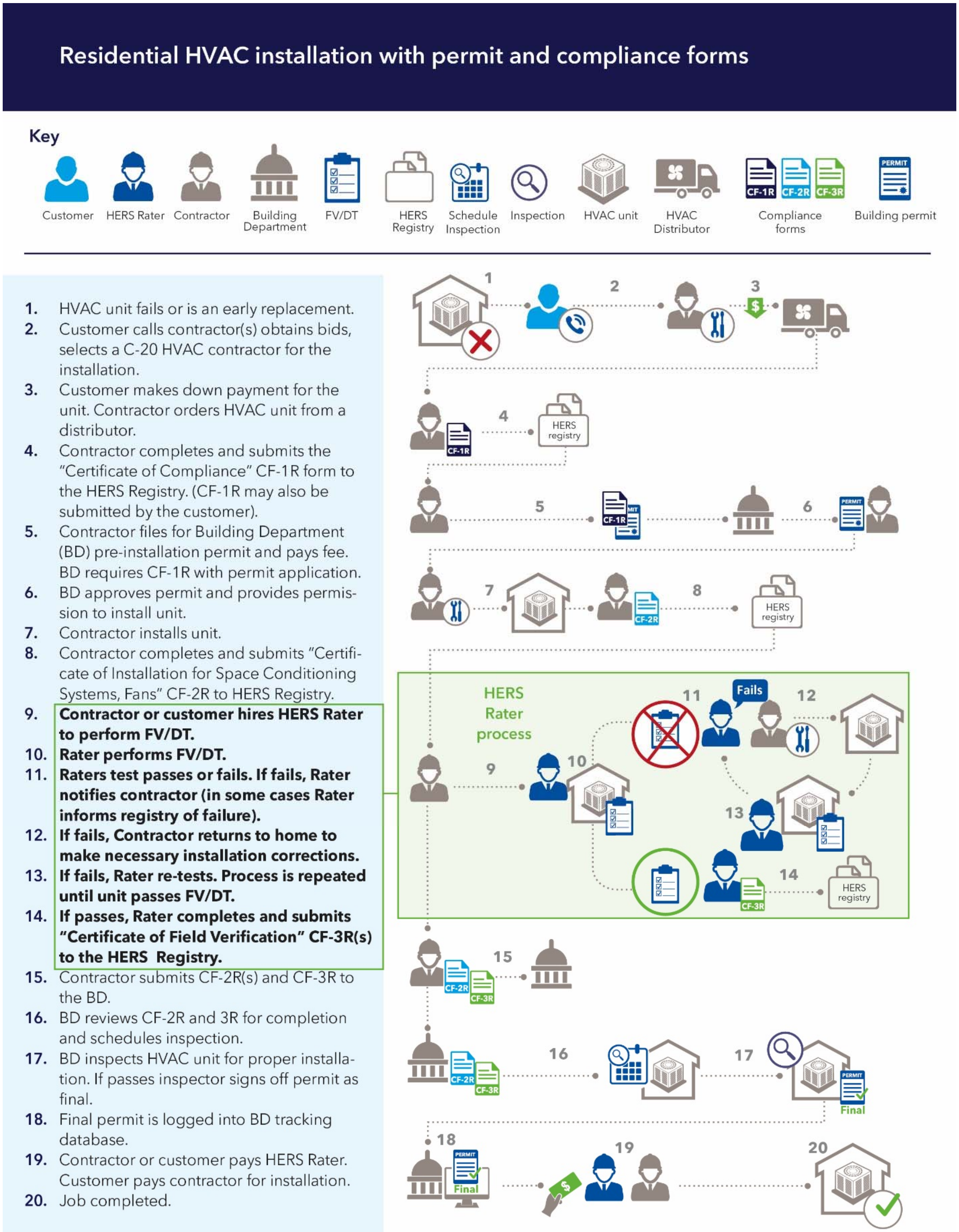
Figure 127. Number of building officials HERS Raters work with at one building department (HERS Rater online survey, 2016)



Percentages represent the proportion of projects the Raters account for, in each category.

The figure also shows that respondents accounting for 40% of projects said they do not interact with code enforcement officials, likely because contractors have all the interactions with code officials in those circumstances. As illustrated in flow diagram of the permit and compliance process below, HERS Raters only need to upload compliance forms to the HERS Registry they do not necessarily have a role to interact with building departments (Figure 128).

Figure 128. Flow diagram depicting the permit and compliance process



Consistency within building departments

Among the 23 HERS Raters who reported that they interacted with multiple code enforcement officials within the same building department, roughly two-thirds reported that they observed differences in the way that individual code enforcement officials enforced requirements for HVAC inspections (16 respondents), six reported that they had not observed any differences, and one was unsure.

Just as we compared consistency among code enforcement officials across jurisdictions regarding seven specific elements of the code, we performed the same comparison within building departments. Respondents again used a five-point scale ranging from “always” (a rating of 5) to “never” (1). Sample sizes are fairly small, and as such, results suggest more variation than in the discussion comparing building departments (above). Nonetheless, roughly two-thirds of respondents stated that two aspects of permitting are rarely or never consistent across code enforcement officials within the same building department: following up on open permits and treating all contractors equally. Note that these two aspects also had the highest “rarely/never consistent” ratings when discussing consistency across building departments as well.

RESEARCH QUESTION 8: IS THERE ADEQUATE REGULATION FOR HERS RATERS AND PROVIDERS?

For each of the three categories of regulations described above—regulations for HERS Rater training and testing, regulations for contractors, and regulations as they relate to the QA/QC process—the online survey asked HERS Raters to identify the extent to which they agreed or disagreed with various statements regarding the training. These included statements such as, “field exams should be part of the course requirements” and “the conflict of interest regulation between HERS Raters and HVAC contractors needs better enforcement.” For each of these questions, respondents used a 10-point scale where a rating of 10 indicated that the respondent “strongly agreed” with the statement and 1 indicated that they “strongly disagreed.” In the sections below, we show the mean rating across respondents and also group the ratings into three categories: high agreement (ratings of 8 to10); moderate agreement (ratings of 4 to 7); and low agreement (ratings of 1 to 3). We weighted survey responses up to the population of projects as described in Section 2.5, so the percentages represent the proportion of projects the Raters account for, in each category.

Regulations and HERS Rater training

The online survey asked two groups of questions regarding HERS Rater training: the first focused on possible improvements to HERS training and testing and the second focused on the specific items on which courses would need to focus to generate expertise among Raters. Echoing the findings from Question 1 regarding deficiencies in training, respondents largely agreed that field exams should be part of the training requirements for HERS Raters (average rating of 8.9 out of 10), as shown in Figure 129. HERS Raters provided similar ratings for the concept that minimum standardized requirements for HERS trainings should be established (8.7). Raters accounting for over three-fourths of projects, showing high levels of agreement with these statements, suggesting that exams and minimum standards for training are at least part of the solution from HERS Raters’ perspectives.

Figure 129. HERS Rater agreement with statements regarding training and testing for HERS Raters (HERS Rater online survey, 2016)

Training / Testing Element	Agreement Rating* (n=49)				
	Mean	High (8 to 10)	Moderate (4 to 7)	Low (1 to 3)	Don't Know
Suggested improvements to HERS training and testing					
Field exams should be part of the course requirements.	8.9	76%	21%	2%	-
Establish minimum standardized requirements for HERS trainings.	8.7	75%	21%	2%	2%
There should be better enforcement of HERS Rater tool calibration requirements to improve the accuracy of HERS test results.	6.0	37%	30%	34%	<1%
To be subject matter experts, HERS Rater courses need to provide…					
More hands-on training for the visual inspection of measures.	6.8	37%	51%	13%	-
More technical training of HVAC system operation.	6.7	36%	44%	19%	-
More hands-on training for performing tests (duct leakage, blower door, fan power index, etc.)	6.6	40%	42%	19%	-
More technical training of basic building knowledge.	6.3	32%	49%	19%	-

* Respondents used a 10-point scale where 1 means "strongly disagree" and 10 means "strongly agree." Percentages represent the proportion of projects the Raters account for, in each category.

Thirty-one survey respondents provided specific feedback in response to an open-ended question regarding how regulations might improve the training. Approximately half of these suggested improvements, enhancements, or changes to HERS Rater training, including:

- "Raters need additional training outside of HERS Providers. Perhaps have a continued education requirement."
- "Online training videos would be great of each testing procedure."
- "Field test training should only be required for new Raters versus update classes. If new tests are required through a code change, all Raters should have hands-on training on new equipment."
- "Raters need additional training, NCI, BPI, or Nate certifications."

Other responses were scattered across topics. APPENDIX T provides more detail.

Regulations and contractors

Most observers of the industry generally agree that the majority of residential HVAC jobs are installed without a permit. The respondents here overwhelmingly agreed with this sentiment, with Raters accounting for 85% of projects assigning a rating of 8 or higher on the 10-point scale (Figure 130). However, Raters also agreed that steps could be taken to improve this situation. Improved transparency in terms of customers knowing how often contractors' installations fail HERS inspections (8.1) and a contractor scoring system based on historic pass/fail test performance (7.7) were both supported by the majority of respondents. This could take the form of a Yelp® like reviewer rating system in which customers could compare contractors on these metrics. Additionally, better enforcement of conflict of interest regulation (7.6) was also supported by most respondents.

One possible remedy, however, was not well-received. Respondents accounting for just 9% of projects agreed (8 or higher) that a standardized fee schedule for HERS services would reduce the likelihood that customers would get overcharged. HERS Raters prefer the current, more free-market, system in which Raters decide how much they charge for their services. This was true even as several open-ended comments throughout the survey indicated that some feel cheated when other Raters perform the work for a much lower price than they would charge and suspect that those Raters do not follow the correct protocols. The survey presented several fee schedules, for the research theory two; the results show relatively consistent fee rates with 66% charging $350 or less and 33% charging between $350-$500 for the mock changeout presented.

Figure 130. HERS Rater agreement with statements regarding regulations and contractors (HERS Rater online survey, 2016)

Statement	Agreement Rating* (n=49)				
	Mean	High (8 to 10)	Moderate (4 to 7)	Low (1 to 3)	Don't Know
Most HVAC jobs are installed without a permit and there is little a HERS Rater can do to change that.	8.9	85%	2%	11%	2%
The quality of installations would improve if customers knew how often contractors' installations failed the HERS Rater inspections.	8.1	73%	12%	15%	-
Creating a contractor scoring system based on historic pass/fail test performance will promote contractors who perform quality installations.	7.7	65%	15%	20%	<1%
The conflict of interest regulation between HERS Raters and HVAC contractors needs better enforcement.	7.6	61%	19%	20%	<1%
A standardized fee schedule for HERS services would reduce the likelihood that customers would get over charged.	2.7	9%	18%	68%	5%

* Respondents used a 10-point scale where 1 means "strongly disagree" and 10 means "strongly agree." Percentages represent the proportion of projects the Raters account for, in each category.

We also gave the respondents an opportunity for additional comments regarding regulations and contractors. Of the 34 respondents who provided comment, more than half related to addressing the conflict of interest between HERS Raters and HVAC contractors. For example:

- "HERS Rater firms should not provide a permit obtaining service. Since when is it OK for 3rd party independent inspectors to provide other services to the contractors they are testing? If this is allowed it will open up a host of other services that are not HERS related."

- “Having payment through the homeowner rather than the contractor would definitely be more … non-biased.”
- “Some HERS rating companies are obtaining permits for contractors, which should be done by the installing contractors. I believe that obtaining a permit makes you an authorized representative of the installing contractor. Therefore, there is now a conflict of interest between that HERS Rater and the contractor. CalCERTS turns a blind eye to this fact ...”
- “Conflict of interest needs a clearer definition, i.e., can Raters pull permits for a contractor, etc.?”

Other specific comments addressed improvements to permit enforcement, training for installers, and other topics. APPENDIX T provides more detailed responses.

Regulations of HERS quality assurance/quality control

Overall, respondents thought the current QA/QC process was an effective way to hold HERS Raters accountable (8.8), as presented in Figure 131. However, they also agreed that a screening process to ensure that these individuals are highly qualified to do the job (8.7). They did not agree that an independent entity is necessary to avoid conflicts of interest and improve the reliability of QA/QC tests (4.6). The implication here is that, while Raters are generally satisfied with the process and would not like an independent entity to perform the QA/QC, they would be in favor of a more rigorous, and perhaps transparent, vetting process for the individuals checking their work.

Figure 131. HERS Rater agreement with statements regarding regulation of the HERS QA/QC (HERS Rater online survey, 2016)

Regulation of the HERS QA/QC Process	Agreement Rating* (n=49)				
	Mean	High (8-10)	Moderate (4 to 7)	Low (1 to 3)	Don't Know
The current QA/QC process is an effective way to hold HERS Raters accountable.	8.8	76%	23%	1%	1%
A screening process is necessary for individuals who perform QA/QC tests to ensure they are highly qualified to do the job.	8.7	76%	20%	2%	1%
The HERS Rater Registries are well designed to serve the needs of HERS Raters.	6.6	36%	46%	18%	<1%
An independent entity is necessary to avoid conflicts of interest and improve reliability of QA/QC tests.	4.6	31%	24%	43%	2%

* Respondents used a 10-point scale where 1 means “strongly disagree” and 10 means “strongly agree.” Percentages represent the proportion of projects the Raters account for, in each category.

We also found mixed agreement that the Registries are well-designed to serve the needs of HERS Raters. Several open-ended comments throughout the survey mentioned that, at least from their perspective, the Registries seemed to be designed for the benefit of the Registries and not the Raters in terms of its setup and ease of use.

We again asked survey respondents to offer any additional comments regarding regulations and the HERS QA/QC process, and 30 respondents did so. Of these, more than half offered suggested reforms to the process, including:

- “QA/QC should be more frequent, due to the lack of knowledge and training current Raters have.”
- “With the QA I would like to see actual results from the QA company/Dept. and not just a ‘you passed or you failed’.”
- “Sometimes I wonder if it would work out better if the QA/QC Inspector actually accompanied us on a 'current' job to watch our process of inspections while we are conducting them.”

Other specific comments addressed communication issues, transparency, and other topics. APPENDIX T provides more detail in verbatim responses.

APPENDIX U. RESULTS OF OPEN-ENDED QUESTIONS IN THE HERS RATER FULL-LENGTH SURVEY (ONLINE SURVEY)

This appendix contains the open-ended responses regarding each of the eight research questions related to HERS Raters.

Figure 132. Open-ended comments regarding research question 1: What are the key barriers associated with training for HERS Raters? (HERS Rater online survey, 2016)

Category and % of Commenters	Comments (n=33)
There should be more hands-on training/field experience (36%)	"I feel more hands-on training is needed to truly understand how to use the instruments we use for testing, but also an explanation of the how's and whys. One of the problems is once a newly licensed HERS Rater is in the field, if he/she does not understand AC, system design, static pressure, they can't adequately teach...and ultimately I feel the HERS program and HERS Raters should be above all else, teachers in the field. We would be more widely accepted, and less feared if installers felt we were there to work with them and help them achieve better system design." "More field experiences would be very helpful." "I will answer this as an Owner/Operator. When my employees come back from training and they have passed their certification test, I expect them to be trained. This has NEVER been the case. Perfect example; HERS verifications of hot water heaters/plumbing. There was one black and white picture and NO hands-on examples of the parts of a system they would need to inspect." "Coming from a person in the HVAC trade, the training offered by rating organizations needs to be more in-depth with hands-on tools. I have had to buy special equipment that I had to learn on my own trying to follow compliance procedures." "Once you pass the test, you are mostly left to figure out what to do from that point on. Calling into CalCERTS or USERA is horribly hard to contact anyone." "Need more hands-on training of equipment." "Need to provide more hands on training. I understood because I have been in the field of HVAC for over 10 years. Someone with no experience must be lost." "Hands-on training needs to be improved. There should be training on fan power index using a standard volt meter." "I believe there is a need for more training in the field...especially when it comes to QII. I also believe it is imperative that Installers have some type of training as it relates to HERS Rater training - I seem to spend quite a bit of time assisting them in explaining our Inspection procedures and way too much time explaining the Registry process. It slows down our ability to provide contractors & homeowners their documents in a timely manner." "I feel that the classes should be more spread out rather than trying to learn everything in one day or a series of days. I would also like to see more hands on when it comes to refrigerant charge and the various methods used to calculate airflow. Four hours is not enough time when you are handling hazardous materials for any type of training." "More hands-on. Passing a test/class does not really qualify you."
Training manual/materials not up-to-date (35%)	"The training manual didn't have all of the new information in it, and we haven't been informed when new information is added." "When I was in my training there were several times where we had to cross something out of the manual because it was either the wrong information or no longer applicable. The manual also contradicted itself a few times. While learning this proved to be very confusing because in one chapter you learn something then in the next one it tells you something completely different or I would have to go back to the last chapter and cross out what I had just learned." "Regarding the 2013 classroom update course from CalCERTS I pointed out 3 'errors' they made regarding code…I had anticipated CalCERTS would have sent out an "update" style email to all the Raters who took that course so there would be no confusion in the field of applying the code correctly but sadly nothing was ever done."

Category and % of Commenters	Comments (n=33)
There should be more training on using the Registry (20%)	"Main problem is zero training for use of Registry system." "Very limited help learning how to actually use the Registry." "A little bit of training on the CalCERTS Registry would have been nice." "There needs to be a section of the training where they go over the website line by line." "Registry is convoluted and takes a very long time to figure out (especially with sampling, sharing projects). System could be much more streamlined to make HERS projects more efficient." "The website was very difficult to get used to in the beginning and we were not taught anything really in depth about it." "There was no training on how to use the Registry for the 2013 Standards. I had to figure it out on my own. It is a convoluted process and was very confusing for the first few weeks." "The CalCERTS training does not cover using the CalCERTS database/web form data entry. It would be a great help if they did."
There should be more training on filling out forms (11%)	"There is not enough training for how to fill out the forms on the CalCERTS Registry. The Registry should have a 'practice forms section' that has all the forms to fill out but not able to generate any certs. This could also be used to show contractors, installers, homeowners and Raters what's required and what's needed to comply. Given so many different scenarios this would be a tremendous help for everyone also reducing emails and phone calls to Field Support at CalCERTS. If able to go online answers would be quick and definitive putting everyone on the same page." "More time could be spent training how to fill out the forms online. Took weeks of trial and error, lots of phone calls to support, etc. All of that could have been avoided with better training in class room setting." "I also would like to see more hands-on with learning how to fill out submittal forms for Non Residential and understanding more about how the CEC would like to see the different jurisdictions unite in calling out for the same exact paperwork each time." "More time should have been used to show filling out forms, explaining the pull-down options on each form. Make the forms less complicated."
Raters should be required to obtain training outside of HERS (10%)	"I believe that HERS Raters need additional certifications not offered by HERS rating organizations. HERS testing and verifications can be technical at times and additional training certifications in either NATE, BPI, or NCI should be recommended." "It may be very vital to allow CHEERS be approved provider to the industry. This will stimulate competition between the providers. The trade has lack of training for the individuals (contractors) who are servicing and installing equipment. HERS Raters should be required to obtain additional training or certifications outside the HERS Provider. BPI, NCI, or NATE certifications will improve the knowledge of the individuals (HERS Raters) enforcing the codes and testing systems." "It would be a good idea to require an EPA 608 certification prior to enrollment, this way the trainees could handle the refrigerant gauges. I was unclear on how to put them on and remove them until I practiced with an HVAC contractor."
Other (10%)	"I took training early in the code cycle and the trainers where sketchy on fan/watt draw methods for package units at that time." "The class I took was a residential alteration renewal. Much of the information was segmented into other categories i.e. new construction, residential, nonresidential. Much of the information was missing, for example quite a bit of information that was given in the new construction residential wasn't in the residential alteration, however it applied to both. I think they assumed we had been in the other class. If you weren't you were lost. As it was a re-certification update it was very cut and dry." "There was no 'theatrical smoke' training." "CalCERTS' pricing is way too high compared to the other providers. As a Rater with all 3 companies, I find CalCERTS to be the most difficult to work with." "Dedicate an entire day for refrigerant charge verification and the different types of space conditioning systems. I feel since we were towards the end of our 4 day class that they had to rush through that section and as a result the majority of the class was confused." "CalCERTS needs to have on-going in-classroom training sessions for its HERS Raters at least twice a year as different regulations or field verification modifications take place that is FREE OF CHARGE to its HERS Raters as part of its PROFESSIONAL support system." "It would help more if you can contact the HERS provider while on a job site"

Figure 133. Open-ended comments regarding research question 2: What is the level of competency among HERS Raters in completing accurate inspections? (HERS Rater online survey, 2016)

Category and % of Commenters	Comments (n=30)
Raters offer guidance to contractors (46%)	"I am training insulators how to pass QII. It seems the HERS rater is required to know this and be regulated and the installers continue to do whatever and the Raters have to remind the installer and builder what is required." "We don't tell the installers how to fix the problem but we do offer suggestions of what other people have done in the same scenario to fix the problem." "I would like to be clear that I DO NOT make adjustments to any HVAC systems. I do however offer guidance when something is failing. Often times the HVAC contractor will send a technician to meet me on-site during the HERS testing. If something fails, I offer guidance as to why I believe the duct leakage is failing (where to seal), why the airflow is failing, and/or why the refrigerant charge is failing." "When testing fails I have to communicate what inspections failed to Installing Contractor. This only happens when 100% testing is being done." "I always recommend to inform the installer/contractor why the results are what they are, what the results mean, and how to change the results to pass if the system has failed."
Raters need to be better educated about HERS (13%)	"HERS Raters need to be better educated to handle verifications and the teaching of installers. I feel that it is far too easy to attain a HERS license. Yes, verifications can be done by just about anyone who can figure out how to use the diagnostic equipment, but if that person cannot accurately assess why a measure is failing and explain it to a contractor, it does a disservice to industry as a whole, especially to the compliance side of it. City inspectors, HERS inspectors become the enemy and installers do everything they can to avoid us. This should be a joint effort." "The 2013 HERS Testing Standards are way too lengthy/complicated. The Duct test, Refrigerant Charge and Airflow HERS certs are about 32 pages! The big picture idea is for everyone to save Energy. My opinion is that the red tape is having a negative effect on people's attitudes for saving energy. When people complain about it I try to remind them of the Big Picture and that it's all worth it. If it could be simplified I think it would have much more positive effect on everyone."
Contractors need to be more educated/trained about HERS (10%)	"I noticed there is a lack of training in relationship to HERS compliance for HVAC installers." "Installers should have more routine training, especially when there are code changes or updates." "Contractors need more training." "Please educate the C-20 contractors of the requirements and how they need to be involved in the process." "The contractors are not familiar with the code. How to use the registry. More classes on this." "Our industry lacks installers that are trained and certified. It should not be the Raters' responsibility to translate codes and requirements and installation practices for all brands of equipment." "The Airflow test is the most failed test. Fortunately my regular clients are beginning to understand the test and process, however I have had to share the airflow table for them to use as a guide and often times they do use it and they deviate a little and they still have some trouble passing."

Category and % of Commenters	Comments (n=30)
Code enforcement is too low (7%)	"The local government agencies are not complying. I could give them completely opposite test measures and they will pass the project. All they want is a piece of paper. The contractors are filling in their forms incompletely or incorrect and it doesn't matter." "Either nobody is obtaining permits, or building departments are not enforcing, very little work." "Contractors do not know what the CF2R forms are and this is largely because the building inspectors are not asking for them. I have heard of other HERS companies tell contractors that they only need to do the Duct leakage because that is all the inspector looks for…I understand the building inspectors are busy however by them only asking for a duct leakage test result when there are at least 2 other mandatory tests it seems like this great program is all for nothing. 1 out of 3 tests performed and passed is really only 33% efficient space conditioning system." "The biggest issue is not the inspections but the lack of inspections required by the enforcement agencies. There is NO accountability for the failure of an enforcement agency to enforce state code." "I see a LOT of HVAC systems that are being signed off and they aren't up to code in other areas that are not a HERS Raters responsibility."
Permits not being pulled (6%)	"No installers in my area take out permits, so I don't get any work." "You have these HERS tested systems that have to meet what many contractors feel are very strong standards. There is a huge cost to the contractors because in their words, not only do I have to pay for the permit and extra time, it takes me longer because we have to do the job right. So they do everything they can to convince homeowners not to pull a permit. I've heard figures from 10 to 15% of changeouts pull permits." "According to IHACI, about 3% of homes actually pull permits for HVAC work. I would guess of that 3%, less than half are asked to conduct a HERS test by their city. I think a good majority of cities in CA have yet to implement HERS or enforce it. Ironically, those 3% are the ones getting the largest benefit from city inspections and certainly the implementation of HERS, however the overall impact on energy savings for the state as a whole is miniscule when you take into account the fact that majority of homeowners don't pull permits. We need to level the playing field somehow. Things like force equipment sales to be directly connected to a permit number. Require all municipalities to conduct HERS inspections (by that I mean really force them to do it). If we could make the entire process of obtaining a permit and getting a HERS rating done less daunting and add to that some kind or permit or registration to buy equipment that isn't a nightmare, and get the permit pull rate up to say 50%, the energy savings in the state would be tremendous." "A special CSLB Bulletin needs to be sent out to all HVAC Contractors about the importance of obtaining building permits for all HVAC projects: Alterations or New Construction." "There is no real penalty for an installer to not pull a permit. The role of the CSLB needs to be in the forefront of permit compliance. There should be consequences for installers not obtaining permits and enforcement agencies who do not enforce code. Homeowners lose when we allow this to continue."
Homeowners need to be better educated about HERS (5%)	"Homeowners need to be better educated about the process of HERS and how it relates to their city permit and installations. The truth is, homeowners are often not open to the idea. It takes patience and explaining for them to understand why it is beneficial to them. In an environment where the lowest bid and cheapest piece of equipment reins king, it makes the idea of permit fees and HERS fees seem expensive, despite the fact that the permit fees and HERS fees will in effect save them more money than anything else imaginable. (I suppose the real problem is more a social issue than anything)." "The homeowner has no idea of what is going on."
Difficulties with existing registry (5%)	"Installers and builders need training regarding how to use the registry." "If the CPUC wants to have more fails reported, they should make it easier to report fails in the registry. At this point it's more work than a pass (if the contractor has not made the CF2R yet). Make it a lot easier than reporting a pass and more will be reported."
Contractors struggle with refrigerant charge (4%)	"I find the contractors have learned to deal with most of the testing, but in my area I still see them struggle with split system refrigeration charging on change outs." "I had to train many [contractors] on how to do a refrigerant charge after the 2008 code change."

Category and % of Commenters	Comments (n=30)
Contractors should have T24 certification (3%)	"Most leaks are because proper techniques for sealing are not being used. After failing a number of times the contractors usually start to figure it out." "We need T24 Certified installers, just like we have T24 certified Raters." "A special CSLB Bulletin needs to be sent out to all HVAC Contractors about the importance of training AND require a minimum number of annual hours of In-service Training (PG&E and/or NGAT) necessary for License Renewal @ two years."
Other (18%)	"Many times there is something very obvious upon inspection that can be corrected. If not, leakage to outside usually passes." "As mentioned earlier the target of 300cfm's on some of the programs the state and/or Edison offers it's next to impossible to pass airflow. On the low income programs the installing contractor can't pay out of pocket to change and size the ducting to get the 300cfms and the customer in most cases can't afford to do it themselves." "1) we will never do a duct test to outside; we don't want to risk shutting of other appliances that may not start of relight. 2) Fan power index is kind of a stupid test, 99.9% pass and it's really hard to do on a packaged heat pump or a variable speed everything system. 3) The PDF sign-off is stupid; most HERS raters are doing the sign-off for the installers anyways. The installers want to install systems and have the HERS rater take care of all the paperwork."

Figure 134. Open-ended comments regarding research question 3: What are the key barriers to Title 24 compliance among HERS Raters? (HERS Rater online survey, 2016)

Category and % of Commenters	Comments (n=34)
Lack of knowledge/ training (46%)	"Lack of knowledge and incentive to do right thing" "They lack the knowledge of particular brand equipment." "Most of the HERS Raters when starting up…honestly need more in the field training. If you don't have a little bit of installing experience it can be tough to get answers from CalCERTS and especially Usera. Just recently I attended a CalCERTS class and had a newly certified HERS Rater with no field experience call me upwards of 10 times a day and is still doing so to get answers for simple field testing issues." "Lack of knowledge" "HERS Raters lack the training for specific brand of equipment." "If they don't have the technical ability to perform some of the testing the ability to get training should be made much easier. I answered that "I don't know" on a lot of these because I don't know." "Lack of instruction or experience" "Not trained properly"
Lack of enforcement by building departments (25%)	"I have observed inconsistency among building departments, and that has been a source of irritation to the contractors." "If the City isn't asking for it or asking for the old CF6Rs instead of the CF4Rs. It's not a matter of wanting to. It is a matter of Building Departments and Builders complying. I used to report this to CEC but gave up." "The building department agency does not know exactly what forms/tests are required; therefore they are not requiring that the contractor have those specific tests done." "The biggest is the building departments…most of the time the building department doesn't ask, so I'm not going to waste money and time unless they call me on it. Very common for the building departments to ignore it so the contractor saves money." "The City's building department does not look for any test in particular. They sign off on all permits as long as the homeowner or contractor flashes a report to them. Most of the time they don't even read the certificates given to the home owner. In a lot of cases, airflow and fan efficacy tests are required by the CEC for a brand new HVAC system that provides space cooling. However, the building dept. won't ask for those results. They sign off with just the duct leakage results. So, contractors only want to pay for duct leakage testing and not the required airflow and fan power index test." "Because they know that the building departments are only asking for a Duct leakage test." "Some report false results without testing at all. I have reported them as I have found them, and no action has been taken. So there are no repercussions."
Job security concerns/ pressure from contractors (23%)	"On occasion, when I meet a new contractor and begin performing my HERS Verifications, they are surprised to see the amount of equipment that comes out, and the complexity of what I'm doing, as well as the time it takes to conduct a full inspection. I often hear, 'My old HERS guy didn't do any of this. They were usually in and out in 10 minutes and charge half what you charge.' I often never hear from those contractors again." "Pressure from builders" "If a project fails the contractor will just find another Rater who will make it work." "Fear of alienating the HVAC Subcontractor and/or General Contractor who contacted them." "Afraid the contractor might not call him back ever again and might be on good terms with the contractor." "In the residential change-out market, the Rater essentially works for the HVAC installer. It is against his financial interests to enforce the code more stringently than competing HERS Raters. Most of my competing HERS Raters enforces the code much less stringently than I." "Job security"
Lack of proper equipment (9%)	"They have not purchased all the diagnostic tools required to complete a test." "Most of the Hers Raters when starting up find it hard to buy the testing equipment." "Certain equipment requires special diagnostic tools that Raters need to test properly." "If a HERS Rater doesn't have the proper equipment they shouldn't be performing FV/DT in the first place." "Certainly having a reasonably price tool to measure air-flow would be helpful."
Costs too much (1%)	"To keep down the cost for potential clients." "Too hard and costs too much money to do it right." "Too many test and equipment needed is expensive"

Category and % of Commenters	Comments (n=34)
Other (6%)	“The entire system is flawed. The regulations are incomplete. The enforcement agency is not on board with the intent of the program. The contractors will find and use any loophole possible including fraudulent or incomplete reporting. The home owner is completely oblivious to the process. There is a lack of consistency between HERS Raters. The HERS Rater has little power to affect or enforce the process.” “CEC changing climate zones without proper notification…if contractors would plan their job early with the HERS Rater discussing equipment size, duct size and Rater verifications less problems would arise on site” “Most builders I have worked with do not want to wait for HERS Testing. If the building inspector passes it, they move on, even if the HERS Rater does not.” “Some HERS Raters use non certified hourly employees to do the testing and then report back to the Rater without the Rater being present at the job site.” “HVAC installer never calls.” “Accessibility” “Weather, difficulty of scheduling (i.e. weigh in method)” “Some employers pay by number of tests completed, rather than compensating for time spent testing and travelling between jobs so some HERS Raters may try to cut corners in order to get more tests done each day increase their wages.” “Asbestos still exists in some of the ducting and supply boots. Old fiber type ducting still exists in the walls, ceiling/floor cavity” “For insurance reasons, they may not be able to open an electrical panel to do a fan-watt-draw. For personal safety reasons. For example, climbing to a second story roof to verify a packaged unit when the roof has snow, ice or is slick from rain.”

Figure 135. Open-ended comments regarding research question 5: To what extent are contractors aware of the current requirements for HERS tests and inspections in Title 24? (HERS Rater online survey, 2016)

Category and % of Commenters	Comments (n=27)
Contractors need more training/ Education (45%)	"Need local compliance (trained inspectors) and some seminars to educate contractors." "Continuing education for all contractors. Mandatory!" "They should have Registry training. They don't know what to do when they get on CalCERTS or USERA." "Require installing contractors to attend a BPI training course." "Education, certification, training." "The real issue is education. I am preparing presentations to take to the distributors of HVAC systems of present and past tests to show them, step by step, what we are looking for. I am passionate about this career path and we work really hard at educating our mechanical contractors. We will re-test for free if they have a tech there to observe how to do it correctly when it is within a passing target as well as crawl with them to show them the areas. A picture is worth a thousand words." "Code changes need to be better explained and several different ways to get the message across. Special inexpensive training seminars targeted to the contractor. Perhaps have an on-line open book exam for new changes, which require contractors to watch a training video, prior to answering exam questions."
Permit should be required with every equip. purchase (16%)	"100% permit pulls. I know this sounds crazy, but when that happens and HERS or some form of verification is enforced, it will completely change the industry and raise it to new heights. It will become respected and vast sums of wealth will be created while removing those that are just in it to sell a machine and run away with the money." "Maybe every piece of equipment that is sold in California should somehow be connected to the process of obtaining a permit and location of the work to be performed. This would ensure permits are pulled and title 24 is being enforced. By far this is the only way to ensure Title 24." "Rather than the CEC tightening the noose with a fraction tighter duct regulations, on an extremely small number of changeouts, you can literally save hundreds of times more energy and cut hundreds of times more GHGs by finally forcing permits on every installation. Finally keep in mind; those not obtaining permits are by far the worst installs out there. I know that because every so often a homeowner pulls the permit and a contractor is tested. Those are terrible…If the CEC is serious; they will focus on the 85% of terrible installs, where there is a great deal of potential for energy savings, rather than focus on making the 15% of very efficient systems a very small bit better." "Require a permit at the time the contractor buys the unit from the supply store. This will stop all unpermitted work."
Cost competitiveness (13%)	"Low bidders that don't pull permits on jobs." "Compiling all the extra required info and seemingly unimportant details is costly." "There is a huge competitive advantage to not getting a permit. So many say, I have to charge $1,100 to $1,500 more for the job. My competitors are charging less because they claim it's not needed. As a contractor they say I have to charge for the permit, HERS rating, and the extra time to do the job right. The financial incentive is there for the contractor to not pull a permit, and that is the elephant in the room." "Cost competitiveness. Owners not wanting permits"
Extra paperwork required (12%)	"Simplify and make it more user-friendly. In the real world compiling all the extra required info and seemingly unimportant details is time-consuming." "I believe the paperwork creates a barrier. It would be nice to always have all the information filled out by HERS Raters (CF1R, CF2R, and CF3R). Contractors often make mistakes on their forms and/or do not take the time to learn how to use the Registry."
Lack of/ consistency in enforcement (12%)	"Building departments are not all on the same page. Not all are enforcing the requirements." "If contractors get a pass on completing a CF1R to receive a permit from the permit authority, or don't need a permit, or can skirt the system, they will. Unlicensed installers still run rampant because homeowners don't get that they need a permit." "Inconsistency of Building Officials from requesting HERS docs at the time of Final Inspection." "Where are the code enforcers for all of the HVAC contractors not obtaining permits?"

Category and % of Commenters	Comments (n=27)
Other (12%)	"HVAC contractors DO NOT like HERS Raters telling them their job didn't pass." "I have worked with HVAC contractors that just do the act like they don't know what the requirements are and I seem to spend quite a bit of time explaining to them what the regulations are. Then there are others that take so much pride in their work…and want to do the best job for their homeowners as possible." "Must know how to seal the duct with the boot." "One must care." "Contractors that are not hourly (instead they are paid by job) will try to cut the most corners." "Let Raters test other Raters. Mandatory 1 in 50." "Return airflow is often the worst part. Most installers don't actually calculate the duct size requirements or use prescriptive sizing."

Figure 136. Open-ended comments regarding research question 6: How consistently do local building departments enforce Title 24 requirements throughout the state? (HERS Rater online survey, 2016)

This question asked respondents “Are there any best practices (or worst) that you have observed among individual inspector's enforcement of Title 24 code for HVAC alterations?”

Category and % of Survey Respondents	Comments (n=14)
Best practices (7%)	"I tend to see the inspector requesting HERS paperwork on the inspection card." "New inspectors using paperless forms." "They ask for the HERS report." "When a NEW construction project is approved, be sure to request of the General Contractor that a HERS Rater has been hired to verify the CALGreen Special Inspections. Also when, a HERS Rater "Letter of Hire" is required."
Worst practices (31%)	"I do not like when the code enforcement officer pretends to know what they are doing but by the questions he/she is asking, it is very evident that they do not have a clue what forms are being presented to them and what they need to do with the forms." "Many really don't understand the forms or test results." "One enforcement officer wanted refrigerant charge results but the property was in climate zone 6 which is not required. I had to send him over a zip code map with climate zones and a trigger sheet so he could understand the requirements." "Requiring something from one contractor but not another." "Several units were installed in an apartment complex but no permits were pulled. An HVAC contractor called Code enforcement and they said, what apartments had new AC units installed? The contractor said 15 out of the 30. Code enforcement said they didn't have time to go out and look if the AC units were already installed." "Some inspectors require testing where it isn't needed. They abuse their authority and force home owners and contractors to do unnecessary things. And the majority don’t really care about Title 24 reporting procedures or results for that matter. As long as the HERS Rater came out and gave them something. " "They often don’t read them or even verify they are the correct forms. I have been told may times that all they want to see is the HERS company logo on the forms. THEY DONT READ THEM."
Discrepancies among building departments (7%)	"I work in several jurisdictions and all of them differ." "If an inspector does not care, it doesn't matter. Installers seem drawn to certain inspectors. Most of the people I work with sincerely want to do a good job." "The best practice is simply to tell the installer and homeowner that the permit cannot be closed until a HERS Verification is completed and passed... The worst practice I’ve seen is a city inspector and the clerk say ''This HERS thing is stupid. I'm not even sure what it is. I'm not going to enforce it''."

This question specifically asked respondents, “If you have any other comments to offer on the issue of code enforcement by different building departments please describe.”

Category and % of Commenters	Comments (n=13)
Open ended (100%)	"Building departments are late in enforcing the HERS requirements." "Building departments should allow the HERS Rater to email the documents. Quite often 30 pages per system." "Continued education required." "Continuing education and funding for more of them. They also need to drive through neighborhoods and look for any white van and find out what those folks are doing that may require a permit. If they would only learn how to use the Registry they could clearly see who and how often companies are obtaining permits." "Each department should have database where HERS Rater or contractor couldn't upload PDF file for each address so inspector could find it at any time." “Educating the building departments on HERS verifications and on how to read the CF1R would be greatly beneficial. However the only way to ensure that they are reading and actually verifying all the information on the T-24 report would be some form they would need to fill out via a HERS provider just as HERS raters have to do." "In general we do not interact with building departments, only had a problem with one where they wanted me to test even though there were asbestos ducts in the walls." "It's a known fact that the Goodman supply house sales units to non-contractors and code enforcement do nothing about it." "It's my opinion that city and county budgets are stretched way too thin and they rely on HERS Raters for Title 24 compliance." "Most will "require" the enforcement of the duct test but that is just about it. I do have 2 enforcement agencies require refrigerant charge and airflow ONLY if there is a duct test exclusion--i.e., asbestos." "They should all have to see a HERS inspection being done and have the process explained to them." "Often I am specifically told not to perform required tests. The building dept. won't look for it, so they don't want to waste money testing and perhaps fixing their HVAC systems. Also they only call me in if the HERS certificate is asked for, because more often than not it will be overlooked so why bother paying if it's not required by the building dept." "Too many unlicensed installers offering work to unsuspecting homeowners. Also, some licensed installers performing after-hours work at reduced rates forgoing permitting. Lately I have seen jurisdiction call homeowners on previous installs that weren't permitted, which is a good thing."

Figure 137. Open-ended comments regarding research question 7: How consistently are Title24 requirements enforced by different officials within a local building department? (HERS Rater online survey, 2016)

This question specifically asked respondents “Are there any best practices (or worst) that you have observed among individual inspector's enforcement of Title 24 code for HVAC alterations?”

Category and % of Survey Respondents	Comments (n=14)
Best practices (7%)	"I tend to see the inspector requesting HERS paperwork on the inspection card." "New inspectors using paperless forms." "They ask for the HERS report." "When a NEW construction project is approved, be sure to request of the General Contractor that a HERS Rater has been hired to verify the CALGreen Special Inspections. Also when, a HERS Rater "Letter of Hire" is required."
Worst practices (31%)	"I do not like when the code enforcement officer pretends to know what they are doing but by the questions he/she is asking, it is very evident that they do not have a clue what forms are being presented to them and what they need to do with the forms." "Many really don't understand the forms or test results." "One enforcement officer wanted refrigerant charge results but the property was in climate zone 6 which is not required. I had to send him over a zip code map with climate zones and a trigger sheet so he could understand the requirements." "Requiring something from one contractor but not another." "Several units were installed in an apartment complex but no permits were pulled. An HVAC contractor called Code enforcement and they said what apartments had new AC units installed? The contractor said 15 out of the 30. Code enforcement said they didn't have time to go out and look if the AC units were already installed." "Some inspectors require testing where it isn't needed. They abuse their authority and force home owners and contractors to do necessary things. And majority doesn’t really care about Title 24 reporting procedures or results for that matter. As long as the HERS rater came out and gave them something." "They often don’t read them or even verify they are the correct forms. I have been told may times that all they want to see is the HERS company logo on the forms. THEY DONT READ THEM."
Discrepancies among building departments (7%)	"I work in several jurisdictions and all of them differ." "If an inspector does not care, it doesn't matter. Installers seem drawn to certain inspectors. Most of the people I work with sincerely want to do a good job." "The best practice is simply to tell the installer and homeowner that the permit cannot be closed until a HERS Verification is completed and passed... The worst practice I’ve seen is a city inspector and the clerk say ''This HERS thing is stupid. I'm not even sure what it is. I'm not going to enforce it.”

This question specifically asked respondents, “If you have any other comments to offer on the issue of consistent enforcement of Title 24 by different officials within the same building department please describe.”

Category and % of Survey Respondents	Comments (n=9)
Open ended (14%)	"As a contractor we just want it to be a fair and level playing field." "I don't see code enforcement as such a big deal. The real problem is in new construction where the general contractor does not make sure all the subs get and understand the Title 24 requirements of the job. Many times a general contractor will need to redo a Title 24 report for a job and the subs end up working off an old version. This is a big deal with general contractors that only build one or two houses a year." "I think it's important they understand the WHY of it and not just how it's enforced. They have to get on board heart and soul. Some inspectors simply don't care and just want their paycheck so they don't learn and exercise new knowledge given them. I have installers calling me livid that when they gave their city inspector the HERS paperwork, the inspector says "I don't want this crap" and throws it away. MANY TIMES have I heard of this. Then there are the good ones that actually understand the why and call for HERS Verifications." "I think they are doing a good job." "I'm not sure about inconsistency because I do not deal with the city inspector directly. I always perform ALL testing required by CalCERTS; therefore I do not pay attention if the city inspector is asking for LESS testing. I perform the extra testing anyway. I always produce all required CF3R forms and send them to my clients." "Integrate and have meetings on a quarterly basis with all of the HERS Raters who live and/or service their jurisdiction to dialogue and seek greater uniformity of enforcement and ways CODE could be better enforced. HERS Raters are "special independent inspectors" but generally have little or no contact with Building Officials although they provide an important service to each Building Dept. with their specialized knowledge and test equipment." "More training and or trigger sheets should be distributed." "Some jurisdictions take this effort very seriously indeed! Their inspectors are more diligent, better trained, more knowledgeable." "They consistently ask for a duct leakage weather it is required or not and they consistently do not ask for any other forms (CF2R or CF3R)."

The three open ended questions for research theory 8, merged into a single set of tables, contained between 30 to 34 respondents in total depending on the question.

Figure 138. Open-ended comments for Question 8: Is there adequate regulation for HERS Raters and Providers? (HERS Rater online survey, 2016)

Category and % of Commenters	Comments (n=30 to 34)
Improve training (51%)	"QII training [is] limited and seems to be very subjective to me." "The instructors need to be very well prepared, and students need to be given multiple opportunities for hands on practice before exams." "Raters need additional training outside of HERS Providers. Perhaps have a CEU requirement." "Online training videos would be great of each testing procedure." "Actual field training with the classroom." "I think online training tools could be used more. Interactive...multiple choice...there are some good online classes in HVAC. I also think HVAC manufacturers could also be required to have online training specifically with their equipment. I would bet different manufactures have opinions regarding the testing of their equipment." "Technical training needs to improve. Website use needs to be added to training. I just finished new construction certification. I do not feel confident doing QII, there needs to be real field training." "The one thing I really believe is that there should be mandatory training available for installing contractors regarding Title 24 regulations. For HERS Raters there is also a big difference between training and testing. Hands-on training is so valuable...but it can be extremely costly...that is difficult for those of us that are individual Raters or have small companies. It is one thing to be able to pass a written test and another thing to have hands-on training. I personally mostly have to travel pretty far for both training & testing. I understand for the testing...but I would like to see more training done closer to home." "I've taken CalCERTS training and it's not as effective as USERA was. Class too big, not enough time to learn. Very 'crash course' like, and NO TECHNICAL TRAINING for field support. Their system is ineffective as well." "Field test training should only be required for new Raters vs. update classes. If new tests are required through a code change, all Raters should have hands-on training on new equipment." "Raters need additional training, NCI, BPI, or Nate certifications." "I would have liked more hands-on and better explanation of the flow hood testing and the watt draw testing. Also, I would have liked to learn the reasons WHY the systems are failing in more detail to have been able to address the problems at an earlier stage before I learned myself through experience." "More hands-on training." "From what I have heard, there are other HERS Raters that can pass a test based on the academic portion of the test but when it comes to field application fail to really understand what is happening. Understanding through academic and field experience is essential to what we do. Having a firm understanding of building science is essential to becoming an expert HERS Rater…I would love to have the opportunity to really understand the Energy Pro software or the CEC's software for that matter but I have no place to turn."
More responsive field support (36%)	"Onsite training for new Raters or a system where a new Rater can go into the field with an experienced Rater to see how a real-time test goes and have the option to converse real time with experienced Raters on say a message board as it can be hard to get as answers as quickly as possible." "There ought to be an annual 'mandatory' meeting of all HERS Raters with their Provider to discuss field issues." "I find that there is a large gap between homeowners, contractors, building department officials, HERS Raters, HERS Providers and finally the CEC. I make several calls to the CEC personally because the HERS Provider 'field line' is not a dedicated line for answers when I am actually in the field with a question. Every time I have called the 'field line' I have had to leave a message and normally do not get a call back until at least the next day if not longer. Of all the times I have called the CEC I believe I have only had to leave a message once and was called back the next day. Every other time I have called the T-24 support has been extremely helpful and knowledgeable."

Category and % of Commenters	Comments (n=30 to 34)
Better training and support for Registry (32%)	"I would like more advance notice of any changes in requirements before they show up in the Registry. For example the question about the number of bedrooms showed up with little or no explanation." "The training rooms are rented and don't always have the options for test equipment. I struggled with the new QII 2013 after the training. I needed better examples of how it should look, it was a learning curve." "Training is mostly OK except for how to use the CalCERTS Registry." "Everyone across the board needs more training using the Registry. Registry needs to be MUCH EASIER to work with!"
Education on forms (3%)	"Sometimes forms get too complicated." "How to fill out the complicated forms. Make forms less complicated." "There ought to be an annual "mandatory" meeting of all HERS Raters with their Provider to discuss…updates of forms used and/or how to fill them out."
Other (12%)	"I personally do not agree with the policy of installers being in any way in the business of HERS testing. I also do not agree with the policy of allowing Title-24 consultants too close to HERS testing. I have experienced certain special programs like "EmPower..." develop cozy relationships between favored their program approved contractors and HERS Raters verifying work or performing "whole house" ratings. In some cases County employees steering work to select Raters." "There is no evidence I am aware of any calibration issues with HERS Raters. Most contractors use analog gauges where we use digital. We can confirm our own calibration. There should be standardized HERS tests and testing between providers." "Standard testing equipment. QA inspectors should be using the same equipment that the Rater used, properly calibrated. I use a very accurate flow grid. They use a 40% variance flow hood by manufacturer claims. There can be huge discrepancies."
Address conflicts of interest (54%)	"HERS Rater firms should not provide a permit obtaining service. Since when is it okay for 3rd party independent inspectors to provide other services to the contractors they are testing? If this is allowed it will open up a host of other services that are not HERS related." "Family members shouldn't be allowed to RATE on other family members projects." "Having payment through the homeowner rather than the contractor would definitely be more of a non-biased test." "The Rater is often being paid by the contractor that he/she is testing for. Just think about that for a while." "Some HERS rating companies are obtaining permits for contractors, which should be done by the installing contractors. I believe that obtaining a permit makes you an authorized representative of the installing contractor. Therefore there is now a conflict of interest between that HERS Rater and the contractor. CalCERTS turns a blind eye to this fact and has even helped some companies achieve this." "Conflict of interest needs a clearer definition, i.e., can Raters pull permits for a contractor, etc.?" "I think that it is good that a contractor cannot test their own work so that there will not be any conflict of interest and it would reduce false results. I think that the regulations should stay in place and an outside party should be used for HERS testing."

Category and % of Commenters	Comments (n=30 to 34)
Improve permit enforcement (25%)	"Need to enforce permits." "What's going well is that new construction projects are mandatory permits with HERS Rater verification. Residential alterations [are] what contractors are getting away from Title 24 enforcement." "Better enforcement of non-licensed contractors." "Many of our local jobs are not permitted and it increases the costs for the HVAC contractors who do actually permit jobs." "I'd say that 65% of HVAC contractors are NOT obtaining a building permit for their alterations, etc." "You have missed the elephant in the room. How is the CEC going to enforce HVAC installers getting permits?" "I've heard that there are those contractors that offer lower prices on install if they don't have to pull a permit...and some homeowners either don't know the laws (or some just don't care). You don't hear about it until there is a problem, and somehow it comes out that a permit wasn't pulled, or a jurisdiction figures it out. By then it is usually a nightmare for the homeowner, because not only do they find out that they have to pull a permit on a job previous done, but then some also find out that their job wasn't done correctly." "With the lack of enforcement agencies enforcing code appropriately and the lack of permit issuance, no installer rating scale or scoring system could work." "I think there should be focus on getting the contractors some sort of incentive to actually pull permits. Why can't you regulate it so that in order to purchase a listed HVAC system, they have to prove that they have pulled a permit?" "Make contractors use a permit for every job."
Training for installers (10%)	"Training for installers on what the HERS Rater is looking for." "I believe the HERS regulations are [stricter] than contractor. CEC is relying on Building Officials and Raters to regulate the contractors and that's not working. They hire off the street and train in-house. Their lack of consistency, they should be required to be certified. Raters get QA'd, and written up. Nothing happens to the contractors. Raters are supposed to enter failed results, but nothing is being done with that data to my knowledge." "If I, as a HERS Rater, could offer training to installers and general contractors, much would improve." "What concerns me is the amount of contractors who have absolutely no clue as to what I am talking about. This (2013) code is not new anymore and just as people are starting to catch on I am warning them that the new code cycle is coming and everyone is going to have to learn a lot of new things. I think the same classes that the building department should have; all contractors should have to attend as well. That way everyone will know what is to be expected and why. By offering this 'reading the CF1R' and maybe a 'filling out the CF2R's' form class it would close the gaps between everyone involved in the entire construction process." "Contractor education is lacking big time."
Reduce paperwork and red tape (6%)	"The entire system is a money-making machine for the HERS Provider companies. It is a feather in the cap of the state. Once it hits the contractor level or jurisdiction level it completely falls apart. HERS Raters can't change the contractors, contractors can't change the inspectors. Make it all a specific and precise code with teeth." "Whatever you do, keep the regulations as simple as possible. The whole process, including the code requirements, is much too complex." "I would be surprised if more state involvement in the transaction improved things. In my experience, the more the state gets involved in a transaction, the worse the overall situation gets." "The more regulations and more difficult it is to get a system to pass, reduces the number of permitted jobs. Increased rules and regulations = fewer permitted jobs."
Better Rater and installer coordination (5%)	"Contractor waits until job is done to notify HERs Raters. Good planning is a must to limit problems on the job." "We all just need to be on the same page. Contractors don't always know the regulation and requirement on their systems." "Working with the contractor before work is started is beneficial."

Category and % of Commenters	Comments (n=30 to 34)
Other (11%)	"As of now, the only person that can be hurt in the entire process is the HERS Rater. No one else can be held accountable. The city inspector can't be held accountable for anything. The contractor, when he fails to pull a permit, can't be held accountable because there is no system of accountability in place. Same goes for the homeowner. If they don't pull a permit, what difference does it make? The HERS Rater on the other hand can lose business for making the verifications too difficult to pass, can be held liable and lose his/her license for a myriad of things." "It takes time to adapt to the changes in each code cycle, but the quality contractors are willing to learn and apply the changes. The paperwork is always a bit of a struggle and the provider has attempted to educate contractors with videos but live support from the provider is very frustrating." "The contractor scoring system is a bad idea because many duct tests fail due to bad existing duct systems and then get repaired during a smoke test. It could be fairer on new construction jobs but even things could happen after the install and before testing." "Homeowners often get way too angry if you notify them that their job 'FAILED'. Often times a minor adjustment by the contractor will allow them to pass. As long as the system is passing in the end, the homeowner does not need to be notified that it failed the first time. A standardized fee schedule is not fair. Lower pricing is the best way to get ahead in a capitalist market. A standardized fee would eliminate healthy competition." "Personally, I don't care who pays me. Some contractors are glad to exclude HERS Rater test fees from their contracts. Some contractors want to give their clients one complete price, and they add something to the HERS Rater's fee. Many customers view this HERS test as just another way to complicate the job and have to pay more $."
Better training and support for Registry (32%)	"I would like more advance notice of any changes in requirements before they show up in the Registry. For example the question about the number of bedrooms showed up with little or no explanation." "The training rooms are rented and don't always have the options for test equipment. I struggled with the new QII 2013 after the training. I needed better examples of how it should look, it was a learning curve." "Training is mostly OK except for how to use the CalCERTS Registry." "Everyone across the board needs more training using the Registry. Registry needs to be MUCH EASIER to work with!"
Education on forms (3%)	"Sometimes forms get too complicated." "How to fill out the complicated forms. Make forms less complicated." "There ought to be an annual "mandatory" meeting of all HERS Raters with their Provider to discuss…updates of forms used and/or how to fill them out."
Other (12%)	"I personally do not agree with the policy of installers being in any way in the business of HERS testing. I also do not agree with the policy of allowing Title-24 consultants too close to HERS testing. I have experienced certain special programs like "EmPower..." develop cozy relationships between favored their program approved contractors and HERS Raters verifying work or performing "whole house" ratings. In some cases County employees steering work to select Raters." "There is no evidence I am aware of any calibration issues with HERS Raters. Most contractors use analog gauges where we use digital. We can confirm our own calibration. There should be standardized HERS tests and testing between providers." "Standard testing equipment. QA inspectors should be using the same equipment that the Rater used, properly calibrated. I use a very accurate flow grid. They use a 40% variance flow hood by manufacturer claims. There can be huge discrepancies."

Category and % of Commenters	Comments (n=30 to 34)
Address conflicts of interest (54%)	"HERS Rater firms should not provide a permit obtaining service. Since when is it okay for 3rd party independent inspectors to provide other services to the contractors they are testing? If this is allowed it will open up a host of other services that are not HERS related." "Family members shouldn't be allowed to RATE on other family members projects." "Having payment through the homeowner rather than the contractor would definitely be more of a non-biased test." "The Rater is often being paid by the contractor that he/she is testing for. Just think about that for a while." "Some HERS rating companies are obtaining permits for contractors, which should be done by the installing contractors. I believe that obtaining a permit makes you an authorized representative of the installing contractor. Therefore there is now a conflict of interest between that HERS Rater and the contractor. CalCERTS turns a blind eye to this fact and has even helped some companies achieve this." "Conflict of interest needs a clearer definition, i.e., can Raters pull permits for a contractor, etc.?" "I think that it is good that a contractor cannot test their own work so that there will not be any conflict of interest and it would reduce false results. I think that the regulations should stay in place and an outside party should be used for HERS testing."
Improve permit enforcement (25%)	"Need to enforce permits." "What's going well is that new construction projects are mandatory permits with HERS Rater verification. Residential alterations [are] what contractors are getting away from Title 24 enforcement." "Better enforcement of non-licensed contractors." "Many of our local jobs are not permitted and it increases the costs for the HVAC contractors who do actually permit jobs." "I'd say that 65% of HVAC contractors are NOT obtaining a building permit for their alterations, etc." "You have missed the elephant in the room. How is the CEC going to enforce HVAC installers getting permits?" "I've heard that there are those contractors that offer lower prices on install if they don't have to pull a permit...and some homeowners either don't know the laws (or some just don't care). You don't hear about it until there is a problem, and somehow it comes out that a permit wasn't pulled, or a jurisdiction figures it out. By then it is usually a nightmare for the homeowner, because not only do they find out that they have to pull a permit on a job previous done, but then some also find out that their job wasn't done correctly." "With the lack of enforcement agencies enforcing code appropriately and the lack of permit issuance, no installer rating scale or scoring system could work." "I think there should be focus on getting the contractors some sort of incentive to actually pull permits. Why can't you regulate it so that in order to purchase a listed HVAC system, they have to prove that they have pulled a permit?" "Make contractors use a permit for every job."
Training for installers (10%)	"Training for installers on what the HERS Rater is looking for." "I believe the HERS regulations are [stricter] than contractor. CEC is relying on Building Officials and Raters to regulate the contractors and that's not working. They hire off the street and train in-house. Their lack of consistency, they should be required to be certified. Raters get QA'd, and written up. Nothing happens to the contractors. Raters are supposed to enter failed results, but nothing is being done with that data to my knowledge." "If I, as a HERS Rater, could offer training to installers and general contractors, much would improve." "What concerns me is the amount of contractors who have absolutely no clue as to what I am talking about. This (2013) code is not new anymore and just as people are starting to catch on I am warning them that the new code cycle is coming and everyone is going to have to learn a lot of new things. I think the same classes that the building department should have; all contractors should have to attend as well. That way everyone will know what is to be expected and why. By offering this 'reading the CF1R' and maybe a 'filling out the CF2R's' form class it would close the gaps between everyone involved in the entire construction process." "Contractor education is lacking big time."

Category and % of Commenters	Comments (n=30 to 34)
Reduce paperwork and red tape (6%)	"The entire system is a money-making machine for the HERS Provider companies. It is a feather in the cap of the state. Once it hits the contractor level or jurisdiction level it completely falls apart. HERS Raters can't change the contractors, contractors can't change the inspectors. Make it all a specific and precise code with teeth." "Whatever you do, keep the regulations as simple as possible. The whole process, including the code requirements, is much too complex." "I would be surprised if more state involvement in the transaction improved things. In my experience, the more the state gets involved in a transaction, the worse the overall situation gets." "The more regulations and more difficult it is to get a system to pass, reduces the number of permitted jobs. Increased rules and regulations = fewer permitted jobs."
Better Rater and installer coordination (5%)	"Contractor waits until job is done to notify HERs Raters. Good planning is a must to limit problems on the job." "We all just need to be on the same page. Contractors don't always know the regulation and requirement on their systems." "Working with the contractor before work is started is beneficial."
Other (11%)	"As of now, the only person that can be hurt in the entire process is the HERS Rater. No one else can be held accountable. The city inspector can't be held accountable for anything. The contractor, when he fails to pull a permit, can't be held accountable because there is no system of accountability in place. Same goes for the homeowner. If they don't pull a permit, what difference does it make? The HERS Rater on the other hand can lose business for making the verifications too difficult to pass, can be held liable and lose his/her license for a myriad of things." "It takes time to adapt to the changes in each code cycle, but the quality contractors are willing to learn and apply the changes. The paperwork is always a bit of a struggle and the provider has attempted to educate contractors with videos but live support from the provider is very frustrating." "The contractor scoring system is a bad idea because many duct tests fail due to bad existing duct systems and then get repaired during a smoke test. It could be fairer on new construction jobs but even things could happen after the install and before testing." "Homeowners often get way too angry if you notify them that their job 'FAILED'. Often times a minor adjustment by the contractor will allow them to pass. As long as the system is passing in the end, the homeowner does not need to be notified that it failed the first time. A standardized fee schedule is not fair. Lower pricing is the best way to get ahead in a capitalist market. A standardized fee would eliminate healthy competition." "Personally, I don't care who pays me. Some contractors are glad to exclude HERS Rater test fees from their contracts. Some contractors want to give their clients one complete price, and they add something to the HERS Rater's fee. Many customers view this HERS test as just another way to complicate the job and have to pay more $."
Reform QA/QC (59%)	"The HERS Rater QA/QC system should be designed to develop HERS Raters to do a better job, not to scare the living daylights out of them with 'You will forever be banned from performing HERS Verifications if you make a mistake". What it should be looking for are for those that charge half what everyone else charges and don't actually perform HERS Verifications…If after extensive investigation, you find that the majority of their 'verifications' were fraud, they should be banned period. But for those that are doing their job, and make a mistake here and there, give them teaching and lessons." "It needs to be done by individuals not associated with the HERS providers. The process, websites need to be separated instead of the one size fits all (current)." "QA/QC should be more frequent, due to the lack of knowledge and training current Raters have." "With the QA I would like to see actual results from the QA company/Dept. and not just a 'you passed or you failed'." "I disagree with the idea of "sampling" – it does not serve property owners." "Sometimes I wonder if it would work out better if the QA/QC Inspector actually accompanied us on a 'current' job to watch our process of inspections while we are conducting them."
Better training and support for Registry (31%)	"Zero training for entering data into Registries. This is the biggest hole in HERS training." "The registries are not user friendly at all." "The Registries are too complicated." "CalCERTS Registry is very difficult to use and get acquainted with. They also do not provide any help with Registry training or tech support." "The service we get from the HERS Registries is very poor." "The HERS Registries are not very good. They need to be simplified."

Category and % of Commenters	Comments (n=30 to 34)
Better communication (19%)	"When tech support is contacted there is very little clarification given, half the time the support staff do not know the answer to the question." "Raters need better phone support for the Registries." "[HERS Registries] don't answer phone calls, they close at 4:00pm, and you can't tell them what you think because you don't want to piss them off." "There is no instant support when a Rater has questions."
Improve transparency for learning (10%)	"We have to document all details and we should be supplied the results from QA, as for the Registries more videos, more help on them." "I rarely hear from the QA/QC process from CalCERTS. I would love to hear about what they are finding out in the field, pictures, processes that are working well." "I would like to be notified PRIOR to QA/QC so that I may be present at job site." "There is no feedback loop for Raters to learn from."
Other (7%)	"I have been told a system I refrigerant charge tested was low, and that I should inform the installer. It was charged right when I did the test. But why should I contact the installer or builder other than common courtesy?" "The fee you pay when you get your QC is very high." "There are extenuating circumstances that complicate strict compliance to Test Procedures. These circumstances will cause greater expense to the customer, and not improve efficiency. Therefore, on-site judgment should be allowed when the intent of the code is met."

APPENDIX V. STATISTICALLY SIGNIFICANT DIFFERENCES IN HERS RATER RESPONSES TO RATING SCALE QUESTIONS FULL-LENGTH SURVEY (ONLINE SURVEY)

The figures in APPENDIX V display any statistically-significant[20] differences found between different groups of respondents to the full-length (online) survey of HERS Raters within each relevant category – e.g., years of experience, climate region, and number of jobs in 2015. For example, respondents with less than five years of experience rated the training's usefulness in terms of applying proper verification of mandatory and prescriptive measures higher than respondents with more than 5 years of experience (8.6 vs. 5.8). The table shows ratings only in cases for in which the difference was statistically significant.

[20] All differences are statistically significant at the 90% confidence interval.

Figure 139. HERS Rater ratings regarding usefulness of training on a 10-point scale* (HERS Rater online survey, 2016)

Training Element	Years of experience		Climate region		Number of jobs in 2015		
	Less than 5	More than 5	Inland	Coastal	50 or fewer	51 to 149	150 or more
Testing and verification procedures							
Apply proper testing procedures for duct testing	-	-	-	-	-	-	-
Apply proper testing procedures for blower door testing	-	-	-	-	-	-	-
Apply proper verification of mandatory and prescriptive measures	8.6	5.8	-	-	4.6	-	7.9
Apply proper testing procedures for measuring refrigerant charge level	-	-	-	-	3.2	4.8	8.2
Apply proper testing procedures for measuring airflow and fan power index	8.9	4.8	-	-	-	-	-
Apply proper testing procedures for fog testing (using a theatrical fog machine)	7.9	5.0	6.6	3.4	-	-	-
Other elements of training							
Obtain relevant information on Title 24 requirements for HVAC inspections	-	-	-	-	-	-	-
Learn which compliance forms apply for various HVAC changeout scenarios	-	-	-	-	-	-	-
Ease of use with the HERS Rater manual	8.7	5.6	-	-	4.6	-	7.7
Communicate test results to installation contractors	8.8	4.9	-	-	3.1	-	7.6
Become familiar with the form submission process for the HERS Provider's Registry	7.1	2.6	-	-	-	-	-

* Respondents used a 10-point scale where 1 means "not at all useful" and 10 means "very useful."

Figure 140. Statistically significant differences in satisfaction with HERS Rater training on a 10-point scale* (HERS Rater online survey, 2016)

Training Elements	Years of experience		Climate region		Number of jobs in 2015		
	Less than 5	More than 5	Inland	Coastal	50 or fewer	51 to 149	150 or more
Hands-on experience							
Hands-on experience visually verifying mandatory and prescriptive measures	7.8	5.6	-	-	-	-	-
Hands-on experience using testing equipment	-	-	-	-	3.1	-	7.5
The training support HERS Raters receive while in the field or on the job	-	-	-	-	3.0	-	7.4
Hands-on experience using certification forms	-	-	-	-	-	-	-
Training logistics							
Course length	-	-	-	-	-	-	-
Course location	-	-	-	-	-	-	-
Course frequency	-	-	-	-	-	-	-
Course cost	8.3	5.2	-	-	3.3	4.9	7.7
Other training elements							
The instructors' technical knowledge of HVAC systems	-	-	-	-	5.9	-	8.7
The relevance of the material presented	9.0	6.5	-	-	-	-	-
The ease of working with the training manual	8.8	6.4	-	-	-	-	-
The content of the training course	8.5	6.0	-	-	4.7	7.2	7.8

* Respondents used a 10-point scale where 1 means "not at all satisfied" and 10 means "very satisfied."

Figure 141. Statistically significant differences in barriers to Title 24 compliance among Raters on a 10-point scale* (HERS Rater online survey, 2016)

Potential Barrier	Years of experience		Climate region		Number of jobs in 2015		
	Less than 5	More than 5	Inland	Coastal	50 or fewer	51 to 149	150 or more
Rater preparedness							
Raters may not have enough technical experience to perform a quality inspection	-	-	-	-	-	6.9	9.3
Raters may not have all the right equipment to perform all the required tests	6.0	9.0	-	-	-	-	-
Raters may not understand which Title 24 mandatory and prescriptive measures apply to their jobs	-	-	-	-	-	-	-
Lack of enforcement							
Raters may work in local jurisdictions that enforce only some of the required tests and verification requirements	-	-	-	-	-	-	-
Job security concerns							
Raters may not correctly report all the test results for job security	-	-	-	-	-	-	-
Raters may not perform all the required tests and verification requirements if they think they will fail	-	-	3.4	7.1	7.2	-	2.9
Other factors							
Raters may not have the desire to do a quality inspection	-	-	-	-	-	-	-
Raters may not have enough time to do a quality inspection	-	-	-	-	-	-	-

* Respondents used a 10-point scale where 1 means "strongly disagree" and 10 means "strongly agree."

Figure 142. Statistically significant differences in barriers to Title 24 compliance among contractors on a 10-point scale* (HERS Rater online survey, 2016)

Potential Barrier	Years of experience		Climate region		Number of jobs in 2015		
	Less than 5	More than 5	Inland	Coastal	50 or fewer	51 to 149	150 or more
Systemic barriers							
Contractors may not pull a permit if they think their installation will not comply with Title 24	-	-	8.8	5.7	-	-	-
Contractors may work in local jurisdictions that enforce only some of the required test and verification requirements	-	-	8.6	4.8	-	-	-
Contractors may not have enough time to do a quality installation	-	-	3.8	7.6	7.9	-	3.4
Contractor shortcomings							
Contractors may not understand which Title 24 mandatory and prescriptive measures apply to their installations	-	-	8.7	6.1	8.6	6.1	8.7
Contractors may not know how to repair the installation when it fails the HERS tests	-	-	-	-	-	-	-
Contractors may not have the right equipment to do a quality installation	-	-	-	-	7.9	5.4	-
Contractors may not have enough technical experience to complete a quality installation	-	-	-	-	8.6	6.7	-
Motivational barriers							
Contractors may not believe they need a HERS Rater to tell them if their installation is correct	-	-	8.7	5.9	-	-	-
Contractors may not have the desire to do a quality installation	-	-	-	-	-	-	-
Contractors may not believe the HERS inspections are needed	-	-	-	-	9.1	-	5.3

* Respondents used a 10-point scale where 1 means “strongly disagree” and 10 means “strongly agree.”

Figure 143. Statistically significant differences in contractor knowledge about Title 24 requirements on a 10-point scale* (HERS Rater online survey, 2016)

Element of Title 24	Years of experience		Climate region		Number of jobs in 2015		
	Less than 5	More than 5	Inland	Coastal	50 or fewer	51 to 149	150 or more
Permit requirements for different types of installations	-	-	-	-	-	-	-
Duct sealing requirements for new versus existing ducts	-	-	-	-	-	6.8	3.4
Air flow and fan power index requirements	-	-	-	-	-	-	-
Compliance form requirements for residential HVAC alterations	-	-	-	-	-	-	-
Difference in Title 24 prescriptive and mandatory compliance requirements for different types of installations. e.g. packaged unit vs. split systems	-	-	-	-	-	-	-
Difference in Title 24 prescriptive and mandatory compliance requirements by climate zones	-	-	2.8	4.9	-	-	-

* Respondents used a 10-point scale where 1 means "not at all knowledgeable" and 10 means "very knowledgeable."

Figure 144. Statistically significant differences in regulations regarding training and testing on a 10-point scale* (HERS Rater online survey, 2016)

Training / Testing Element	Years of experience		Climate region		Number of jobs in 2015		
	Less than 5	More than 5	Inland	Coastal	50 or fewer	51 to 149	150 or more
Suggested improvements to HERS training and testing							
Field exams should be part of the course requirements.	-	-	-	-	-	-	-
Establish minimum standardized requirements for HERS trainings.	-	-	9.0	5.7	-	-	-
There should be better enforcement of HERS Rater tool calibration requirements to improve the accuracy of HERS test results.	-	-	-	-	-	3.4	6.3
To be subject matter experts, HERS Rater courses need to provide…							
More hands-on training for the visual inspection of measures.	-	-	-	-	-	-	-
More technical training of HVAC system operation.	-	-	-	-	-	-	-
More hands-on training for performing tests (duct leakage, blower door, fan power index, etc.)	-	-	-	-	-	-	-
More technical training of basic building knowledge.	-	-	-	-	-	-	-

* Respondents used a 10-point scale where 1 means "strongly disagree" and 10 means "strongly agree."

Figure 145. Statistically significant differences in regulations regarding contractors on a 10-point scale* (HERS Rater online survey, 2016)

Statement	Years of experience		Climate region		Number of jobs in 2015		
	Less than 5	More than 5	Inland	Coastal	50 or fewer	51 to 149	150 or more
Most HVAC jobs are installed without a permit and there is little a HERS Rater can do to change that.	-	-	-	-	8.7	5.2	9.4
The quality of installations would improve if customers knew how often contractors' installations failed the HERS Rater inspections.	-	-	-	-	6.6	3.4	8.8
Creating a contractor scoring system based on historic pass/fail test performance will promote contractors who perform quality installations.	-	-	-	-	-	4.2	8.2
The conflict of interest regulation between HERS Raters and HVAC contractors needs better enforcement.	-	-	7.9	3.8	4.8	3.5	8.3
A standardized fee schedule for HERS services would reduce the likelihood that customers would get over charged.	-	-	-	-	-	-	-

* Respondents used a 10-point scale where 1 means "strongly disagree" and 10 means "strongly agree."

Figure 146. Statistically significant differences in regulations regarding HERS QA on a 10-point scale* (HERS Rater online survey, 2016)

Regulation of the HERS QA Process	Years of experience		Climate region		Number of jobs in 2015		
	Less than 5	More than 5	Inland	Coastal	50 or fewer	51 to 149	150 or more
The current QA/QC process is an effective way to hold HERS Raters accountable.	-	-	-	-	-	-	-
A screening process is necessary for individuals who perform QA/QC tests to ensure they are highly qualified to do the job.	-	-	-	-	8.6	5.1	9.1
The HERS Rater Registries are well designed to serve the needs of HERS Raters.	-	-	-	-	-	-	-
An independent entity is necessary to avoid conflicts of interest and improve reliability of QA/QC tests.	-	-	-	-	6.9	3.3	-

* Respondents used a 10-point scale where 1 means "strongly disagree" and 10 means "strongly agree."

APPENDIX W. HERS RATER TELEPHONE AND ONLINE SURVEY INSTRUMENTS

HERS Rater Screener Survey (Telephone Survey)

Survey House Instructions

1. Text in brackets [ ] are instructions for interviewer, minor programming such as skips, or answer choices and should NOT be read.
2. Unless specifically noted, do NOT read answer choices [Other], [Don't know] and [Refused].

Data variables

Rater Count	Count of HERS Raters per company
Company	Name of Company in HERS Provider list
Phone	Phone number for Company
Rater 1-21	Contact Name for each Rater for Company

Definitions

Variable	Definition
HERS	Home Energy Rating System
HERS Rater	An individual who conducts Home Energy Inspections
HERS Provider	A data repository where HERS documentation is stored and managed by a company, referred to as a "Provider."
HVAC Alteration	A replacement of a central heating or cooling system.
Climate Zone	Climate regions in California

Voice mail

Answering machine: Messages should be left the first time you call and every three calls after that. Here is a script for the answering machine:

- *Hi <Rater Name>, this is <Interviewer name> the reason for my call is I'm conducting a state-wide study on HERS Raters and their experience performing field inspections and working with HERS Providers. I'd like to ask you about 5 minutes of questions. This call is sponsored by the CA Public Utilities Commission performed here at Pacific Market Research. (PAUSE) We're not selling anything. (PAUSE)* We will try back again another time, or you can call us back at 1-877-271-2300 and refer to project S029, thank you.

Introduction

Intro1. Hello, my name is __________; I'm calling on behalf of the California Public Utilities Commission concerning a state-wide study on HERS Raters and their experience conducting inspections on residential households.

[INTRO IF RATER COUNT =1] I'd like to speak with <Rater1> if available?
[INTRO IF RATER COUNT =2] I'd like to speak with either <Rater1> or <Rater2> if available?
[INTRO IF RATER COUNT > =3] I'd like to speak with one of the HERS Raters at your company, is anyone available?

[Yes]	1	Record Rater's Name
[No]	2	Intro2
[Don't know]	98	Intro2
[Refused]	99	Thank & Terminate

[Indicate Rater Name for the Interview]

Intro2. Can you please confirm the name of the Rater?

< Merged Field Rater Name1>	1	Name becomes Rater X for the remainder of survey
<Rater2>	2	
<Rater3>	3	
<Rater4>	4	
<Rater5>	5	
<Rater6>	6	
<Rater7>	7	
<Rater8>	8	
<Rater9>	9	
<Rater10>	10	
<Rater11>	11	
<Rater12>	12	
<Rater13>	13	
<Rater14>	14	
<Rater15>	15	
<Rater16>	16	
<Rater17>	17	
<Rater18>	18	
<Rater19>	19	
<Rater20>	20	
<Rater21>	21	
[Other: RECORD Name:	50	
[Don't know]	98	Thank & Terminate
[Refused]	99	

Intro3. When is a good time I could call back to reach them at this number?

[RECORD DAY and TIME]		Call back later
[Different phone number: Record Number ___________]		
[Don't know]	98	
[Refused]	99	

Purpose of the survey

Hello <Rater X>, the reason for the call is we're gathering information on HERS Rater's and their experience conducting HVAC alteration inspections. This call is sponsored by the California Public Utilities Commission and the information is used to inform research on energy efficiency and the quality of newly installed HVAC systems. I'd like to assure you that I'm not selling anything and the information you provide is treated confidentially. I have a few questions on the type of inspections you perform and where they occur.

Based on the feedback you provide in this survey you may be selected for a follow-up survey where you'll be paid fifty dollars in exchange for your time. The paid survey will include questions on your experience with HERS training, the HERS Registry, testing in the field, and experience with interacting with contractors and code officials.

[AGREES TO PARTCIPATE]	1	Intro4
[DOES NOT AGREE TO PARTCIPATE]	2	Thank & Terminate

[REPEAT IF NEEDED] All survey information collected including the results to this survey will be treated confidentially and reported in aggregate form.

[IF ASKED] If you would like to verify the legitimacy of this research our CPUC manager is Paula Gruendling at (415) 703-1925. If you have questions about this or the follow up survey you can reach our study manager by calling Amber Watkins at (866) 439-8006.

Intro3.1 First, do you mind telling me your business title at <company name>? [If respondent is both a Owner and HERS Rater select Owner]

[HERS Rater]	1	Intro4
[Manager]	2	Intro4
[Owner]	3	Intro4
[Receptionist]	4	Intro5
[Other]	Record	Intro4
[Refused]	-99	Intro4

Intro4. In the last 12 months have you conducted HERS Rater inspections?

[Yes]	1	Q1
[No]	2	Intro5
[Refused]	99	

Intro5. Is there anyone at your company who has completed HERS inspections in the last 12 months?

[Yes]	1	Intro6
[No]	2	Skip to section 5.1 (Thank and terminate)
Don't know		
Refused	99	

Intro6. Could you put me in touch with that person? [If needed: I would like to ask about the HERS tests they have completed]

Proceed	1	Q1
Call back	2	Record and disposition then thank and terminate
Call a different number [Record number]	3	
[Don't know]	98	
[Refused]	99	

Survey questions

Thank you for taking the time to speak with me today. First, I'd like to ask you a few questions about your company.

1) Our records show <merge no. raters> HERS Rater(s) work for <company name originally selected>. Is that correct?

[Yes]	1	Q2
[No]	2	Q1.1
[Don't know]	98	Q2
[Refused]	99	

1.1) How many HERS Raters work for your company?

[Record]	Num.	Q2
[Don't know]	-98	
[Refused]	-99	

2) How many Raters work **full time** for this company?

[Total]	Num.	Q3
[Don't know]	-98	
[Refused]	-99	

3) Which of the following HERS inspection types do you typically perform? Do you do…[Read List, reflect all that apply]

Residential Alterations	1	Q4
Non-Residential Alterations	2	
New Construction	3	
Whole house	4	
Energy Efficient Mortgage	5	
New Solar Home Inspections	6	
Building Performance Ratings	7	
Energy Star Inspections	8	
[All of the above]	9	
[None of these]	50	
[Refused]	99	

4) How many total HERS inspections, of all types, would you estimate your company completed last year?

[Total]	Num.	Q5
[Don't know]	-98	Q4.1
[Refused]	-99	

4.1) Who at your company would have this information on the number of inspections completed last year?

[Record Name and Title]	Num.	Q5
[Don't know]	-98	
[Refused]	-99	

5) Approximately how many of those inspections were related to residential HVAC alterations?

[Total]	Num.	Q6
[Don't know]	-98	

[Refused]	-99	

6) Was this a typical year for your company, in terms of the total number of residential HVAC alteration inspection, completed annually? [IF NEEDED, "Or do you typically perform more or less in a typical year?]

[Yes, typical]	1	Q7
[More in a typical year]	2	Q6.1
[Less in a typical year]	3	
[Don't know]	98	Q7
[Refused]	99	Q7

6.1) How many HVAC inspections would you estimate your company completes in a typical year?

[Record]	Num.	Q7
[Don't know]	-98	
[Refused]	-99	

7) [IF RATER COUNT IN Intro2 =1 THEN ASK OTHERWISE SKIP TO Q9] How many residential HVAC alteration inspections would you estimate that you personally completed for this company last year?

[Total]	Num.	Q8
[Don't know]	-98	
[Refused]	-99	

8) Did you complete any HVAC alteration inspections for any other companies last year? [Only accept "Yes" if other inspections were HVAC inspections.]

[Yes]	1	Q8.1
[No]	2	Q9
[Refused]	99	

8.1) Our records show your name listed as a HERS Rater for the following company(s) <read from merge from list>. Which other company(s) besides this one/these ones did you work for last year?

[Record company name]	[Record]	Q8.2
[No other companies]	2	Q8.3
[Don't know]	-98	Q9
[Refused]	-99	Q9

8.2) How many HVAC alteration inspections would you estimate you completed last year for the company(s) you just mentioned?

[Record]	[Num.]	Q8.3
[Don't know]	-98	Q8.3
[Refused]	-99	Q8.3

8.3) How many HVAC alteration inspections would you estimate you completed last year for <merge company name(s)>? [Repeat for each company] How about [company nameX] how many did you complete for them?

[Company A]	Num.	Q9
[Company B]	Num.	
[Company C]	Num.	

[Company D]	Num.	
[Don't know]	-98	
[Refused]	-99	

Next I would like to know where you perform HERS test services.

9) Which regions in California do you most often work in? Do you work in northern, central or southern California?

[Northern]	1	Q9.1
[Central]	2	Q9.2
[Southern]	3	Q9.3
[All of the Above]	4	[Ask Q9.1, 9.2, 9.3]
[Don't know]	98	Q15
[Refused]	99	Q15

9.1) Can you tell me the major northern California cities or climate zones that you often work in? [Record] [If respondent offers both use climate zones 1 through 16]

[Cities Record]	Record	Q10
[Climate Zones]	Record	
[Don't know]	-98	
[Refused]	-99	

9.2) Can you tell me the major central California cities or climate zones you often work in? [Record] [If respondent offers both use climate zones 1 through 16]

[Cities Record]	Record	Q10
[Climate Zones]	Record	
[Don't know]	-98	
[Refused]	-99	

9.3) Can you tell me the major southern California cities or climate zones you work in? [Record] [If respondent offers both use climate zones 1 through 16]

[Cities Record]	Record	Q10
[Climate Zones]	Record	
[Don't know]	-98	
[Refused]	-99	

10) I'd like to know about the HERS Providers you work with. Which HERS Providers are you registered with? [Read List as needed, reflect all that apply]

CalCERTS, Inc.	1	Q10.1
U.S. Energy Raters Association (USERA)	2	
ConSol Home Energy Efficiency Rating Services, Inc. (CHEERS	3	
[Other describe]	50	
[Don't know]	98	Q11
[Refused]	99	

10.1) [If Q10 >1 then ask otherwise skip to Q11] Which Provider do you work with most often?

CalCERTS, Inc.	1	Q11
U.S. Energy Raters Association USERA	2	
ConSol Home Energy Efficiency Rating Services, Inc. CHEERS	3	
[Don't know]	98	
[Refused]	99	

11) How many years have you worked as HERS Rater? Is that … [read list]

Less than a year	1	Q12
1 to 2	2	
3 to 5	3	
6 to 10	4	
or more than 10 years	5	
[Don't know]	-98	
[Refused]	-99	

12) Do you have a background as an HVAC contractor or technician?

[Yes]	1	Q13
[No]	2	
[Refused]	99	

13) Using a scale of 1 to 10 where 1 means "not at all knowledgeable" and 10 means "very knowledgeable," how knowledgeable are you regarding the Standards 2013 code for HVAC systems in residential dwellings?

[Record]	1 to 10	R1
[Don't know]	-98	
[Refused]	-99	

Full-length survey recruitment

R1. Lastly, I'd like to offer you the opportunity to participate a follow up telephone survey to discuss your experience performing residential HVAC alteration inspections. If you agree, and are selected to participate, you will be provided a $50 cash incentive card by mail after you complete the survey. The follow up survey will occur sometime in the next few weeks and will take about 30 minutes. Depending on your responses, it could be slightly more or less time. All survey information collected including the results to this survey will be treated confidentially and reported in aggregate form. Are you interested?

[Yes]	1	R2
[Decline]	2	R1R
[Record Referral if Provided]	3	End Loop
[Don't know]	98	
[Refused]	99	

R1.R For our records, can you explain why you're not interested in the follow up survey?

No Reason	1	End Loop

Time commitment too long	2	
Insufficient incentive	3	
Lack of trust	4	
Don't know enough about it	5	
Other	50	
Refused	99	

R2. [If R1=1 then ask] Is there an alternate number you would like researchers to call you on?

[Record]		R2
[No]	98	
[Refused]	99	

R3. [If R1=1 then ask] Is there an email address we could use to schedule the call with you?

[Record]		End Loop
[No]	98	
[Refused]	99	

Closing statement:

Thank you for your participation in this survey. Those are all of the questions I have for you today.

HERS Rater Full-Length Survey (Online Survey)

Section 1. HERS Training- This section is dedicated to your experience and satisfaction with the HERS certification training courses.

Q1. Have you participated in a HERS Rater certification or re-certification training course for the 2013 Title 24 Energy Code that went into effect on July 1st 2014?

Q2. Who offered the training you most recently attended?

Q3. Was this training based in a classroom setting, in a field setting (with HVAC equipment), or a combination of classroom and field?

Q4. Using a scale of 1 to 10 where 1 is "not at all useful" and 10 is "very useful", how useful was this training as far as helping you with the following:

- Obtain relevant information on Title 24 requirements for HVAC inspections
- Learn which compliance forms apply for various HVAC changeout scenarios
- Ease of use with the HERS Rater manual
- Become familiar with the form submission process for the HERS Provider's registry
- Apply proper testing procedures for duct testing
- Apply proper testing procedures for blower door testing
- Apply proper testing procedures for fog testing (using a theatrical fog machine)
- Apply proper testing procedures for measuring refrigerant charge level
- Apply proper testing procedures for measuring airflow and fan power index
- Apply proper verification of mandatory and prescriptive measures
- Communicate test results to installation contractors

Q5. On a scale of 1 to 10 where 1 is “not at all satisfied” and 10 is “very satisfied,” how satisfied are you with the following aspects of the HERS Rater training(s).
The content of the training course

- The relevance of the material presented
- The instructors' technical knowledge of HVAC systems
- The ease of working with the training manual
- Hands-on experience using testing equipment
- Hands-on experience using certification form
- Hands-on experience visually verifying mandatory and prescriptive measures
- The length of the training course
- The frequency at which training courses are offered
- The cost of the training courses
- The geographic location of the training courses
- The training support HERS Raters receive while in the field or on the job

Q6. If you have any other comments to offer on the issue of HERS Rater training and certification please describe them here:

Section 2. HERS Inspections - This section is dedicated to HERS Rater's experience performing residential HVAC changeout inspections.

Q7. Have you performed HERS Rater inspections on HVAC changeouts with existing ducts in residences/dwellings?

Q8. Which climate zone do you work in most often? {Pick one}

- Survey lists zones 1 through 16

Q9. Consider the following scenario: this week you secured a HERS inspection at a single-family residential dwelling [in climate zone 1-16 selected in Q8]. The HVAC contractor replaced the central heating and cooling unit at the same time. The existing duct work is located in the attic and the house is 1700 SQFT. For this job please briefly describe what measures you would verify and what tests you would perform. Please describe:

Q10. In the previous question you were provided an inspection scenario for a unit replaced in {Q9}. Using this same scenario, would you have performed the following test? Select yes or no for each test and verification requirement.

- Verify manual J load calculations
- Verify measurement access (TMAH & PSP)
- Verify minimum efficiency
- Verify set-back (programmable thermostat)
- Verify refrigerant line insulation
- Verify duct insulation is R-4.2
- Verify duct insulation is from R-4.2 to R-8.0
- Measure duct leakage at 6% or less
- Measure duct leakage at 15% or less
- Measure refrigerant charge
- Measure fan power index consumption
- Measure leakage to the outside

Q11. In the [in climate zone # 1-16] changeout scenario, you haven't worked with the installation contractor before. He asks you for a bid. Approximately how much would it cost to perform the inspection? Assume the system passes your inspection the first time.

- < $350
- $350-500
- $501-650
- $651-800
- >$800
- Refused

Q12. Do you have experience with residential HVAC alterations that did not pass the duct leakage test?

- Yes
- No [skips to Q16]

Q13. Consider the [climate zone # 1-16] installation scenario: The duct leakage test does not pass the first test and the contractor attempts to repair it but still I does not pass. In this situation, what other test(s), if any, would you perform as part of your standard practice?

- Smoke test
- No other test
- Repeat total leakage test
- Leakage to the outside test
- Specify:

Q14. When your residential HVAC inspections fail the duct leakage tests, how often do you perform the following tests? Select one response for each test: Always, Often, Sometimes, Rarely, Never, Don't know

- Repeat total leakage test
- Perform leakage to the outside test
- Perform smoke test

Q15. Do you have experience with HVAC alterations that did not pass the airflow and fan power index tests?

- Yes
- No [skips to Q17]

Q16. If an airflow test does not pass, what do you typically do? Check all that apply

- Repeat test
- Contact the installation contractor
- Nothing
- Specify:

Q17. When you're HERS inspections do not pass how do you typically communicate these results?
[Check all that apply]

- Submit the "no pass" test on the compliance form
- Inform the installer at my company
- Telephone or email the installer that is with another company
- Inform the end user where the unit is installed
- Do nothing
- Something else (specify):

Q18. If a duct or airflow test fails, do you ever advise the contractor on how to fix it?

- Select one response: Always, Often, Sometimes, Rarely, Never, Don't know

Q19. Using a 5 point scale where 1 means "very easy" and 5 means "very difficult," how easy or difficult is it to convey failed test or verification measure results to installation contractors?

- Select one response: Very easy, easy, medium, difficult, very difficult

Q20. What communication tools, if any, would you like to have available to more effectively convey failed test results? Check all that apply.

- A mobile telephone app
- Standardized form or template
- A dedicated website to upload images and notes

- A dedicated job call line
- Hands-on training
- No tools are needed
- Don't know
- Other (Specify):

Q21. If you have any other comments to offer on the issue of HVAC changeout inspections at residential homes please describe here:

Section 3. HERS Rater Barriers - In this section we address potential barriers to Title 24 compliance among HERS Raters.

Q22. Presented is a list of reasons why some HERS Raters may not perform all of the required tests or comply with re-testing requirements for HVAC installations. Using a scale of 1 to 10 where 1 means you "strongly disagree" and 10 means you "strongly agree," please rate your level of agreement with the following statements about why some HERS Raters may not comply with Title 24 requirements.

- Some HERS Raters may not understand which Title 24 mandatory and prescriptive measures apply to their jobs.
- Some HERS Raters may not have enough technical experience to perform a quality inspection.
- Some HERS Raters may not have all the right equipment to perform all the required tests.
- Some HERS Raters may not have the desire to do a quality inspection.
- Some HERS Raters may not have enough time to do a quality inspection.
- Some HERS Raters may work in local jurisdictions that enforce only some of the required tests and verification requirements.
- Some HERS Raters may not perform all the required tests and verification requirements if they think they will fail.
- Some HERS Raters may not correctly report all the test results for job security.

Q23. What are some <u>other</u> reasons, if any, why HERS Raters may not perform all the required test and verification requirements?

Q24. If you have any other comments to offer on the issue of barriers for HERS Raters please describe here:

Section 4. Contractor Barriers - This section addressees key barriers to Title 24 compliance among HVAC installation contractors.

Q25. Using the same scale of 1 to 10 where 1 means "not at all knowledgeable" and 10 means "very knowledgeable", how knowledgeable would you say HVAC installation contractors are in general regarding the 2013 code requirements for HVAC changeouts in residences/dwellings?

Q26. Presented is a list of reasons why some HVAC contractors may not fully comply with Title 24 requirements for HVAC installations. Using a scale of 1 to 10 where 1 means you "strongly disagree" and 10 means you "strongly agree", please rate your level of agreement with the following statements about why contractors may not comply with Title 24 requirements. Some contractors may not understand which Title 24 mandatory and prescriptive measures apply to their installations.

- Some contractors may not have enough technical experience to complete a quality installation.
- Some contractors may not have the right equipment to do a quality installation.
- Some contractors may not have the desire to do a quality installation.
- Some contractors may not have enough time to do a quality installation.
- Some contractors may not know how to repair the installation when it fails the HERS tests.

- Some contractors may not believe they need a HERS Rater to tell them if their installation is correct.
- Some contractors may not believe the HERS inspections are needed.
- Some contractors may work in local jurisdictions that enforce only some of the required test and verification requirements.
- Some contractors may not pull a permit if they think their installation will not comply with Title 24.

Q27. What aspects, if any, contribute to poor quality installations among installation contractors? (Check all that apply.)

- Most jobs go unpermitted
- Compliance requirements are too complex
- Compliance forms are difficult to locate
- Most contractors have never been taught the Title 24 regulations
- Contractors rely on HERS Raters to educate them
- Contractors rely on code officials to educate them
- Don't know
- Other (Specify)

Section 5. Contractor Barriers - To what extent are contractors aware of the current requirements for HERS tests and inspections in Title 24?

Q28_new. On a scale of 1 to 10 where 1 means "not at all knowledgeable" and 10 means "very knowledgeable", how knowledgeable would you say most HVAC installation contractors are with regard to the following: Difference in Title 24 prescriptive and mandatory compliance requirements by climate zones

- Difference in Title 24 prescriptive and mandatory compliance requirements for different types of installations. e.g. packaged unit vs. split systems
- Duct sealing requirements for new versus existing ducts
- Air flow and fan power index requirements
- Compliance form requirements for residential HVAC alterations
- Permit requirements for different types of installations

Q29. What are the most common knowledge gaps have you observed among HVAC installation contractors?

Q30. If you have any other comments to offer on the issue of barriers for HVAC contractors please describe here:

Section 6. Building Departments- This section addresses the consistency of building departments at enforcing Title 24 requirements for HVAC changeouts.

Q31. Do you typically perform your HERS inspection work within the jurisdiction of one building department or multiple building departments?

Pick one: One, several, never interact with building departments

Q32. About how many building departments do you interact with?

Pick one: 2, 3 to 5, 6 to 10, 11 to 15, 16 to 20, More than 20

Q33. For HVAC inspections, have you observed differences in the way different building departments carry out enforcement of the Title 24 requirements for HVAC alterations or, in your view, is enforcement fairly consistent across jurisdictions? Choose the response that aligns with your observations.

- The same across jurisdictions (0%)
- Differs slightly across jurisdictions (<15%) difference
- Differs somewhat across jurisdictions (15-25%) difference
- Differs significantly across jurisdictions (>25%) difference
- Don’t know

Q32. Choose the response that most often aligns with your observations for each of the following aspects regarding uniformity of code enforcement across jurisdictions.

For each question select one response: Always, Often, Sometimes, Rarely, Never, Don’t know

- Code enforcement from various jurisdictions do all the required inspections
- Code enforcement from various jurisdictions do an appropriate level of due diligence on inspections
- Code enforcement from various jurisdictions are precise in collecting all forms and data
- Code enforcement from various jurisdictions know what compliance requirements are required
- Code enforcement from various jurisdictions know what compliance forms are required
- Code enforcement from various jurisdictions treat all contractors equally
- Code enforcement from various jurisdictions follow up on open permits

Q35. Are there any best practices (or worst) that you have observed regarding building department enforcement of Title 24 HVAC alterations? Please describe.

Q36. If you have any other comments to offer on the issue of code enforcement by different building departments please describe here:

Section 7. Enforcement Officials - This section addresses consistent enforcement of Title 24 by different code enforcement officials within the same building department.

Q37. Thinking of the building department jurisdiction where you most often perform your work. Do you typically interact with just one code enforcement official or more than one?

- Never interact with code enforcement officials
- More than one

Q38. In the jurisdiction where you often work, about how many code enforcement officials do you typically interact with?

Pick one

- 2
- 3 to 5
- 6 to 10
- More than 10

Q39. Have you observed differences in the way individual code enforcement officials, within the same department, have enforced requirements for HVAC inspections, or is the enforcement fairly consistent from one inspector to another?

- Observed differences
- Have not observed differences [Skip to Q41]
- Don’t know

[Skip to Q41]

Q40. Choose the response that most often aligns with your observations for each of the following aspects regarding uniformity of code enforcement from one enforcement inspector to another within the same building department.
For each question select one response: Always, Often, Sometimes, Rarely, Never, Don't know

- All inspectors do all the required inspections
- All inspectors provide an appropriate level of due diligence on inspections
- All inspectors are precise in collecting all forms and data
- All inspectors know what compliance requirements are required
- All inspectors know what forms are required
- All inspectors treat all contractors equally
- All inspectors follow up on open permits

Q41. Are there any best practices (or worst) that you have observed among individual inspector's enforcement of Title 24 code for HVAC alterations?

Q42. If you have any other comments to offer on the issue of consistent enforcement of Title 24 by different officials within the same building department please describe here:

Section 8. Industry Regulation - This last section addresses regulation for HERS Raters and HERS Providers.

Q43. As you may know, the California Energy Commission regulates the building code, HERS Providers, and HERS Rater data collection requirements. On a scale of 1 to 10 where 1 means "do not agree at all" and 10 means "complete agree", please rate your level of agreement with the following statements regarding training and testing for HERS Raters.

- To be subject matter experts, HERS Rater courses need to provide more hands-on training for the visual inspection of measures.
- To be subject matter experts, HERS Rater courses need to provide more hands-on training for performing tests (duct leakage, blower door, fan power index, etc.)To be subject matter experts, HERS Rater courses need to provide more technical training of HVAC system operation.
- To be subject matter experts, HERS Rater courses need to provide more technical training of basic building knowledge.
- Field exams should be part of the course requirements.
- Establish minimum standardized requirements for HERS trainings.
- There should be better enforcement of HERS Rater tool calibration requirements to improve the accuracy of HERS test results.

Q44. What concerns, if any, do you have regarding regulations for trainings? Please describe what's going well and what needs to be improved.

Q45. On a scale of 1 to 10 where 1 means "do not agree at all" and 10 means "complete agree", please rate your level of agreement with the following statements regarding contractors and regulations.

- The quality of installations would improve if customers knew how often contractors' installations failed the HERS Rater inspections.

- Creating a contractor scoring system based on historic pass/fail test performance will promote contractors who perform quality installations.
- The conflict of interest regulation between HERS Raters and HVAC contractors needs better enforcement.
- A standardize fee schedule for HERS services would reduce the likelihood that customers would get over charged.
- Most HVAC jobs are installed without a permit and there is little a HERS Rater can do to change that.

Q46. What concerns do you have regarding HERS Rater and contractor regulations? Please describe what is going well and what needs to be improved.

Q47. On a scale of 1 to 10 where 1 means "do not agree at all" and 10 means "complete agree", please rate your level of agreement with the following statements regarding regulation of the HERS quality assurance/quality control (QA/QC).

- A screening process is necessary for individuals who perform QA/QC tests to ensure they are highly qualified to do the job.
- An independent entity is necessary to avoid conflicts of interest and improve reliability of QA/QC tests.
- The current QA/QC process is an effective way to hold HERS Raters accountable.
- The HERS Rater registries are well designed to serve the needs of HERS Raters.

Q48. What concerns do you have regarding HERS Rater QA/QC process and the HERS registries? Please describe what is going well and what needs to be improved.

Q49. This concludes our survey. If there are any last comments, please provide your input below.

Standard practices when compliance tests fail

The primary role of a HERS Rater is to perform diagnostic tests on newly installed HVAC units. The most common tests are described above in "Diagnostic Testing Procedures" Section 3.4.3.1 We designed the standard practice questions to identify when diagnostic tests fail:

- Would Raters re-test or apply alternate test methods: what are their practices?
- How well do Raters communicate these results to contractors, customers, and to the HERS Registry?

Raters with no experience with a one of the failed tests were excluded from the questions on standard practice.

Duct test practices

The first standard practice question was on duct testing. The question asks:

"Consider the [climate zone # 1-16] installation scenario: The duct leakage test does not pass the first test and the contractor attempts to repair it but still does not pass. In this situation, what other test(s), if any, would you perform as part of your standard practice?"

Raters were asked to consider what they would do in this duct leakage scenario. Figure 147. Tests Raters would perform in hypothetical scenario when the duct test fails (HERS Rater online survey, 2016) presents the range of responses for this multiple response question. In this scenario, all Raters would perform a smoke leakage test to demonstrate whether accessible leaks have been sealed. (This is an acceptable alternative to the total duct leakage test.) Raters accounting for only 17% of projects would perform an LTO test - another acceptable alternative - if the total leakage test failed, and Raters accounting for 4% of projects would never perform an LTO test at all. To measure LTO, Raters must perform a separate Blower Door Test; it's possible that few Raters are performing LTO tests because of the added expense of the additional equipment and because the size and weight of the equipment is rather burdensome to carry from job to job.

Figure 147. Tests Raters would perform in hypothetical scenario when the duct test fails (HERS Rater online survey, 2016)

Test	Percent of Respondents (n=49)
Smoke test	100%
Repeat total leakage test	29%
Leakage to the outside test	17%
Inspect the system with contractor	16%
Seal ducts	12%
Visual inspection	6%
Would not perform leakage to outside test	4%
Other	<1%

Note: These totals exceed 100% due to multiple responses. Percentages represent the proportion of projects the Raters account for, in each category.

The next question in the duct leakage series asks about frequency in which Raters perform test. Respondents were asked:

"When your residential HVAC inspections fail the duct leakage tests, how often do you perform the following (3) tests?" The survey presented them with five response options: always, often, sometimes, rarely, or never.

The results in Figure 148. Frequency with which Raters perform standard tests when duct tests fail (HERS Rater online survey, 2016) slightly contradict those presented above in the hypothetical scenario (Figure 147). Raters accounting for 87% of projects said they always or often repeat the total leakage test, in comparison to the Raters accounting for 100% of projects said that said they would perform that test as reflected in the above responses.

Figure 148. Frequency with which Raters perform standard tests when duct tests fail (HERS Rater online survey, 2016)

Test	Always / Often	Sometimes	Rarely / Never	Total
Repeat total leakage test	94%	5%	1%	100%
Perform smoke test	87%	11%	2%	100%
Perform leakage to the outside test	6%	13%	81%	100%

Percentages represent the proportion of projects the Raters account for, in each category.

Airflow and fan power index test practices

As described above, these two tests measure the volume of air moving through the system and the electrical power needed to push that volume of air. Failure to properly size the system (whether too large or too small) can lead to comfort issues, excessive power usage, and early burnout of equipment. These tests apply in all climate zones but only when there is a complete system changeout with new ducts or when 75% of the ducts have been replaced.

HERS Raters accounting for only 84% of projects overall claimed to have experience with HVAC alterations that did not pass the airflow and fan power index tests. Respondents with less than 5 years' experience in the field and fewer than 50 tests in a typical year were the least likely to experience these situations (accounting for 73% and 72% of projects, respectively).

After first screening out the respondents who had no experience with fan power index and airflow tests, the survey asked Raters:

"If an airflow test does not pass, what do you typically do?"

Figure 149 presents the range of responses on actions Raters take when airflow test fail. It's interesting to note there are few options for Raters beyond contacting the contractor (97% of projects) and repeating the tests (61% of projects). Additionally, we note while the Standards state a system must be properly sized there is no compliance form designed to capture and illustrate the results as such it is likely the contractors do not perform the calculations but rather perform rough estimates based on total house square footage.

Figure 149. Actions taken when airflow / fan power index tests fail (HERS Rater online survey, 2016)

Action	Percent of Respondents (n=41)
Contact the installation contractor	97%
Repeat test	61%
Perform static pressure test	11%
Check fan speed	4%
Other	5%

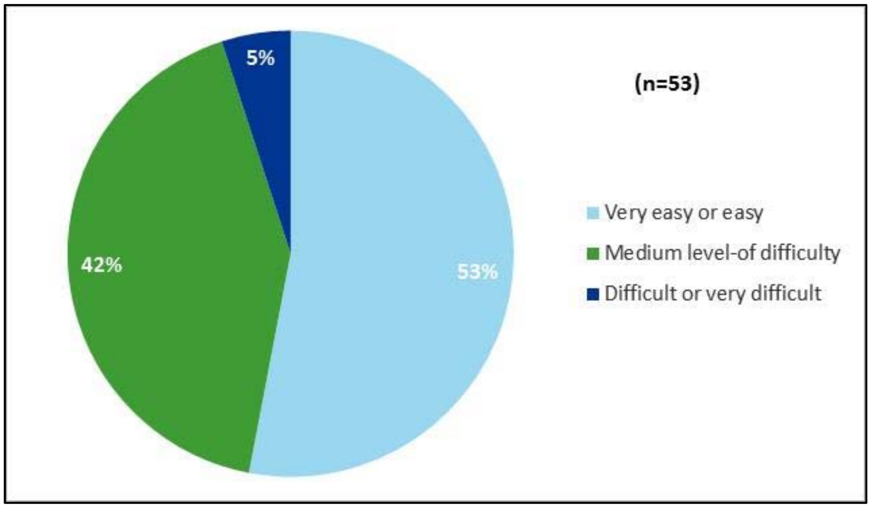
Note: These totals exceed 100% due to multiple responses. Percentages represent the proportion of projects the Raters account for, in each category.

Communication with contractors when tests fail HERS inspection

DNV GL conducted a small-scale pilot phase of the full-length survey. This process revealed that HERS Raters find it challenging to communicate failed test results to contractors. Challenges may exist because Raters are most often informed of job opportunities by the installing contractor, and a failed test may result in additional time and expense for the contractor, to get the job to comply. Conflicts of interest may result when test results are unfavorable to the contractor. To avoid the additional time and expense to get the job to comply, we hypothesize that unethical Raters may not actually perform all the required tests and some may not accurately report test results. Raters who accurately report failed tests run the risk of not being hired, or informed of future jobs, by the contractor when another HERS inspection is needed. HERS Raters may perceive a lack of tools to communicate test results to contractors as a barrier to the successful execution of their work. To address this barrier DNV GL developed questions to identify whether adequate communications tools do exist and/or whether additional tools would benefit HERS Raters.

First, we asked Raters if they give advice to contractors when the duct or airflow test fails, by in large Raters accounting for the majority of projects (96%) provide some level of advice. We then asked Raters to use a 5 point scale "1" means "very easy" and "5" means "very difficult," *how easy or difficult is it to convey failed test or verification measure results to installation contractors?* The results mostly agree with pilot test respondents that there are some barriers. As illustrated in Figure 150, Raters accounting for a slight majority of projects at 53% found it to be very easy or easy while the remaining 47% found some level of difficulty.

Figure 150. Ease in communicating failed test results to installing contractors (HERS Rater online survey, 2016)



Percentages represent the proportion of projects the Raters account for, in each category.

The current ways in which Rates convey test results are presented in Figure 151. For this multiple-choice question, the results show Raters most often call or email the installer. It is interesting to note that Raters accounting for 2% of projects contact the installer at their own company indicating the companies hire both installers and Raters. Surprisingly, Raters accounting for only 19% of projects are informing the end user and very few (6% of projects) submit the results these first set of results to the HERS Registry. Among the large majority of the Raters accounting for 30% of projects who stated "something else," many cited they are "trying to find the problem, then re-inspecting the system with the contractor, or check for obstructions, or repeat tests before communicating failed test results."

Figure 151. How Raters typically communicate failed test results to contractors (HERS Rater online survey, 2016)

Communication method	(n=52)
Telephone or email the installer that is with another company	73%
Inform the end user where the unit is installed	19%
Submit the "no pass" test on the compliance form	6%
Have installer present during inspection	6%
Inform the installer at my company	2%
Something else	30%

Note: These totals exceed 100% due to multiple responses. Percentages represent the proportion of projects the Raters account for, in each category.

Raters were presented with a list of communication tools that could help alleviate the challenges in conveying failed test results. Specifically, they were asked

> *"What communication tools, if any, would you like to have available to more effectively convey failed test results? (Check all that apply.)*

As previously reported, not all Raters agree that tools are needed; 19 of 52 respondents (representing 36% of projects inspected) indicated no tools were needed, while the majority (33 respondents, representing 62% of projects) would like to additional tools. Among those, the top interests were a mobile telephone application, a standardized form or template, a dedicated website to upload images and notes, and hands-on-training to communicate the results in a prescriptive manner (Figure 152).

Figure 152. Communication tools to more efectively convey failed test results (HERS Rater online survey, 2016)

Communication tool	Percent of Respondents (n=52)
No tools are needed	51%
Mobile telephone application	27%
Standardized form or template	24%
Dedicated website to upload images and notes	21%
Hands-on training	19%
Dedicated job call line	7%
Flowchart	5%
Other	9%

Note: These totals exceed 100% due to multiple responses. Percentages represent the proportion of projects the Raters account for, in each category.

Lastly, Raters were asked an open-ended question on whether they had any comments to offer on the issues of HVAC changeout inspections at residential homes. Raters accounting for more than half at 55% of projects had suggestions, and the post-coded range of responses is presented in Figure 153. The most commonly-cited response at was Raters ought to offer guidance to contractors to help improve the installation and contractors need to be better educated about HERS.

Figure 153. Comments on changeout inspection at residential homes (HERS Rater online survey, 2016)

Post-coded category	Percent of Respondents (n=29)
Raters offer guidance to contractors	46%
Contractors need to be more educated/trained about HERS	23%
Code enforcement is too low	7%
Permits not being pulled	6%
Homeowners need to be better educated about HERS	5%
Difficulties with existing registry	5%
Contractors struggle with refrigerant charge	4%
Contractors should have Title 24 certification	3%
Other	18%

Note: These totals exceed 100% due to multiple responses. Percentages represent the proportion of projects the Raters account for, in each category.

RESEARCH QUESTION 3: WHAT ARE THE KEY BARRIERS TO TITLE 24 COMPLIANCE AMONG HERS RATERS?

Research theory

The third research theory we investigated was whether there are barriers to Title 24 compliance among HERS Raters. We specifically investigated the potential barriers of the time and the expense involved with proper HERS testing.

Detailed findings

To investigate the key barriers to compliance, we asked respondents about a list of potential barriers, or reasons why some Raters may not fully comply with the Title 24 requirements. Respondents used a 10-point scale in which 10 indicated that the respondent "strongly agreed" that the item was a barrier and 1 indicated that they "strongly disagreed." We grouped the potential barriers into four categories: Rater preparedness, lack of enforcement, job security concerns, and other factors.

Figure 154 shows the mean rating across respondents and the ratings grouped into three categories: high agreement (ratings of 8 to 10); moderate agreement (ratings of 4 to 7); and low agreement (ratings of 1 to 3). We weighted survey responses up to the population of projects as described in Section 2.5, so the percentages represent the proportion of projects the Raters account for, in each category. In some cases, survey participants offered specific feedback on these issues through open-ended survey questions; we provide representative responses below, but more detail can be found in APPENDIX U.

First, in terms of Rater preparedness, respondents overwhelmingly agreed that some HERS Raters may not have enough technical experience to perform quality installations, with an average agreement rating of 8.9 on the ten-point scale. This was the strongest barrier identified, echoing the findings from theory one regarding a lack of field experience component in the training. HERS Raters accounting for approximately 46% of projects had additional comments in the online survey specifically regarding this issue, including:

- "Most of the HERS Raters when starting up… honestly need more in-the-field training. If you don't have a little bit of installing experience it can be tough to get answers from CalCERTS and especially USERA. Just recently I attended a CalCERTS class and had a newly certified HERS Rater with no field experience call me upwards of 10 times a day and is still doing so to get answers for simple field testing issues."
- "HERS Raters lack the training for specific brand[s] of equipment."
- "If [HERS Raters] don't have the technical ability to perform some of the testing, the ability to get training should be made much easier."

Many respondents also agreed that a lack of enforcement by local jurisdictions presented a barrier (average agreement rating of 8.1 out of 10). Specifically, some jurisdictions enforce only some of the required testing and verification, leading to Raters not complying with Title 24. HERS Raters accounting for approximately 25% of projects had additional comments in the online survey specifically regarding this issue, including:

- "The building department agency does not know exactly what forms/tests are required; therefore they are not requiring that the contractor have those specific tests done."
- "The biggest is the building departments… most of the time the building department doesn't ask, so I'm not going to waste money and time unless they call me on it. [It's] very common for the building departments to ignore [enforcement] so the contractor saves money."

- “Some report false results without testing at all. I have reported them as I have found them, and no action has been taken [by the local building departments]. So there are no repercussions.”

Respondents expressed moderately high levels of agreement with the ideas that some raters:

- Do not have the right equipment to perform all the required tests (average rating of 7.5)
- May not have the desire to perform quality inspections (average agreement rating of 7.1)
- May not understand which Title 24 measures apply to their jobs (6.6)
- Some HERS Raters may not correctly report all test results because of concerns regarding job security (6.5)

Agreement was relatively low with the idea that Raters may not perform all the required testing and verification if they think it will fail (average agreement rating of 3.6 out of 10) or that the time required to complete quality inspections is not a major barrier (average agreement of 3.1).

Figure 154. Level of agreement with potential barriers to Title 24 compliance among HERS Raters (HERS Rater online survey, 2016)

Potential Barrier	Agreement Rating* (n=52)				
	Mean	High (8 to 10)	Moderate (4 to 7)	Low (1 to 3)	Don't Know
Rater preparedness					
Raters may not have enough technical experience to perform a quality inspection	8.9	75%	10%	5%	10%
Raters may not have all the right equipment to perform all the required tests	7.5	59%	10%	19%	13%
Raters may not understand which Title 24 mandatory and prescriptive measures apply to their jobs	6.6	45%	16%	24%	15%
Lack of enforcement					
Raters may work in local jurisdictions that enforce only some of the required tests and verification requirements	8.1	54%	18%	6%	23%
Job security concerns					
Raters may not correctly report all the test results for job security	6.5	40%	13%	22%	25%
Raters may not perform all the required tests and verification requirements if they think they will fail	3.6	15%	14%	46%	26%
Other factors					
Raters may not have the desire to do a quality inspection	7.1	52%	19%	19%	11%
Raters may not have enough time to do a quality inspection	3.1	18%	10%	58%	14%

* Respondents used a 10-point scale where 1 means "strongly disagree" and 10 means "strongly agree." Percentages represent the proportion of projects the Raters account for, in each category.

In addition to asking HERS Raters to rate their level of agreement or disagreement with potential barriers, the online survey also provided respondents with the opportunity to voice any other comments they may have regarding barriers to HERS Raters in complying with Title 24 requirements. These responses provided further nuance regarding several of the issues addressed above and also included issues such as fraudulent Raters with cut-rate services not failing installations when a failure is appropriate, rating firm owners manipulating testing results to maintain business (related to the job security concerns described above), and low frequency of contractors obtaining the appropriate permits.

RESEARCH QUESTION 4: WHAT ARE THE KEY BARRIERS TO TITLE 24 COMPLIANCE AMONG CONTRACTORS?

Research theory

Similar to the previous theory about HERS Raters, we also investigated whether barriers to compliance with Title 24 requirements exist for HVAC contractors.

Detailed findings

To investigate HERS Raters' perspectives regarding the key barriers to compliance among contractors, we asked respondents to provide their level of agreement or disagreement with a list of potential barriers, or reasons why some contractors may not fully comply with the Title 24 requirements). Respondents used a 10-point scale in which 10 indicated "strongly agree" and 1 indicated "strongly disagree." We grouped these potential barriers into categories including systemic barriers, contractor shortcomings, and motivational barriers. Note that the survey included no open-ended questions with regard to this research question.

Figure 155 shows the mean rating across respondents and the ratings grouped into three categories: high agreement (ratings of 8 to10); moderate agreement (ratings of 4 to 7); and low agreement (ratings of 1 to 3). We weighted survey responses up to the population of projects as described in Section 2.5, so the percentages represent the proportion of projects the Raters account for, in each category. Results suggest that HERS Raters agreed that most of the potential barriers we laid out were in fact barriers to contractors complying with Title 24 requirements.

In terms of the systemic issues at play, HERS Raters agreed most strongly that there are barriers related to contractors not obtaining permits if they think their installations will not comply and local jurisdictions only enforcing some of the required testing and verification (average agreement ratings of 8.5 and 8.3 out of 10, respectively). However, much like the potential barriers for HERS Raters, respondents overall did not think that not having enough time to do quality installations was a barrier for HVAC contractors (average rating of 4.0).

Some of these barriers had to do with contractor shortcomings, such as not understanding which Title 24 measures apply to their installations and not knowing how to repair the installation if it fails HERS tests (ratings of 8.4 and 8.2, respectively). HERS Raters also exhibited fairly strong agreement that contractors lack the right equipment and/or that contractors lack the technical experience to complete a quality installation (average ratings of 7.1 for each).

Some of the potential motivational barriers to contractors also resonated with the HERS Rater respondents, such as the perception that contractor do not believe that they need a HERS Rater to tell them if their installation was done correctly and/or that contractors simply may not have the desire to perform a quality installation (agreement ratings of 8.4 and 8.0, respectively). HERS Raters' level of agreement with the idea that contractors do not believe that HERS inspections are needed was lower, averaging 5.9 out of 10.

Figure 155. HERS Raters' level of agreement or disagreement with barriers to Title 24 compliance among contractors (HERS Rater online survey, 2016)

Potential Barrier	Agreement Rating* (n=52)				
	Mean	High (8 to 10)	Moderate (4 to 7)	Low (1 to 3)	Don't Know
Systemic barriers					
Contractors may not pull a permit if they think their installation will not comply with Title 24	8.5	70%	12%	8%	11%
Contractors may work in local jurisdictions that enforce only some of the required test and verification requirements	8.3	72%	15%	12%	1%
Contractors may not have enough time to do a quality installation	4.0	26%	15%	53%	6%
Contractor shortcomings					
Contractors may not understand which Title 24 mandatory and prescriptive measures apply to their installations	8.4	78%	11%	11%	-
Contractors may not know how to repair the installation when it fails the HERS tests	8.2	71%	23%	6%	-
Contractors may not have the right equipment to do a quality installation	7.1	48%	18%	20%	15%
Contractors may not have enough technical experience to complete a quality installation	7.1	55%	27%	18%	-
Motivational barriers					
Contractors may not believe they need a HERS Rater to tell them if their installation is correct	8.4	77%	12%	10%	2%
Contractors may not have the desire to do a quality installation	8.0	68%	19%	13%	-
Contractors may not believe the HERS inspections are needed	5.9	45%	18%	37%	-

* Respondents used a 10-point scale where 1 means "strongly disagree" and 10 means "strongly agree." Percentages represent the proportion of projects the Raters account for, in each category.

RESEARCH QUESTION 5: TO WHAT EXTENT ARE CONTRACTORS AWARE OF THE CURRENT REQUIREMENTS FOR HERS TESTS AND INSPECTIONS IN TITLE 24?

Research theory

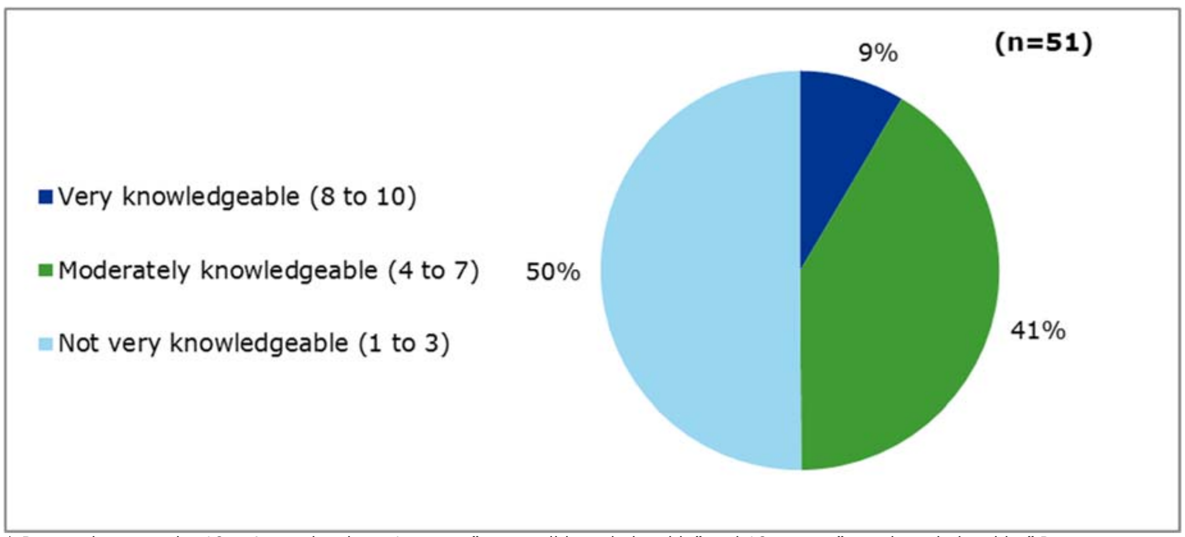
The fifth theory we investigated was HERS Rater perspectives on whether HVAC contractors find it difficult to keep up with changes to Title 24—if so, they may not be aware of the current requirements for HERS tests and inspections. If true, this could lead to poor quality inspections. Currently in the state of California there are 11,433 licensed contractors with a C-20 license.

Detailed findings

Contractor knowledge of Title 24

First, we asked the respondents to provide their perspectives regarding HVAC contractors' general knowledge regarding the 2013 residential code requirements for HVAC changeouts. Respondents used a 10-point scale in which 10 indicated "very knowledgeable" and 1 indicated "not at all knowledgeable." As Figure 156 shows, respondents accounting for half of all projects rated HVAC contractor knowledge as low (ratings of 3 or lower) and Raters accounting for only 9% of projects rated contractor knowledge as high (ratings of 8 or higher). The average rating was 3.9, and no respondents gave a response of 10 ("very knowledgeable"). We weighted survey responses up to the population of projects as described in Section 2.5, so the percentages represent the proportion of projects the Raters account for, in each category.

Figure 156. HERS Rater perspectives on HVAC contractors knowledge regarding 2013 residential code requirements for HVAC changeouts* (HERS Rater online survey, 2016)



* Respondents used a 10-point scale where 1 means "not at all knowledgeable" and 10 means "very knowledgeable." Percentages represent the proportion of projects the Raters account for, in each category.

We then asked the respondents for their perspectives regarding HVAC contractor knowledge regarding six specific Title 24 requirements, including:

- Permit requirements for different types of installations
- Duct sealing requirements for new versus existing ducts
- Air flow and fan power index requirements
- Compliance form requirements for residential HVAC alterations

- o Difference in Title 24 prescriptive and mandatory compliance requirements for different types of installations (e.g., packaged unit versus split systems)
- o Difference in Title 24 prescriptive and mandatory compliance requirements by climate zones

As in the last question, respondents used a 10-point scale in which 10 indicated "very knowledgeable" and 1 indicated "not at all knowledgeable." Figure 157 shows the mean rating across respondents and the ratings grouped into three categories: highly knowledgeable (ratings of 8 to10); moderately knowledgeable (ratings of 4 to 7); and low knowledge (ratings of 1 to 3).

Overall, respondents were pessimistic about HVAC contractors' knowledge of Title 24 requirements. Each of the 6 specific Title 24 requirements received average scores lower than 5 on the 10-point knowledge level scale described above. The highest-rated aspects, permit requirements for different types of installations and duct sealing requirements for new versus existing ducts, only received averages of 4.8 and 4.2 on the 10-point scale, respectively. Respondents accounting for just six percent or fewer of projects said that HVAC contractors were knowledgeable (8 or higher) with airflow and fan power index requirements, compliance form requirements, and difference in Title 24 prescriptive and mandatory requirements for different types of installations and across climate zones.

Figure 157. HERS Rater perspectives on HVAC contractor knowledge regarding specific Title 24 requirements (HERS Rater online survey, 2016)

Element of Title 24	Knowledge Rating* (n=50)				
	Mean	High (8 to 10)	Moderate (4 to 7)	Low (1 to 3)	Don't Know
Permit requirements for different types of installations	4.8	28%	16%	43%	13%
Duct sealing requirements for new versus existing ducts	4.2	16%	38%	46%	-
Air flow and fan power index requirements	3.3	5%	47%	49%	<1%
Compliance form requirements for residential HVAC alterations	3.3	6%	37%	57%	-
Difference in Title 24 prescriptive and mandatory compliance requirements for different types of installations. e.g. packaged unit vs. split systems	3.0	5%	32%	61%	1%
Difference in Title 24 prescriptive and mandatory compliance requirements by climate zones	3.0	3%	30%	67%	1%

* Respondents used a 10-point scale where 1 means "not at all knowledgeable" and 10 means "very knowledgeable." Percentages represent the proportion of projects the Raters account for, in each category.

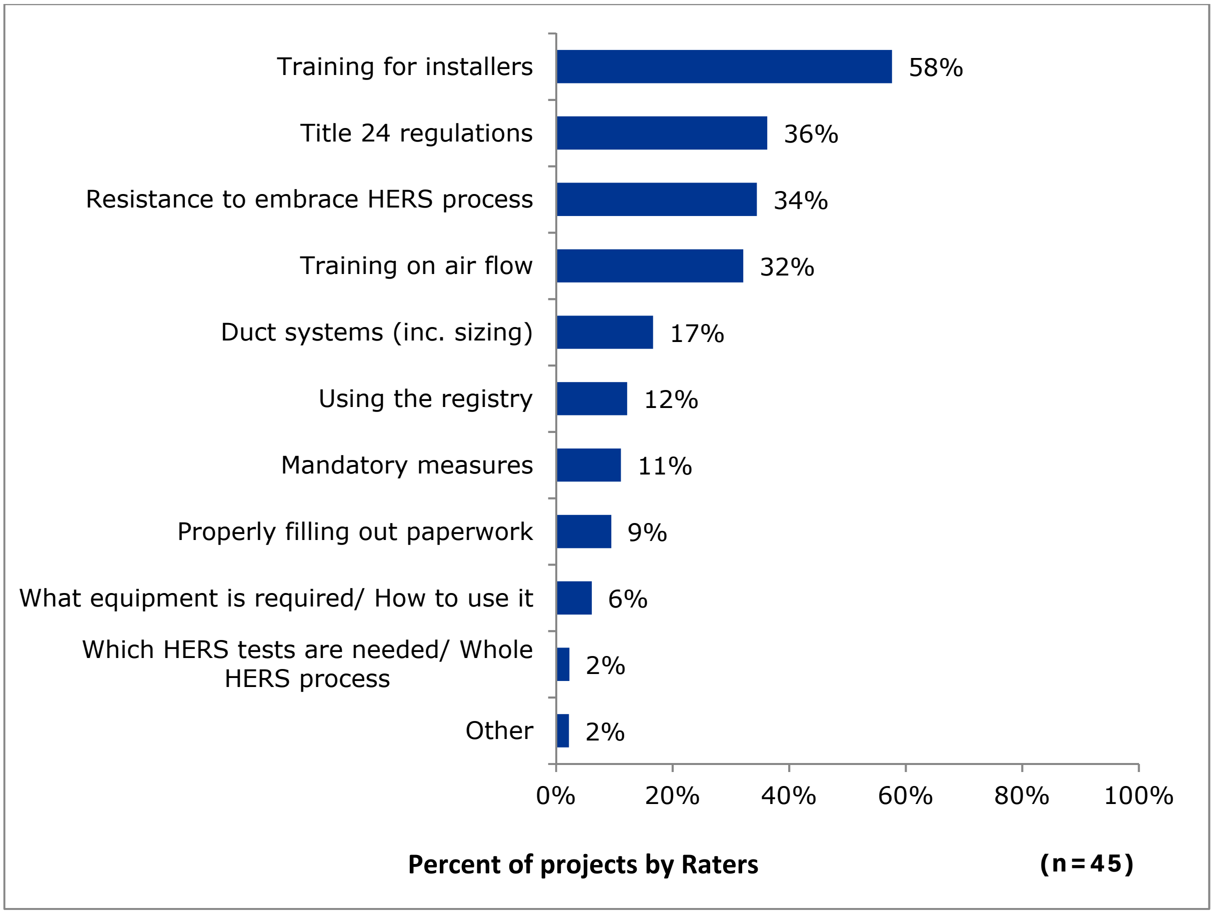
Continuing in the same vein, we asked respondents an open-ended question: what are the most common knowledge gaps you have observed among HVAC installation contractors? When we grouped these responses, the prevalent gaps were:

- o Lack of training for this group (accounting for 58% of projects)
- o Lack of knowledge regarding Title 24 in general (36%)

- o Contractor resistance to embrace the HERS process (34%).

In terms of specific knowledge gaps, respondents most frequently cited training on airflow (accounting for 32% of projects), duct systems (17%), and using the Registry (12%). Figure 158 provides further detail below, and APPENDIX U provides verbatim survey responses.

Figure 158. HERS Raters' perspectives regarding gaps in HVAC contractor knowledge of Title 24 (HERS Rater online survey, 2016)



Note: The percentages in the figure reflect the percentage among those giving a response. These totals exceed 100% due to multiple responses. Percentages represent the proportion of projects the Raters account for, in each category.

While there were few statistically significant differences in responses based on respondent group, we did find that a higher proportion of Raters with more than five years of experience suggested that contractors have resisted HERS process (accounting for 57% of projects versus 9%). One theory for the difference by years of experience, is contractors may becoming less resistant to the HERS process now that the majority of installations requires a HERS inspection. Additionally, Raters who worked primarily in coastal climate zones were significantly more likely than those working mainly inland to say that duct systems were a knowledge gap for HVAC contractors (accounting for 67% projects versus 12%). One theory for this difference by climate zone, is contractors performing work in coastal zones haven't been required to perform duct testing on all ducted system until the recent Title 24 2013 code change came into effect on July 1, 2014 and this contributes to poor-quality installations in those regions.

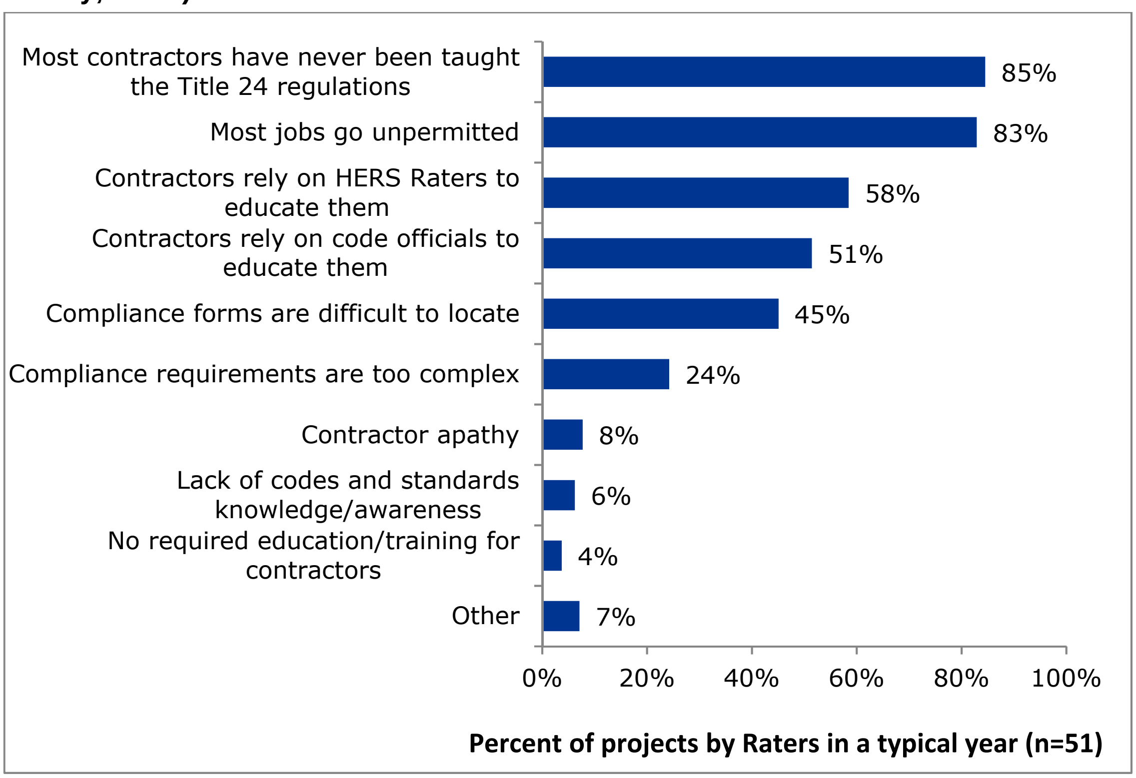
Research question five suggests that a lack of contractor knowledge regarding Title 24 requirements could lead to poor-quality installations. In the online survey, we asked Raters to indicate whether any one or more of the following six issues contribute to poor quality installations among installation contractors:

- Most jobs go unpermitted
- Compliance requirements are too complex
- Compliance forms are difficult to locate
- Most contractors have never been taught the Title 24 regulations
- Contractors rely on HERS Raters to educate them
- Contractors rely on code officials to educate them

We also allowed respondents to fill in their own answers (which included contractor apathy, lack of contractor knowledge/awareness of codes and standards, no required education/training for contractors, and a handful of other responses).

Figure 159 shows that most HERS Raters agreed that the fact that most contractors never having been taught the Title 24 regulations contributed to poor-quality installations (accounting for 85% of projects). A similar proportion said that most jobs going unpermitted led to poor-quality installations (83%). On the contrary, Raters accounting for just 24% of projects suggested that complex compliance requirements contributed to poor-quality installations.

Figure 159. Contributors to poor quality installations among contractors (HERS Rater online survey, 2016)



Note: These totals exceed 100% due to multiple responses. Percentages represent the proportion of projects the Raters account for, in each category.

One interesting finding was that significantly higher proportions of Raters with more than 150 residential HVAC alteration inspection jobs in 2015 (who are able to base their assessments on many data points) than those with fewer jobs cited that most contractors have never been taught the Title 24 regulations, that most jobs are/were going unpermitted, and/or that contractors rely on code officials to educate them.

As noted above, HERS Raters noted a lack of contractor training as strong factor contributing to poor-quality installations. A dozen respondents provided specific feedback on this issue, including:

- "Continuing education for all contractors. Mandatory!"
- "They should have Registry training. They don't know what to do when they get on the CalCERTS or USERA registry."
- "The real issue is education. I am preparing presentations to take to the distributors of HVAC systems of present and past tests to show them, step by step, what we are looking for."
- "Code changes need to be better explained and several different ways to get the message across. Special inexpensive training seminars targeted to the contractor. Perhaps have an online open book exam for new changes, which require contractors to watch a training video, prior to answering exam questions."

Other open-ended comments were scattered among various topics; Figure 160. Number of jurisdictions with which HERS Raters work (HERS Rater online survey, 2016) in APPENDIX U provides more detail.

RESEARCH QUESTION 6: HOW CONSISTENTLY DO LOCAL BUILDING DEPARTMENTS ENFORCE TITLE 24 REQUIREMENTS THROUGHOUT THE STATE?

Research theory

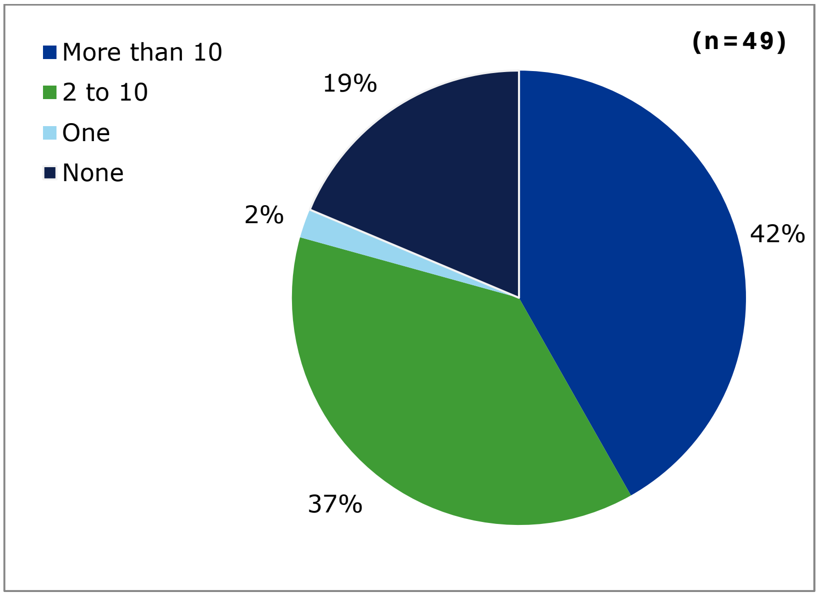
While Standards applies across every jurisdiction in California, compliance requirements may be enforced inconsistently across different building departments; this could be in part to the fact that the requirements vary by climate zone and the lack of uniformity results in misinterpretation of the code. In theory, this could cause confusion among contractors that operate within the jurisdiction of multiple building departments and/or lead to contractors only adhering to the aspects of the code that are enforced most strongly across the majority of building departments. Question 6 investigates the consistency with which local building departments enforce Title 24 requirements throughout the state.

Detailed findings

HERS Raters accounting for 79% of projects said they work with more than one building department, with Raters accounting for 42% of projects saying they work with more than 10 building departments (Figure 63). We believed these respondents would have a good perspective regarding the potential inconsistencies in code enforcement across local jurisdictions, and thus focused the remaining questions on this topic to these 41 respondents.

One interesting finding from the online survey is that HERS Raters accounting for about one-fifth of the projects said that they do not deal with any building departments directly. The likely explanation is that, in those situations, the contractor has all of the interaction with building officials.

Figure 160. Number of jurisdictions with which HERS Raters work (HERS Rater online survey, 2016)



Percentages represent the proportion of projects the Raters account for, in each category.

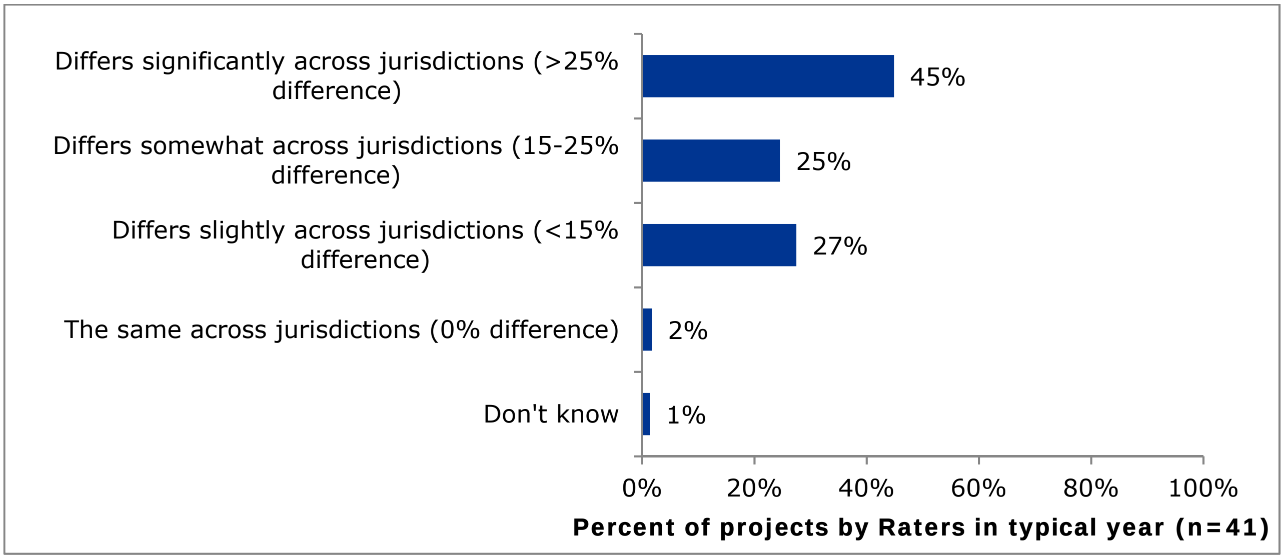
Consistency across building departments

We asked the 41 respondents who reported that they work with more than one building department whether they have observed differences in the way different building departments carry out enforcement of the Title 24 requirements for HVAC alterations or if enforcement was fairly consistent across jurisdictions. Respondents could choose among four options:

- The same across jurisdictions (0%)
- Differs slightly across jurisdictions (<15% difference)
- Differs somewhat across jurisdictions (15-25% difference)
- Differs significantly across jurisdictions (>25% difference)

Raters accounting for almost half of projects said that jurisdictions differ significantly (>25% difference; 45%), and Raters accounting for another 25% of projects said that jurisdictions differ somewhat (15-25% difference; see Figure 64). Raters accounting for just 2% of projects said that enforcement is the same across jurisdictions.

Figure 161. HERS Rater perspectives on the extent to which jurisdictions differ in their enforcement of Title 24 requirements for HVAC alterations (HERS Rater online survey, 2016)

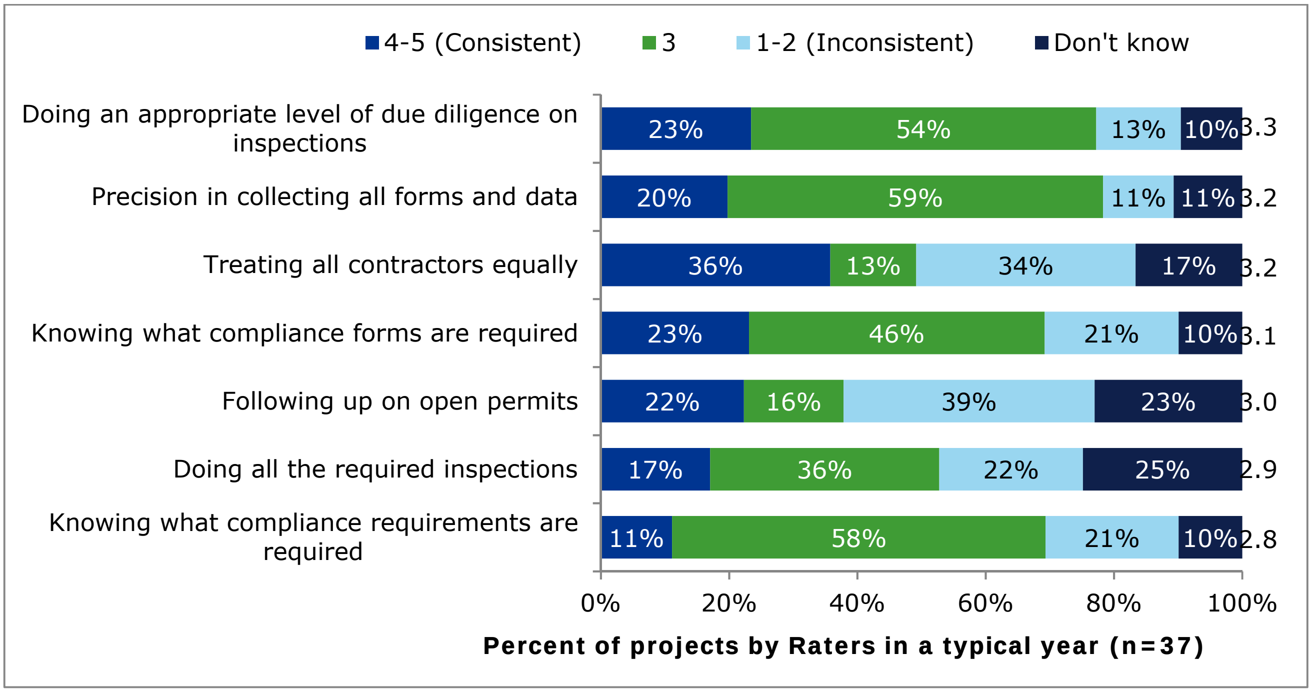


Percentages represent the proportion of projects the Raters account for, in each category.

In addition to the overall assessment described above, we also asked HERS Raters how consistently they thought the different building departments enforced seven specific elements of the Title 24 code for HVAC alterations. Respondents used a five-point scale where 5 meant "always consistent" and a 1 meant "never consistent." Figure 65 shows the results arranged from most to least consistent.

Respondents accounting for over one-third of projects stated that enforcement is rarely or never consistent in terms of following up on open permits and treating all contractors equally (39% and 34% of projects, respectively). The latter was a polarizing statement, however, with a roughly equal proportion stating building departments are often or always consistent in treating contractors fairly (accounting for 36% of projects). Raters representing less than one-fourth of the projects indicated a high level of consistency in enforcement for all of the remaining statements. One especially troubling result was that Raters accounting for over half of projects (58%) said that the foundational aspect of knowing what is required for compliance is only "sometimes" consistent.

Figure 162. Consistency of code enforcement across jurisdictions (HERS Rater online survey, 2016)



PERCENTAGES REPRESENT THE PROPORTION OF PROJECTS THE RATERS ACCOUNT FOR, IN EACH CATEGORY.

RESEARCH QUESTION 7: HOW CONSISTENTLY ARE TITLE 24 REQUIREMENTS ENFORCED BY DIFFERENT OFFICIALS WITHIN A LOCAL BUILDING DEPARTMENT?

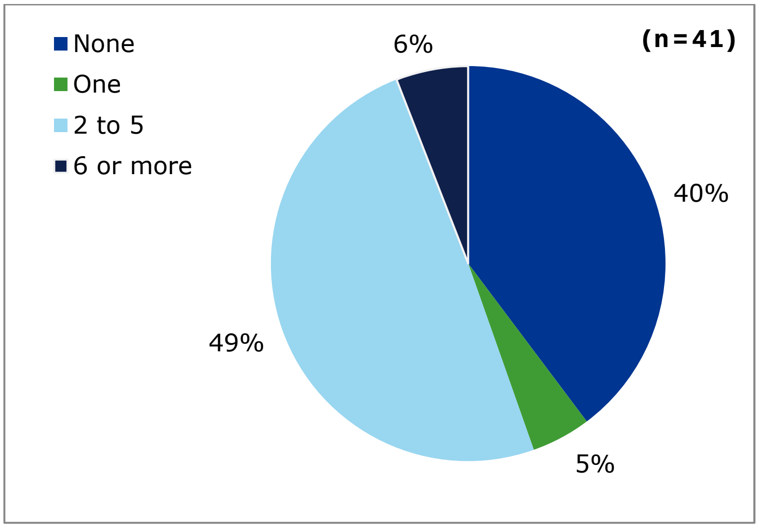
Research theory

While there may be inconsistency across building departments, different officials within a single local building department may also enforce the HVAC compliance requirements inconsistently. This could also cause confusion among contractors and lead them to adhere only to the aspects of the code that particular building officials enforce most strongly. We thus explored the consistency with which different officials within a local building department enforce Title 24.

Detailed findings

To identify HERS Raters who could provide perspectives on the consistency with which different officials within a local building department enforce Title 24, we first asked respondents to identify the number of officials with whom they work within the building department at the jurisdiction in which they most often work. As Figure 66 shows, Raters accounting for more than half of projects reported that they worked with 2 or more building officials within the same building department (55% of projects). The vast majority said they worked with between 2 and 5 officials (49% of projects). The figure also shows that respondents accounting for 40% of projects said they do not interact with code enforcement officials, likely because contractors have all the interactions with code officials in those circumstances. As illustrated in Volume I of the main report in the flow diagram of the permit and compliance process, HERS Raters only need to upload compliance forms to the HERS Registry they do not necessarily have a role to interact with building departments.

Figure 163. Number of building officials HERS Raters work with at one building department (HERS Rater online survey, 2016)



Percentages represent the proportion of projects the Raters account for, in each category.

Consistency within building departments

Among the 23 HERS Raters who reported that they interacted with multiple code enforcement officials within the same building department, roughly two-thirds reported that they observed differences in the way that individual code enforcement officials enforced requirements for HVAC inspections (16 respondents), six reported that they had not observed any differences, and one was unsure.

Just as we compared consistency among code enforcement officials across jurisdictions regarding seven specific elements of the code, we performed the same comparison within building departments. Respondents again used a five-point scale ranging from "always" (a rating of 5) to "never" (1). Sample sizes are fairly small, and as such, results suggest more variation than in the discussion comparing building departments (above). Nonetheless, roughly two-thirds of respondents stated that two aspects of permitting are rarely or never consistent across code enforcement officials within the same building department: following up on open permits and treating all contractors equally. Note that these two aspects also had the highest "rarely/never consistent" ratings when discussing consistency across building departments as well.

RESEARCH QUESTION 8: IS THERE ADEQUATE REGULATION FOR HERS RATERS AND PROVIDERS?

Research theory

The eighth and final theory we investigated was whether additional targeted regulation would improve the HERS Rater services and lead to better quality installations. As such, we explored HERS Raters' perspectives regarding whether there is adequate regulation for HERS Raters and Providers.

Detailed findings

For each of the three categories of regulations described above—regulations for HERS Rater training and testing, regulations for contractors, and regulations as they relate to the QA/QC process—the online survey asked HERS Raters to identify the extent to which they agreed or disagreed with various statements regarding the training. These included statements such as, "field exams should be part of the course requirements" and "the conflict of interest regulation between HERS Raters and HVAC contractors needs better enforcement." For each of these questions, respondents used a 10-point scale where a rating of 10 indicated that the respondent "strongly agreed" with the statement and 1 indicated that they "strongly disagreed." In the sections below, we show the mean rating across respondents and also group the ratings into three categories: high agreement (ratings of 8 to10); moderate agreement (ratings of 4 to 7); and low agreement (ratings of 1 to 3). We weighted survey responses up to the population of projects as described in Section 2.5, so the percentages represent the proportion of projects the Raters account for, in each category.

Regulations and HERS Rater training

The online survey asked two groups of questions regarding HERS Rater training: the first focused on possible improvements to HERS training and testing and the second focused on the specific items on which courses would need to focus to generate expertise among Raters. Echoing the findings from Question 1 regarding deficiencies in training, respondents largely agreed that field exams should be part of the training requirements for HERS Raters (average rating of 8.9 out of 10), as shown in Figure 164 HERS Raters provided similar ratings for the concept that minimum standardized requirements for HERS trainings should be established (8.7). Raters accounting for over three-fourths of projects, showing high levels of agreement with these statements, suggesting that exams and minimum standards for training are at least part of the solution from HERS Raters' perspectives.

Figure 164. HERS Rater agreement with statements regarding training and testing for HERS Raters (HERS Rater online survey, 2016)

Training / Testing Element	Agreement Rating* (n=49)				
	Mean	High (8 to 10)	Moderate (4 to 7)	Low (1 to 3)	Don't Know
Suggested improvements to HERS training and testing					
Field exams should be part of the course requirements.	8.9	76%	21%	2%	-
Establish minimum standardized requirements for HERS trainings.	8.7	75%	21%	2%	2%
There should be better enforcement of HERS Rater tool calibration requirements to improve the accuracy of HERS test results.	6.0	37%	30%	34%	<1%
To be subject matter experts, HERS Rater courses need to provide…					
More hands-on training for the visual inspection of measures.	6.8	37%	51%	13%	-
More technical training of HVAC system operation.	6.7	36%	44%	19%	-
More hands-on training for performing tests (duct leakage, blower door, fan power index, etc.)	6.6	40%	42%	19%	-
More technical training of basic building knowledge.	6.3	32%	49%	19%	-

* Respondents used a 10-point scale where 1 means "strongly disagree" and 10 means "strongly agree." Percentages represent the proportion of projects the Raters account for, in each category.

Thirty-one survey respondents provided specific feedback in response to an open-ended question regarding how regulations might improve the training. Approximately half of these suggested improvements, enhancements, or changes to HERS Rater training, including:

- "Raters need additional training outside of HERS Providers. Perhaps have a continued education requirement."
- "Online training videos would be great of each testing procedure."
- "Field test training should only be required for new Raters versus update classes. If new tests are required through a code change, all Raters should have hands-on training on new equipment."
- "Raters need additional training, NCI, BPI, or Nate certifications."

Other responses were scattered across topics in APPENDIX U provides more detail.

Regulations and contractors

Most observers of the industry generally agree that the majority of residential HVAC jobs are installed without a permit. The respondents here overwhelmingly agreed with this sentiment, with Raters accounting for 85% of projects assigning a rating of 8 or higher on the 10-point scale (Figure 165). However, Raters also agreed that steps could be taken to improve this situation. Improved transparency in terms of customers knowing how often contractors' installations fail HERS inspections (8.1) and a contractor scoring system based on historic pass/fail test performance (7.7) were both supported by the majority of respondents. This could take the form of a Yelp® like reviewer rating system in which customers could compare contractors on these metrics. Additionally, better enforcement of conflict of interest regulation (7.6) was also supported by most respondents.

One possible remedy, however, was not well-received. Respondents accounting for just 9% of projects agreed (8 or higher) that a standardized fee schedule for HERS services would reduce the likelihood that customers would get overcharged. HERS Raters prefer the current, more free-market, system in which Raters decide how much they charge for their services. This was true even as several open-ended comments throughout the survey indicated that some feel cheated when other Raters perform the work for a much lower price than they would charge and suspect that those Raters do not follow the correct protocols. The survey presented several fee schedules, for the research theory two; the results show relatively consistent fee rates with 66% charging $350 or less and 33% charging between $350-500 for the mock changeout presented.

Figure 165. HERS Rater agreement with statements regarding regulations and contractors (HERS Rater online survey, 2016)

Statement	Agreement Rating* (n=49)				
	Mean	High (8 to 10)	Moderate (4 to 7)	Low (1 to 3)	Don't Know
Most HVAC jobs are installed without a permit and there is little a HERS Rater can do to change that.	8.9	85%	2%	11%	2%
The quality of installations would improve if customers knew how often contractors' installations failed the HERS Rater inspections.	8.1	73%	12%	15%	-
Creating a contractor scoring system based on historic pass/fail test performance will promote contractors who perform quality installations.	7.7	65%	15%	20%	<1%
The conflict of interest regulation between HERS Raters and HVAC contractors needs better enforcement.	7.6	61%	19%	20%	<1%
A standardized fee schedule for HERS services would reduce the likelihood that customers would get over charged.	2.7	9%	18%	68%	5%

* Respondents used a 10-point scale where 1 means "strongly disagree" and 10 means "strongly agree." Percentages represent the proportion of projects the Raters account for, in each category.

We also gave the respondents an opportunity for additional comments regarding regulations and contractors. Of the 34 respondents who provided comment, more than half related to addressing the conflict of interest between HERS Raters and HVAC contractors. For example:

- "HERS Rater firms should not provide a permit obtaining service. Since when is it OK for 3rd party independent inspectors to provide other services to the contractors they are testing? If this is allowed it will open up a host of other services that are not HERS related."

- "Having payment through the homeowner rather than the contractor would definitely be more … non-biased."
- "Some HERS rating companies are obtaining permits for contractors, which should be done by the installing contractors. I believe that obtaining a permit makes you an authorized representative of the installing contractor. Therefore, there is now a conflict of interest between that HERS Rater and the contractor. CalCERTS turns a blind eye to this fact ..."
- "Conflict of interest needs a clearer definition, i.e., can Raters pull permits for a contractor, etc.?"

Other specific comments addressed improvements to permit enforcement, training for installers, and other topics. APPENDIX U provides more detail.

Regulations of HERS quality assurance/quality control

Overall, respondents thought the current QA/QC process was an effective way to hold HERS Raters accountable (8.8), as presented in Figure 166. However, they also agreed that a screening process to ensure that these individuals are highly qualified to do the job (8.7). They did not agree that an independent entity is necessary to avoid conflicts of interest and improve the reliability of QA/QC tests (4.6). The implication here is that, while Raters are generally satisfied with the process and would not like an independent entity to perform the QA/QC, they would be in favor of a more rigorous, and perhaps transparent, vetting process for the individuals checking their work.

Figure 166. HERS Rater agreement with statements regarding regulation of the HERS QA/QC (HERS Rater online survey, 2016)

Regulation of the HERS QA/QC Process	Agreement Rating* (n=49)				
	Mean	High (8-10)	Moderate (4 to 7)	Low (1 to 3)	Don't Know
The current QA/QC process is an effective way to hold HERS Raters accountable.	8.8	76%	23%	1%	1%
A screening process is necessary for individuals who perform QA/QC tests to ensure they are highly qualified to do the job.	8.7	76%	20%	2%	1%
The HERS Rater Registries are well designed to serve the needs of HERS Raters.	6.6	36%	46%	18%	<1%
An independent entity is necessary to avoid conflicts of interest and improve reliability of QA/QC tests.	4.6	31%	24%	43%	2%

* Respondents used a 10-point scale where 1 means "strongly disagree" and 10 means "strongly agree." Percentages represent the proportion of projects the Raters account for, in each category.

We also found mixed agreement that the Registries are well-designed to serve the needs of HERS Raters. Several open-ended comments throughout the survey mentioned that, at least from their perspective, the Registries seemed to be designed for the benefit of the Registries and not the Raters in terms of its setup and ease of use.

We again asked survey respondents to offer any additional comments regarding regulations and the HERS QA/QC process, and 30 respondents did so. Of these, more than half offered suggested reforms to the process, including:

- "QA/QC should be more frequent, due to the lack of knowledge and training current Raters have."
- "With the QA I would like to see actual results from the QA company/Dept. and not just a 'you passed or you failed'."
- "Sometimes I wonder if it would work out better if the QA/QC Inspector actually accompanied us on a 'current' job to watch our process of inspections while we are conducting them."

Other specific comments addressed communication issues, transparency, and other topics. APPENDIX U provides more detail.

APPENDIX X. RECOMMENDATIONS

Recommendations in standard format (IESR)

Study Type	Study Title	Study Manager
Market	Draft Report: 2014-16 HVAC Permit and Code Compliance Market Assessment (Work Order 6) Volume 1-Report	CPUC, Energy Division

No.	Program or database	Summary of findings	Add'l Supp ort Info.	Best Practice / Recommendation	Rec. Recipient	Affected work-paper or DEER
1	N/A	**Permitting rates are low**, with permits pulled for less than one-third of all change-outs that require them. Our estimates ranged from 8% to 29%.	Ch. 3 & 4	Evaluate current residential pilot programs that aim to increase permit rates in light of this study's findings and current regulations aimed at addressing permitting within energy efficiency programs (e.g., SB1414).	IOU's	N/A
2	N/A	See above	Ch. 3 & 4	Inform homeowners that the permitting responsibility is theirs and that they must hold contractors accountable.	IOUs and Building Departments	
3	N/A	See above	Ch. 3 & 4	Have program contractors emphasize other potential benefits of permitted installations for customers, and consider literature for homeowners that does the same. Given that the Standards already dictate permits for IOU program participants, programs that incentivize system efficiency improvements (such as Home Upgrade or Quality Installation) should	IOU's	N/A

				raise permitting rates to some degree.		
4	N/A	**Under current market and enforcement conditions, permitting does not lead to increased energy-efficiency** of HVAC changeouts, as we found similar levels of efficiency for equipment at permitted and non-permitted sites in a representative statewide sample.	Ch. 5	Leverage local government partnerships and non-IOU program administrators where feasible. Community Choice Aggregators (CCAs) and Regional Energy Networks (RENs) can administer energy efficiency programs under the same guidelines and funding mechanisms as the IOUs. However, these local program administrators could work directly with the building departments in their regions to improve their enforcement processes over multiple years. Because of the large number of building departments in each IOU's service territory, it may be less feasible for the IOUs to work directly with the building departments.	IOU's	N/A
5	N/A	See above	Ch. 5	Based on findings from the HERS interviews, we recommend the IOUs continue to support workforce education and training (WET). Studies from the early 2000s identified a number of issues related to HVAC changeouts. The 2005 update to the Standards addressed these issues. We also know the IOUs have supported WET during the same timeframe. As an example, the Standards require temperature measurement access, and we found this at over 80% of non-	IOU's	N/A

				permitted installations. This would indicate installer knowledge of some aspects of the Standards. We believe that in the current market these IOU and CEC trainings affect contractors that perform both permitted and non-permitted installations. Future studies on permit rates and compliance should account for any changes in WET efforts as they may affect installation quality regardless of permit status.		
6	TBD	See above	Ch. 5	Leverage this study's performance test results to support workpaper inputs for measures addressed in the Home Upgrade and Quality Installation programs. This includes information regarding cases in which code requirements are not triggered, such as equipment-only replacements or system airflow in certain climate zones. The appendices of this report (Volume II) include summaries of data collected at sites that go beyond the analysis of compliance and energy efficiency associated with compliance. There are specific opportunities where code is not triggered based on	IOUs	Home Upgrade and RQI workpapers

				installation scope and some limited opportunities for improvement above code where code is triggered. While we did not find statistically significant differences based on permit status, current practice (permitted or not) on average does not meet full compliance.		
7	N/A	See above	Ch. 5	Continued collaboration between the California Energy Commission (CEC) and CPUC is essential to continue improving the energy efficiency of HVAC installations in California. This could take the form of simultaneous improvement in permitting and enforcement processes, improvement in efficacy of the inspections process, or through other means.	CPUC and CEC	N/A
8	N/A	See above	Ch. 5	The CEC and CPUC should consider developing energy modeling software or approaches for existing residential buildings to estimate the energy saving potential for changeouts in single family residential dwellings. The California Technical Forum may be a venue for this collaboration since it includes the IOUs and the largest publicly-owned utilities in California. The absence of a functioning model prevents stakeholders from making realistic predictions about the impacts associated with the required set of compliance measures. The absence of such a model also necessitated the	CEC, CPUC, IOUs, and POUs	N/A

				creation of metrics by this study using secondary information. We recommend the model include features such as a cost calculator to factor average costs estimates for permit and compliance requirements including HERS certification.		
9	N/A	See above	Ch. 5	Reevaluate, from an energy efficiency perspective, codes that, effectively, provide no energy impacts or verification benefits. This includes requiring calculations be performed for sizing, but there is no requirement to reduce size whenever possible. Consider new cost calculations that explicitly show non-energy cost savings or extended equipment life to improve the value proposition.	CEC	N/A
10	N/A	There were documentation gaps for permitted installations. We found 3/4th of permitted installations had the HERS compliance forms. Among the forms submitted, only a subset contained a complete set of the required tests.	Ch. 6	CEC and HERS Registries should take action to ensure public access to information collected by HERS Raters for the benefit of homeowners. The documentation required in the HERS process includes measurements of home performance, but these documents are not required to be provided to the homeowner or to the building department for later access. Streamlined access could be achieved by mandating building	CEC	N/A

				departments retain the compliance forms or by the CEC retaining the forms or by Registries responding to requests for information. Information regarding a current or prospective home's performance characteristics could be valuable to homeowners.		
11	N/A	Permit rates are low AND Interviews with HERS Raters and homeowners confirmed our hypothesis that lack of knowledge on the part of homeowners and contractors as well as inconsistency among building departments contribute to low permitting rates and low rates of compliance with energy efficiency standards requirements.	Ch. 3, 4, & 7	CEC and HERS Registries should take action to ensure public access to information collected by HERS Raters for the benefit of homeowners. The documentation required in the HERS process includes measurements of home performance, but these documents are not required to be provided to the homeowner or to the building department for later access. Streamlined access could be achieved by mandating building departments retain the compliance forms or by the CEC retaining the forms or by Registries responding to requests for information. Information regarding a current or prospective home's performance characteristics could be valuable to homeowners.	CEC, HERS Providers, Bldg. Dept.	
12	N/A	See above	Ch. 3, 4, & 7	CPUC and IOUs should inform stakeholders of energy efficiency requirements currently	CPUC & IOUs	N/A

				being met for permitted installations, including the results of this study and general research in HVAC performance.		
13	N/A	See above	Ch. 3, 4, & 7	Streamline and simplify statewide codes for mandatory and prescriptive HVAC requirements throughout California. Contractors and building departments may not have the resources to understand or enforce the nuances of the code or the interest in doing so. Design forms that reduce the paperwork required for code compliance.	CEC	N/A
14		Training is expensive, not readily available, not effective (e.g., includes no or limited field training), and/or training material is inconsistent among training HERS Providers.	Ch. 6 & 7	Evaluate HERS Rater training for field-testing procedures intended to assess prescriptive measures. Also, consider developing mentoring programs for new Raters.	CEC and HERS Providers	N/A
15	N/A	Inconsistent knowledge among HERS Raters of the Standards leads to inconsistent/erroneous assessments in customers' homes.	Ch. 6 & 7	Find creative ways to reiterate diagnostic testing requirements periodically.	CEC and HERS Providers	N/A
16	N/A	There may be barriers to Standards compliance among HERS Raters including the expense and time associated with HERS testing.	Ch. 6 & 7	Improve the process for submission of forms and provide technical training on new methods. Explore ways to provide information in mobile-based or web-based forms so that data enters a database directly and then	CEC and HERS Providers	N/A

				specific forms can be populated electronically. An additional potential benefit would be to allow homeowner access to information about their HVAC system performance.		
17	N/A	There may be barriers to Standards compliance among contractors including the expense and time associated with HERS testing.	Ch.6 & 7	Improve the marketing and branding of the HERS compliance process. Improve customer awareness of permit and compliance requirements for HVAC changeouts. Presently, there are very few relatively recent articles online to promote the program.	CEC, HERS Providers with CPUC/IOU support	N/A
18	N/A	Contractors may find it difficult to keep up with changes to Standards, which may contribute to poor-quality installations.	Ch.6 & 7	We recommend the CEC and IOUs improve engagement with the California's Contractors State Licensing Board (CSLB) to establish additional requirements for C-20 contractors. Specifically, encourage them to adopt requirements for continued education training courses and leverage IOU resources such as "Energy Code Ace." In order to get all parties in the value chain on the same path, we recommend establishing requirements for building inspectors to participate in continued education training courses.	CEC, CSLB, Building Departments with CPUC/IOU support	N/A
19	N/A	Contractors may find it difficult to keep up with	Ch.6	The Contractors State License Board should	CEC, CSLB, with	N/A

		changes to Standards, which may contribute to poor-quality installations. And enforcement of HVAC compliance requirements by building officials is inconsistent between building departments.	& 7	consider requiring workforce education and training credits for C-20 contractors to verify knowledge of the Standards and changes to the Standards and HERS process (e.g. forms and use of Registry).	CPUC/IOU support	
20	N/A	Enforcement of HVAC compliance requirements by building officials is inconsistent between building departments.	Ch. 7	The CEC could work with building departments to have HERS Raters perform all HVAC inspection points with marginally increased fees and then offload building department staff from doing HVAC replacement inspections. This would allow homeowners to only pay for a single inspection instead of one from the building department and another from a HERS rater.		N/A
21	N/A	Enforcement of HVAC compliance requirements by building officials is inconsistent between building departments.	Ch. 6 & 7	Create a compliance complaint line to be used by contractors, HERS Raters, and homeowners who believe building departments are not providing adequate enforcement.	CEC and Building Departments	N/A
22	N/A	Enforcement of HVAC compliance requirements by building officials is inconsistent between building departments. Additional regulation will improve the HERS Rater services and lead	Ch. 7	Consider enforcement paths other than penalty fees (e.g., HERS requirements, inspections at the time of sale).	CEC, CPUC, and Building Departments	N/A

		to better-quality installations.				
23	N/A	This study provides a snapshot for the time period studied. Additional research in this area can provide additional insights and also provide indications of changes in market and enforcement conditions.	Ch. 8	Study whether spillover savings may exist for the CEC's and IOUs' workforce education and training efforts. The relatively high rates of compliance and energy efficiency at non-permitted installations among non-participants in energy efficiency programs may be indirectly attributable to these efforts. This study did not pursue evidence suggesting this connection, but such a connection is plausible. It may be important to acknowledge that these trainings are being taken by contractors who are not pulling permits. This implies the education and training to improve compliance affects the broader HVAC replacement market and not just permitted installations.	CPUC	N/A
24	N/A	This study provides a snapshot for the time period studied. Additional research in this area can provide additional insights and also provide indications of changes in market and enforcement conditions.	Ch. 8	Continue analyzing performance data; If data access is improved as recommended in the previous section, compliance data collected by HERS Raters can be mined and analyzed to help target insufficient installation practices. Reviewing detailed data can help to track progress toward improving compliance of HVAC	CPUC	N/A

				replacements.		
25	N/A	See above	Ch. 3, 4, & 7	To increase the incidence of HVAC inspections, building departments should consider requiring duct testing and performance measurement for air conditioners at the time of sale for existing homes. Homes should be required to be "to code" when sold. Such a requirement would be easier to enforce than permitting at time of replacement and would be difficult to ignore, as several other inspections are ordered at time of sale. The City of Davis has already adopted this model for existing home sales. Another option would be to provide homebuyers with a path to order a HERS rating just as they can order other inspections during sale negotiations.	CEC and Building Departments	N/A
26	N/A	Enforcement of HVAC compliance requirements by building officials is inconsistent within building departments.	Ch. 7	Building departments should eliminate inconsistent enforcement of the Standards among employees through more routine training and internal auditing.	CEC and Building Departments	N/A
27	N/A	Contractors may find it difficult to keep up with changes to Standards, which may contribute to poor-quality installations.	Ch. 6	Building departments and HERS Registries should improve coordination to eliminate open permits.	Building Departments and HERS Providers w/CEC	N/A

28	N/A	This study provides a snapshot for the time period studied. Additional research in this area can provide additional insights and also provide indications of changes in market and enforcement conditions.	Ch. 8	Perform a "secret shopper" study in regions of California with high uncertainty of permitting and compliance. Consider working with Contractors State License Board and specific building departments to identify the worst cases that may avoid scrutiny. The actual volume of the extreme cases is a particular research question to answer.	CPUC	N/A

APPENDIX Y. STUDY REPLICATION AND CHALLENGES

This Appendix describes some of the challenges researchers encountered while performing the study which should be considered should this study be replicated. We addressed several challenges faced during and after developing the research plan.

Equipment eligible for inclusion of the study

The study addresses both types of HVAC changeout situations: altered space conditioning with mechanical cooling systems and entirely new or replacement space-conditioning systems (all HVAC equipment and ducts replaced). If the entirely new HVAC equipment includes an addition and/or renovation to an existing building, the dwelling was excluded from the study. The study focuses on changeouts that do not include the possibility of a compliance trade-off approach, which applies to additions and new construction. Additionally, at the onset of the study, the code cycle was restricted to projects that complied with or should have complied with the 2008 Standards. Projects under pre-2008 Standards were excluded from the study. Early on in the study we found a trend in the data set whereby a higher proportion of installations had occurred under the 2013 Standards as opposed to the 2008 Standards as we expected. As such, limiting to the 2008 Standards significantly limited our sample pool and it was decided projects under the 2013 should be included. Given the relatively infrequent occurrence of an HVAC changeout in residential dwellings future studies should plan to collect data across multiple code cycles.

Unlike impact evaluations with specific populations of participants, in this type of study we have very limited prior knowledge of the study population. There are several aspects that we did not know about the population, such as regional variation in enforcement and the frequency in which each requirement applies to a given replacement. In these calculations, we continue to assume overall variation is higher than the variation for a specific mandatory or prescriptive requirement. The reported relative precisions and sample sizes should allow future studies to plan samples and also plan for oversampling if the goal is a sample target for a specific requirement.

Data acquisition

Permit (look ups)

The permit status was independently verified by evaluators through building department’s public records request, online historical permit records and through telephone calls with permit technicians. The Public Record Act, requires building departments to respond within 10 days, was an instrumental policy that allowed us to collect the necessary information. However, future studies should anticipate some inefficiencies such as onsite visits at building departments and expect a general lack of uniformity on the content of the records. There are more than 500 building departments (city and county) in California and we found no evidence of uniform requirements on what data ought to be obtained for a given job or for how long. Additional researchers should not expect permit records to contain any HERS compliance forms. Given the inconsistencies researchers should be nimble in their approach to collect data. We found permit data for non-residential building to be very challenging as their changeouts were often coupled with tenant improvements and lacked adequate descriptions.

Determining final permit status posed some challenges. The study contained three types of projects: final, open and unpermitted. Permit status- filed vs. final – requires researchers to have a complete set of records to determine the stage in which the permit was completed. As a result, a second round of phone calls was often made to the permit technician to verify record requests or data found online. To streamline, future studies may want to limit to two categories of either permit filed or permit not filed.

Compliance forms

Many code requirements under the 2008 code were climate-zone specific for changeouts therefore HERS certificates will only exist for certain equipment types in certain climatic zones. Researchers assessed compliance consistent with the Title 24 and HERS documentation on inspection and testing procedures and calculations of the metrics for measured requirements.

The repository where compliance forms are held (the Registries) are managed by privately held companies and overseen by the CEC. At the onset of the study, researchers made routine telephone calls and emails requesting the companies supply compliance form data for the study. After a series of non-responsive months, the registry owners declined the data request. However, a compromise was finally agreed to by one of the two companies. This compromise included costly fees to pull data from the registry and in the end the quality of the data lacked, and did not serve all the intended purposes. Data acquisition from the registry was a constant challenge throughout the study. As such, one of the study recommendations is the CEC evaluate the Registries compliance to the CA Public Records Act given the registries are storing public records.

Should the study be replicated, HERS compliance form requests should first be issued to the CEC. We also believe the HERS compliance form data is underutilized when confined to the registries. The data may provide useful information to prospective homeowners, realtors, renters and researchers if accessible to the public.

A fair amount of uncertainty exists as to why some samples did not contain a complete set of forms or why samples contained no forms. We recommend earlier coordination with CEC on to explain the different paths to compliance and describe allowable exclusions and cases for "sample groups". An additional study suggestion is to request the complete set CF1R through CF4R for each sample site as the CF3R lacked relevant installation information. It was later discovered in the study the desire to have the CF1Rs and the registries declined to provide them without any explanation as to why.

Analysis methods to estimate impacts

This study was the first of its kind to develop a methodology to measure energy impacts for HVAC changeouts in existing residential buildings. Currently there is no energy modeling software that serves this function. DNV GL relied on a variety of sources such as DEER and Case Studies however there is some disagreement among stakeholders as to which sources provide the most reliable estimate of savings. Additionally, for some certain measures there are no studies that estimate savings therefore DNV GL leveraged estimated based on DNV GL's engineering experience.

Ideally the CEC would develop a software program that performs the function of estimating gas and electric savings using various parameters. The analysis methods DNV GL developed can be applied to existing buildings under the 2013 code however the template will need to be updated with each code cycle change and as new studies in this topic area become available (DEER, Workpapers, etc.).

Enlisting study participants

Performing comprehensive HVAC testing on a large number of homes across the state poses a challenge on its own merits, this is then exacerbated by legality of the unpermitted installations. In order to obtain accurate information on installation practices and perform in home inspections it was necessary to camouflage the intent of the study in various states. Should the study be replicated we recommend pulling from a larger sample of customers (greater than 20,000) due to the infrequence of HVAC changeouts, coupled with common requirement barriers. Due to non-response and lower than expected HVAC changeouts under the 2008 code DNV GL expanded the sample to changeouts under the 2013 code. RASS was a good starting point but it the targeting advantages did not bear out as we needed more eligible sample. Since we used multiple modes, there is no reason why we couldn't do a general population survey at a lower cost per complete or achieve the same results assuming a starting with a larger frame and low response rate since we are looking for relatively unique events in the market.

We focused on single-family and additional work would be necessary to reach the multifamily market (individual and master metered accounts). While mobile homes do not fall under Title 24, multifamily and utility low-income (CARE rates, ESA program) may represent the hard to reach market that requires additional methods and different recommendations.

Another enhancement would be multiple types of screener surveys to target communities, different phone/web survey designs, and change name and look of the study to capture non-respondents.

Non-residential

For the Non-Residential market, we planned to leverage sites from other studies, especially the CPUC CSS and CMST studies. After we went through the requirements, we determined none of the sites had sufficient information assess compliance. This shifted the need to be all primary data collection and we then would achieve insufficient precession for permit non-permit comparisons if we relied only on the planned primary data collection. We developed an analysis method and data collection protocols, but we decided to not go forward. The final development of protocols was provided to the CPUC and IOUs via the HVAC PCG for future studies. Unlike the residential HERS registries the Non-residential acceptance testing does not have an apparent repository of results. .