DNV·GL

Memo to:
CPUC Energy Division Staff & CEC

Memo No.: V5
From: HVAC 6 Team at DNV GL
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ED Review: Complete
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Subject: Results of HVAC6 Phase One Market Asessment of Residential HVAC Installations

1 INTRODUCTION

This memo presents preliminary results of DNV GL's market assessment of heating, ventilation, and air conditioning (HVAC) equipment replacements (changeouts) for the first phase of our residential analysis (HVAC6). The work scope includes 99 inspections of residential HVAC changeouts. The results compare the two metrics developed for this study between permitted and non-permitted changeouts relative to California's energy code requirements in Title 24, Part 6 (Standards) for code cycles 2008 and 2013. For further information on the study's objectives, scope, additional methods and timelines please refer to the research plan.[1]

The small sample sizes that were studied in this evaluation along with the significant potential for self-selection bias caused the reliability of the preliminary results to be limited which tends to constrain the ability to draw conclusions or apply to a larger population. Even so, the research plan outlined this interim deliverable to take the developed analysis metrics and apply them to the data set that was obtained. These should not be perceived as valid for drawing conclusions or applying to any larger population. Exercising the full analysis at this stage allows for feedback and refinement.

This study aims to inform a common assumption that permitted projects are expected to be compliant and non-permitted projects are not compliant. This task was designed to estimate and compare the rates of compliance to requirements and HVAC installation efficacy based on the permit status. In Appendix A we provide the full methodology memo that was developed to support this analysis and made available for public review. Note that in this memo the terminology has changed from partial compliance to HVAC installation efficacy and other changes to the methodology are described. In Appendix B we provide the onsite data collection instrument and in Appendix C we present the data collection protocols for onsite inspections. Appendix D presents additional data obtained from onsite testing. Appendix E provides responses to public comments on this memo.

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

1.1 Definitions of key words

Provided are definitions of key words used in this memo. Several definitions are direct citations from the California Energy Commission (CEC) Building Energy Efficiency Standards.[2] These definitions are presented in order of relevance to the memo.

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

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.

Final permit: is an installation where there is documentation of a mechanical permit issued by an enforcement agency and the permit has been signed off as final. Throughout the memo we refer to final permits as "permit".

Un-final permit: is an installation where there is documentation of a mechanical permit issued by an enforcement agency but the permits were allowed to **expire or are still open** and do not contain a building department sign-off. Throughout this memo we refer to un-final permits as still "open".

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 memo we refer to no permits as "no permit".

HVAC: is heating, ventilation, and air conditioning

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 in the home

Title 24: is the California Code of Regulations that provides energy efficiency standards for buildings. http://www.bsc.ca.gov/Codes.aspx

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

Climate region: is one of two regions, coastal and interior, designated in this study based on similar geographic characteristics. A climate region is made up of groups of CZs for the purpose of this study.

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

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

Prescriptive measures: are measures 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

[2] http://www.energy.ca.gov/2012publications/CEC-400-2012-004/CEC-400-2012-004-CMF-REV2.pdf

install/replace specific components of HVAC systems and 2) alterations that install/replace entire HVAC systems, including all components and ducts.

Performance standards: A building complies with the performance standard if 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 this path were excluded.

Additions: are changes to an existing building the increase both conditioned floor area and volume. Installations that followed this path were excluded. Installations that contained additions at the same time the HVAC unit was installed were excluded.

Alterations: that are not additions, are changes to a building's envelope, space conditioning system, water heating system or lighting system. This system type was the focus of the study.

Load calculations: are calculations for estimating building cooling and heating loads, which are used for equipment sizing. According to the Standards, load calculations must be calculated in accordance with a method based on any one of the following: ASHRAE Handbook, SMACNA Res. Manual, or ACCA Manual J.

Duct insulation: is insulation wrapped around or integral with ducting units. Unless ducts are installed entirely in conditioned space, the minimum duct insulation value allowed by the Standards is R-4.2

Refrigerant line insulation: is insulation installed around refrigerant lines. The Standards require cooling system line insulation with a minimum thickness as calculated by Equation 150-A from the Standards.

Refrigerant charge: is the amount of refrigerant gas that a cooling system must have. 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 confirmed through field verification (home energy rating system or HERS) and diagnostic testing using procedures in the Reference Residential Appendix RA3.2 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.

Airflow: is the volume of air per minute that central forced air cooling system fans maintain across the return. To comply with the Standards, for CZs 10-15, when entirely when new or replacement HVAC system changeouts (including new/replacement duct systems) are installed, the system must be tested and confirmed through field verification to have an airflow greater than 350 cubic feet per minute (CFM) per nominal ton of cooling capacity. This requirement does not apply to when only some of the HVAC components are new/replaced, which is more common than changeouts. However, the protocol for measuring and verifying refrigerant charge requires airflow greater than 300 CFM to exist for the refrigerant charge testing to be valid. Therefore, for projects with new/replacement components that are required in the climate zones stated in the refrigerant charge definition above, failure to have 300 CFM airflow indicates that the project has not complied with the refrigerant charge requirement.

Fan watt draw: is the measure of wattage drawn by the central system air handler fans. 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 watt draw of less than 0.58 W per measured CFM for CZs 10-15. The requirement does not apply to the much more common occurrence when the entire duct system is not new/replaced.

Measurement access: is a measure of access for refrigerant charge. 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

Additional duct insulation: this is additional duct insulation required beyond the minimum R-value of 4.2. Depending on CZ, the Standards require that duct insulation must be increased to at least R-6 or R-8 to be compliant.

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 ducting 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. Requirements for compliance: no more than 15% total leakage or 10% leakage to outside, or 60% measured improvement compared with existing leakage conditions (2008 Standards only), or demonstration that all accessible leaks have been sealed confirmed through a smoke test. See Section 152(b)E (CZs 2 and 9-16) for the 2008 Standards.

HERS: is the California Home Energy Rating System as described in Section 1670 Title 20 of the California Code of Regulations.

HERS provider: is an organization that administers a home energy rating system 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 a HERS test.

HERS rater: is a person who has been trained, tested, and certified by and subject to the oversight of a HERS Provider to perform the field verification and diagnostic testing required for demonstrating compliance with Title 24, Part 6.

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

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

Compliance document: is any of the documents specified in Section 10-103(a) that demonstrates compliance with Title 24, Part 6. Examples include a certificate of compliance, certificate of installation, certificate of acceptance, and certificate of verification.

1.2 Definitions of Analysis Metrics

This section summarizes analysis metrics developed for this study. The original methodology Memo, attached as Appendix A, defined three possible metrics that may be useful to various stakeholders.

Requirement-level compliance: is the percentage that field verification of a performance measure (e.g., airflow) is compliant with the Standards. The analysis is across sites for each measure. The requirement-level compliance rate is 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 is a percentage between 0% and 100% calculated as the number of compliant units divided by the total number in the sample group for each compliance requirements. This metric is calculated across all installations in the sample where the particular requirement was applicable.

HVAC installation efficacy (HIE): is a measure of all requirements aggregated at the site level. This metric is estimated by taking the weighted average of the requirement-level compliance rate scores across requirements at each site. This metric includes different weights for each requirement based on potential energy savings, which vary by requirement and by climate. If a requirement has potential energy savings of zero it is not included in the analysis. This metric is estimated by taking the energy-weighted average of the requirement-level scores for a site. Some requirements are pass/fail with a score 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 with another requirement which is allowed in the performance compliance approach. For this evaluation we are evaluating 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%, which helped set the appropriate range for scores. Each site has a maximum potential score if it meets or exceeds all requirements.

2 EVALUATION SCOPE

The study addresses two types of HVAC changeouts: (1) alterations that include new/replacement HVAC components and (2) alterations that include entirely new or replacement HVAC systems (that is, all HVAC equipment and ducts are new/replaced). If the entirely new HVAC equipment was installed in conjunction with a building addition and/or renovation to an existing building where the shell of the building was altered, the dwelling is excluded from the study. To limit the focus to prescriptive and mandatory measures, the study excludes changeouts that use a performance compliance trade-off approach.

The first phase of data collection had a target of 100 inspections. To date, DNV GL has completed 102 inspections, 99 of which are used in this preliminary analysis. We are planning to complete another 100 inspections for the second phase so the final data set will have a relatively balanced sample of permitted and not permitted residential HVAC changeouts.

2.1 Recruiting IOU residential customers for onsite inspections

In 2009 DNV GL managed the Residential Appliance Saturation Study (RASS)[3] where more than 24,000 IOU customers self-reported appliances, equipment (including HVAC), and general consumption patterns. The HVAC6 study draws its sample population (a sub-sample) from RASS. The RASS data contains a wealth of information used in the current study including HVAC unit type and estimated age of units.

After selecting HAVC6 participants, we administered a mixed-mode self-reported “Home Improvement” Screener Survey. The Screener Surveys were administered online and via telephone with two-thirds of respondents participating online and one-third by phone.

The survey asked about improvement projects completed in the last five years and about ten different types of improvement projects. The intent of the survey was to gather information on whether an HVAC unit was replaced among homes with aging heating and cooling units, and if so, what type and when.

For the screener survey, respondents were presented with three HVAC categories: heating and cooling (both), heating only, and cooling only. They were then asked questions about the project to characterize whether the changeout was part of an addition or an alteration to the existing home, whether it was a replacement or new central system install, and whether the equipment was permanently installed or portable (for example, a room air conditioner). If a replacement occurred sometime after 2010, the site was recruited for an inspection. Addition details about the scope of the installation were also collected once onsite.[4] We completed a separate analysis of the permit status.

Preliminary results among the 99 on-site compliance participants are presented in Table 1. Projects that included both heating and cooling components accounted for more than half of the changeouts (57%). The prevalence of heating-only changeouts is notable at 35%, while cooling changeouts were remarkably low at less than 10%.

[3] http://www.energy.ca.gov/appliances/rass/

[4] A full description of the survey and methods will be included in the final HVAC6 report.

Table 1. System type by climate region

System Type	Coastal	Inland	Total	Percent of Total
Both heating and cooling components	14	42	56	**57%**
Cooling component only	4	4	8	**8%**
Heating component only	16	19	35	**35%**
Total	**34**	**65**	**99**	**100%**

Coastal CZs are 1, 3, 5-7, and inland CZs are 2-4, and 8-16

At the onset of the study, researchers planned to restrict the compliance inspection sample to projects that should have been compliant under the 2008 Standards code cycle. The rationale for using 2008-only projects was a process of elimination. Reasons for excluding other code cycles include that 2005 Standards projects may show unit degradation and unreliable customer recall of HVAC replacement events. For the 2013-Standards projects, the sample was assumed to be too small given the effective date of July 1, 2014, and the launch of the study in early 2015. However, restricting to sample to 2008-only significantly limited the pool of sample changeouts available for inspections as a sufficient number of 2013-projects were installed.

Due to the limited eligible 2008-only sample (further limited by low rates of cooperation with onsite inspection requests), we made the decision to allow changeouts that occurred in the 2013 code cycle (July 2014-present). The effect of this change is relatively insignificant apart from the fact that some compliance requirements (e.g. duct leakage and fan efficacy) under the 2013-Standards need to be accounted for in all CZs compared with the 2008-Standard where some of these compliance requirements were CZ-specific. Essentially there is no effect for inland areas and modest effect for coastal areas.

The permit status for each site was independently verified by evaluators through building department public records and a HERS registry certificate. Many code requirements under the 2008 code were CZ-specific for changeouts, so HERS certificates for certain equipment types will only exist in certain zones. In a separate document (final report) we will describe installations with HERS certificate results to evaluator's field test data. We assessed 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 characteristics that we do not currently know about the population, such as regional variation in enforcement and the frequency that each requirement applies to a given replacement. In our calculations, we continue to assume overall variation is higher than the variation for a specific mandatory or prescriptive requirement. The variation estimates we used for sampling are based on our experience and standard evaluation assumptions.

As expected, the number of non-permitted changeouts was more than double the permitted ones, making some comparisons difficult to interpret due to small sample sizes. To complement the results and provide additional data points, we also applied compliance results from the 2014 Pacific Gas and Electric HVAC

Permitting for IOU Programs Study (PG&E study) that contained data for 51 changeouts.[5] From that study, 47 changeouts could be used for comparison purposes and reasonably added to our CPUC sample given the PG&E changeouts were in the same code cycle and used comparable field data collection techniques. The PG&E study collected unit efficiency, load calculations, airflow, fan watt draw, and duct leakage and these data were re-analyzed using the methodology described in this memo.

However, there are some limitations of the PG&E study. The field data did not collect characteristics for all requirements (measures), thus there is no compliance disposition for some measures. Data were not collected explicitly for thermostats, duct insulation, refrigerant line insulation, or refrigerant charge. As a result, those measures are not included in the site-level compliance evaluation for PG&E study changeouts. For the PG&E study there were independent load calculations performed for all sites, while for this sample the code requirements were followed that load calculations only needed to be performed and documented.

Figure 1 shows the compliance requirements for the HVAC6 and PG&E study sample.

Figure 1. Field data collected for HVAC6 and PG&E study samples

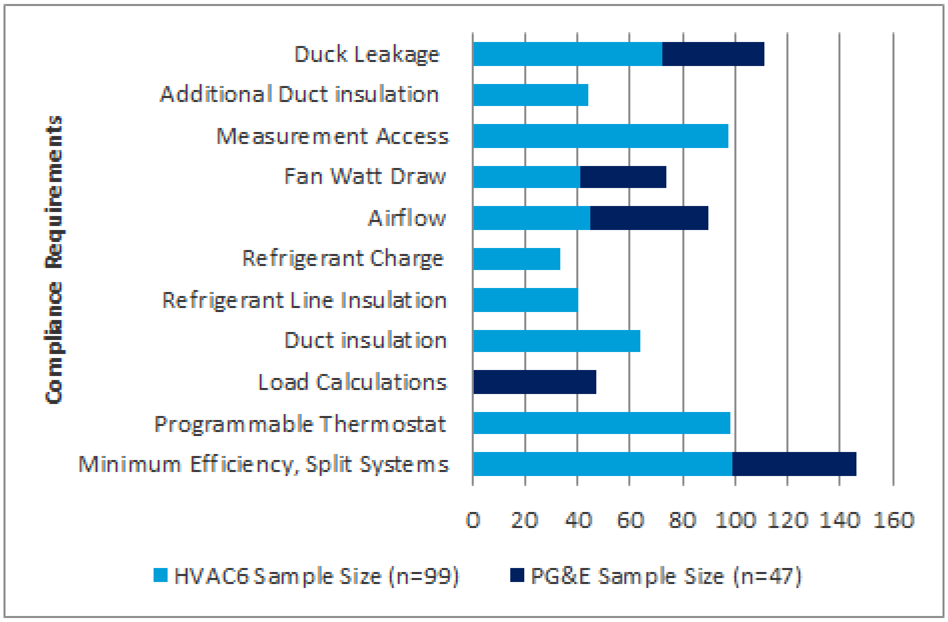

Table 2 identifies the requirements of the 2008 and 2013 code cycles for residential HVAC changeouts.

5 http://www.calmac.org/publications/FINAL_REPORT_PGE_HVAC_Permitting_for_IOU_Programs_Study_v20141010ES.pdf

Table 2. Residential HVAC changeout compliance requirement details

Compliance Requirement	Code Details	2008 Threshold	2013 Threshold
Minimum Efficiency	Certification by Manufacturers- HVAC equipment must be certified by the manufacturer to meet specific efficiency requirements. (Section 112). They must comply with applicable federal and industry efficiency certifications and ratings requirements that are adopted by the Title 24 Standards.	SEER 13, AFUE 78, HSPF 7.7	SEER 14, AFUE 78, 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 -a clock mechanism that allows the building occupant to program for at least 24 hours	Yes/No	Yes/No
Load Calculations	Building cooling and heating loads - must be calculated in accordance with a method based on any one of the following 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	Cooling system line insulation- Section 150(j)2 –cooling system lines shall be thermally insulated. The insulation shall have a minimum thickness as calculated by Equation 150-A	Yes/No	Yes/No
Refrigerant Charge	According to the standards proper refrigerant charge must be confirmed through field verification (HERS) and diagnostic testing in accordance with procedures set forth in the Reference Residential Appendix RA3.2 or have a Charge Indicator Display.	Diagnostic within tolerance of target. CZ 2, and CZ's 8-15. Dependent on scope	Diagnostic within tolerance of target. CZ 2, and CZ's 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 CZ's. Dependent on scope
Fan Watt Draw	Completely new (equipment, ducts, etc.) air cooling must have a supply fan watt draw of less than 0.58W per measured CFM. (The above limitation clause applies to this requirement.)	0.58 W per CFM. CZs 10-15. Dependent on scope	0.58 W per 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
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
Duct Leakage	When a space-conditioning system is altered by the installation or replacement of space-conditioning equipment (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) 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. Targets for compliance: 15% total leakage, or 10% leakage to outside, or 60% measured improvement, or compliance using smoke test and sealing all accessible leaks. Section 152(b)E	6% Total leakage or 15% Total Leakage, or 10% leakage to outside, or 60% improvement. Dependent on scope. CZs 2, 9-16.	6% Total leakage or 15% Total Leakage, or 10% leakage to outside. Dependent on scope. All CZ's

2.2 Weighting strategy to estimate site-level and aggregated compliance

The ultimate goal of the Standards is to increase the energy efficiency of HVAC changeouts. However, a simple yes or no compliance does not provide enough information for the CPUC to understand the current market or inform future policy and energy efficiency measure savings. It is relatively straightforward to report compliance levels for each requirement across sampled projects. For example, we can report how many units complied with each requirement and determine which requirements are being met and which are not. This metric is intended to have primary value to the CEC and IOU codes and standards programs that advocate for specific requirements. Rather than look at each requirement independently, we can also look at each installation and assign it a score that estimates the efficiency of the installation from 0% (no requirements met) to 100% (all requirements met or exceeded). The CPUC desired a metric that can estimate the relative efficiency of permitted and non-permitted installations. This would provide one of the required baseline metrics for pilot and proposed IOU programs that seek to increase permitting. There is currently no relative estimate of the efficiency increase associated with pulling a permit, which would be a leading indicator that energy savings can be associated with a permit.

An approach that equally weights the applicable requirements describes how many of the requirements are being met, but it may not reflect the “lost opportunity” in terms of energy efficiency of an energy-weighted approach. To capture the variation in energy savings of different requirements and provide useful information to multiple stakeholders, we created an additional metric termed HVAC installation efficacy, which is site level with energy savings weights for each applicable requirement.

- **Requirement-level compliance rate:** This rate is a percentage between 0% and 100% calculated as the number of compliant units divided by the total number in the sample group. The requirement-level compliance rates are presented in **Error! Reference source not found.** with a row for each requirement along with the sample size and any relevant statistics.
- **HVAC installation efficacy**: is a measure of all requirements aggregated at the site level. This metric is estimated by taking the weighted average of the requirement-level compliance rate scores across requirements at each site. This metric includes different weights for each requirement based on potential energy savings, which vary by requirement and by climate. If a requirement has potential energy savings of zero it is not included in the analysis. This metric is estimated by taking the energy-weighted average of the requirement-level scores for a site. Some requirements are pass/fail with a score 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 with another requirement which is allowed in the performance compliance approach. For this evaluation we are evaluating 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%, which helped set the appropriate range for scores. This metric is used in each additional phase of the project for the final report. When reporting compliance for permitted versus non-permitted changeouts, we report the weighted average installation efficacy for each group. The study team compared installation efficacy by climate region (groups of CZs) in this memo. The weights were developed and are shown in Appendix A. They are not taken directly from CASE reports or from DEER, but rather they are based on those sources where applicable. The CASE reports provide savings assuming new construction context and DEER assumes single measures are corrected independent of a new HVAC installation. These sources were determined to be the best available estimate at the time and do not represent an absolute expected amount of savings.

3 PERMIT STATUS FOR INTERIM SAMPLE

The overall study includes additional tasks to estimate the total number of permits pulled annually and the annual permitting rate. This section focuses on the permit status of the sample such that the two analysis metrics: requirement-level compliance and HVAC Installation Efficacy (HIE) can be compared by permit status.

California law requires newly installed and replaced HVAC components and systems be permitted and installed by a state-licensed (C-20) contractor.[6] When installing or replacing HVAC systems the requirement is to take out a building permit which is issued by local city or county building enforcement agencies. Inspection processes of enforcement agencies are intended to assure HVAC systems are properly installed. To assure the system is not wasting energy due to installation defects, the Standards require the installation undergo testing and field verification performed by certified HERS Raters. The potential consequences of non-permitted changeouts include defective installation, homeowner and worker safety hazards, higher energy costs, and higher maintenance costs, and could result in fines and correctional repairs required by building enforcement agencies. The compliance measurements, presented in Section 1, only focus on energy efficiency requirements.

This study examines whether newly installed and replacement HVAC units are installed with a permit that is issued by the local enforcement agency. The 1968 California Public Records Act allows the public to obtain or inspect a copy of identifiable public records.[7] For this study, mechanical permits were collected primarily through public record requests filed with the appropriate city or county building departments. Often the requests were fulfilled with historical permit data for the service address. Public Record Act requests were unnecessary for building departments that have transferred their records to an online public search engines or for those that require in-person visits to view public records. Often online public record searches were followed by a telephone call to collect additional details, but in-person visits were seldom necessary.

If a permit was identified, the permit data were then compared with the residential survey respondent's self-report as collected in the screener survey that included the year the changeout occurred (from 2010-15) and the type of equipment (heating, cooling, or both). Inconsistencies for both timing of the installation and installation type were common occurrences when comparing permit data and customer self-report data.

All permit data went through a quality control (QC) evaluation process. Ultimately, we categorized timing and equipment data based on a compilation of data points for both permit and non-permit changeouts. The following are key considerations that led to changes among the permit samples:

- If the respondent self-reported the units was one system type (such as furnace only) but the permit showed a different system (such as both) we deferred to the permit records.
- If the respondent self-reported the units was installed in a certain year but the permit showed a different year we deferred to the permit records.
- If the permit record showed the installation was prior to 2010 we dropped the sample point.

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[6] By law, homeowners can install their own HVAC system without a C-20 license, but must have a building permit and comply with the Energy Code. These projects are subject to the same level of inspections as a licensed contractor.

[7] http://www.thefirstamendment.org/publicrecordsact.pdf

Among unpermitted samples where we had no permit data as a reference point – samples were frequently dropped. The following QC processes were applied:

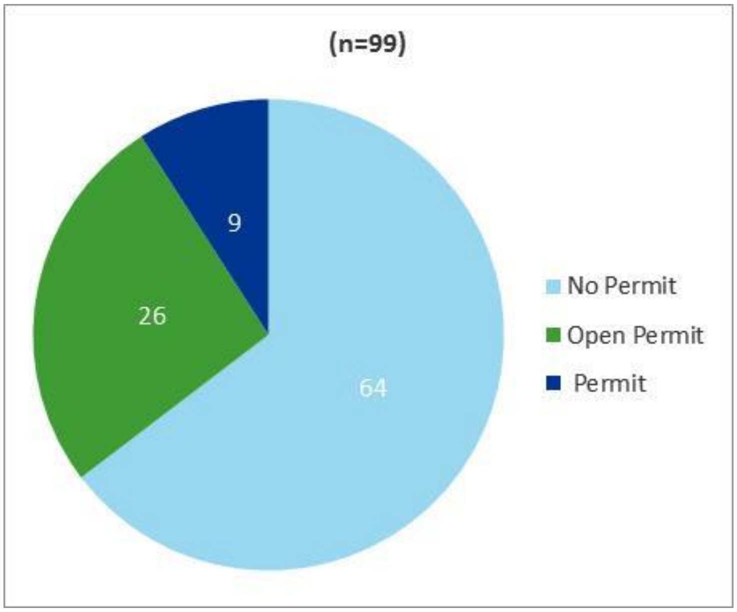
- If the screener survey to recruitment survey self-report of timing was inconsistent, whereby the install occurred prior to 2010, then the site was dropped.
- Recruitment survey to onsite survey, if upon arrival the inspection and discussion with the homeowner revealed the confusion about the timing of changeout then the site was dropped.
- If the equipment showed significant degradation then the sample was dropped.
- Unit manufacturer dates were also considered.

A total of three sample points were dropped, after the data was collected, which reduced the sample size from 102 to 99. Two sample points had permits filed in the second half of 2009 and were dropped because they are out of scope (installation completed under the 2005 Building Energy Efficiency Standards). A third changeout, non-permitted, was dropped as it was apparent from the onsite photographs that the furnace and condenser were too old to be subject to the Standards requirements; it may have been repaired with some new parts.

The distinction between a final (closed) permit versus a filed (open or expired) permit was also identified and flagged. Permits that were allowed to expire without final building department sign-off were treated as non-permitted and assigned to their own category of "open permit." By removing the expired and open permits and the installations completed under the 2005 Standards, the total number of changeouts evaluated was reduced to 99 from the previously planned 100 for phase one of the study. In subsequent chapters when we provide compliance results by permit categories of "permit" and "no permit" we have excluded the cases of open permits because there are so few.

Results from the permit data collection is illustrated in Figure 2. For the study scope, 9% of permits were expired or open, 26% were finalized, and 65% had no mechanical permit that could be reasonably associated to the installation.

Figure 2. Permit status for the inspection sample



In comparison, the 2014 PG&E Permit Study reported 17 of 48 projects were permitted. When the distinction between expired and final permits was analyzed and other QC processes were applied,[8] the permit number of the PG&E study was slightly reduced to 13 of 48 for final permits. In general the two studies have comparable proportions of numbers of permitted cases in the respective samples, at 17 of 48 and 35 of 99 for both expired/open and final permits.

The preliminary results included a number of permits similar to the PG&E study, but previous estimates cited by the CEC are much lower. The larger study includes additional analysis to estimate the permit rate using multiple data sources. This onsite sample requires significant customer cooperation, but is required to assess all code requirements and HVAC system characteristics. Based on ongoing analysis the study expects there is a self-selection bias meaning that the non-permitted cases will not represent all changeouts regardless of sample size. The CPUC has added scope to this project to further quantify the extent of the bias. This memo further presents the breakdown of the sample achieved and applies the planned analyses.

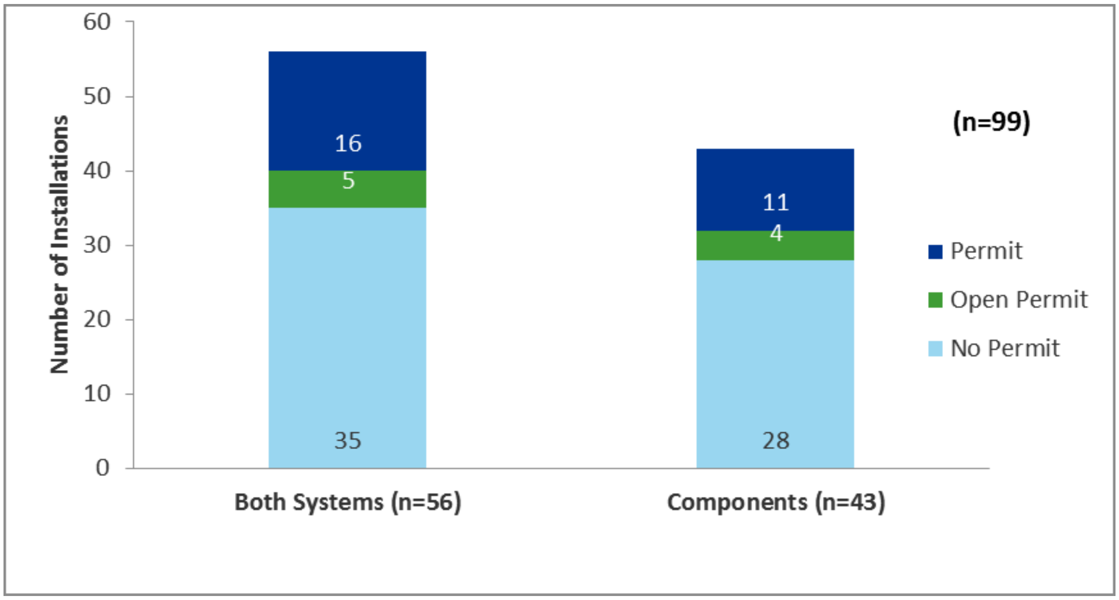
Permit status by replacement type

Figure 3 compares the number of permits by system replacement type where "Both Systems" represent changeouts of both a heating and cooling unit and "Components Only" represents changeouts of either a heating or cooling unit. As shown, the practice of pulling permits for entire system changeouts (both systems) versus single component changeouts is only slightly higher at 38% and 35%, respectively, which is unlikely to be a statically significant difference given the sample sizes. The permit rate for the entire system

[8] Dropped reasons included not the correct code cycle and installation type.

changeouts (both systems) ranges from a low of 29% (final permits) to a high of 38% when including final and open permits. For single component changeouts, the permit rate difference is slightly larger (9% difference) between final permit and final plus open permit.

Figure 3. Permit status by system replacement type

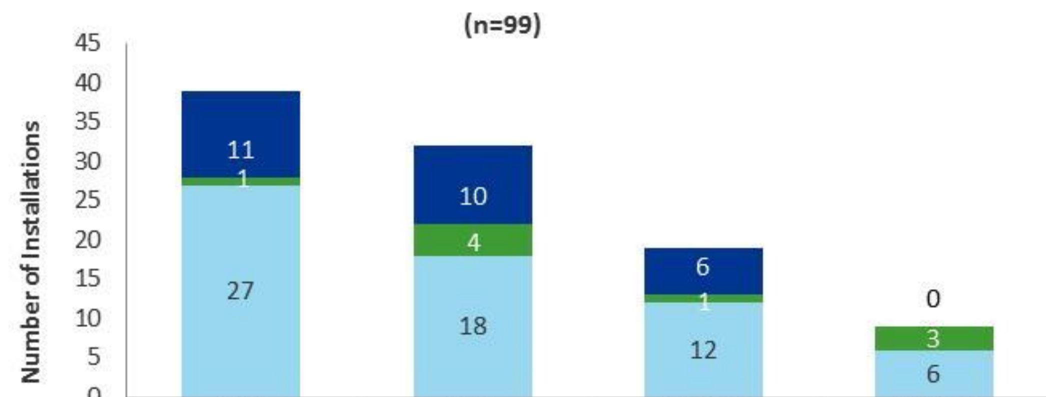


Permit status by utility

Figure 4 compares the number of permits that occurred in each of the four utility service territories. The highest permit rate is in the PG&E service territory and the lowest is in Southern California Edison (SCE) service territory. In this figure, similar to the previous figure, we present the permit rate for both final permits and for final plus open permits. Similar to permit status by replacement type above, there were no statistically meaningful differences in permit status by utility service provider.

A total of 67 unique jurisdictions were represented among the 99 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 27 jurisdictions, SCE/SCG 31 jurisdictions, SDG&E 7 jurisdictions, and Los Angeles Department of Water and Power electric with SCG gas contained 2 jurisdictions.

Figure 4. Permit status by electric utility service



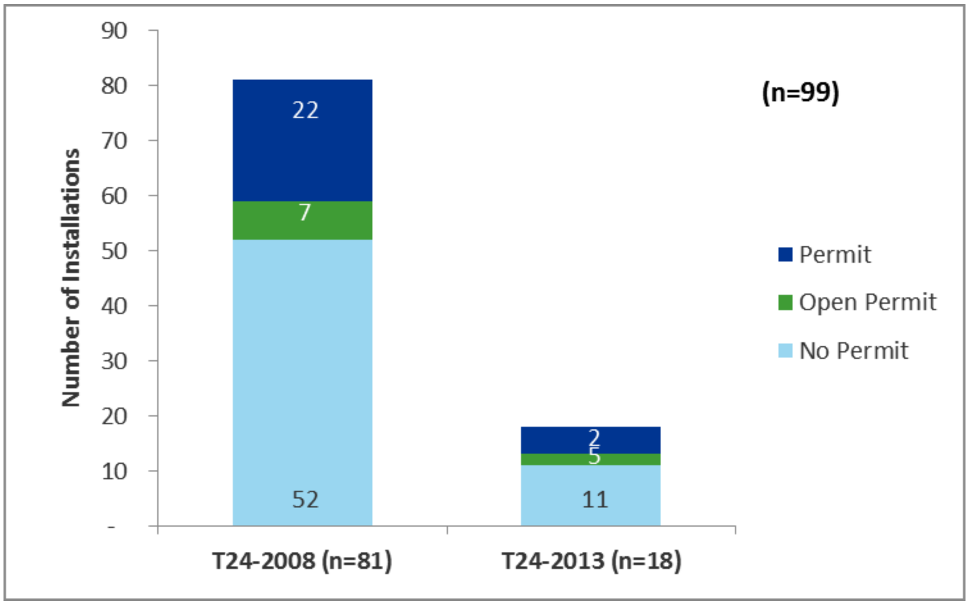
	SCE	PGE	SDG&E	LADWP
Permit	11	10	6	0
Open Permit	1	4	1	3
No Permit	27	18	12	6

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

Permit status by code cycle

Figure 5 compares the number of permits by the two code cycles; 2008 and 2013. The data show a similar pattern; for the sources compared there are no significant differences. When comparing the closed permits the proportions are similiar at 22 of 81 for 2008 and 2 of X18 for 2013. When comparing the closed plus open permits, again the differences are marginal, in this case just 3%.

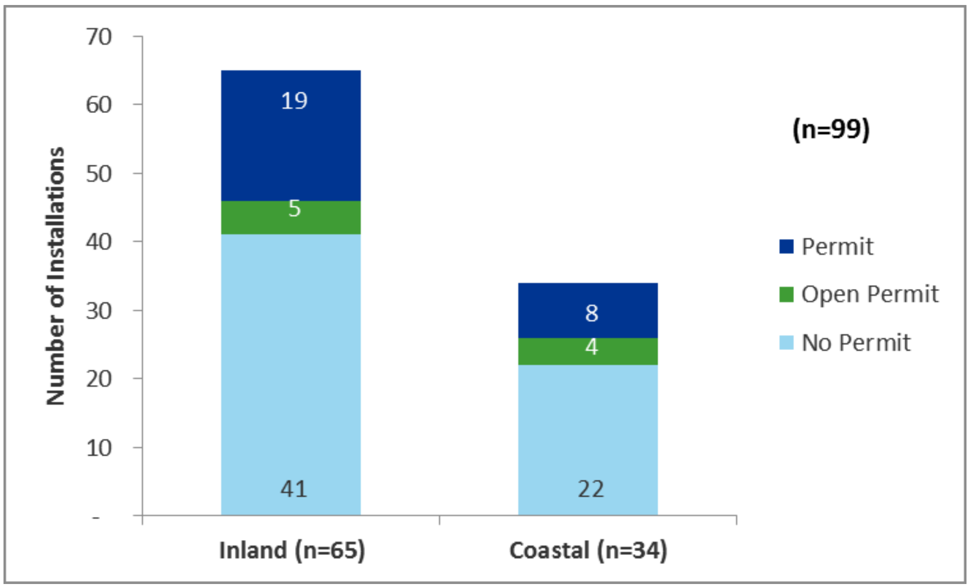
Figure 5. Permit status by Title 24 code cycle



Permit status by climate region

Figure 6 compares the permit status by two climate regions of coastal and inland. Given the small samples across the state, DNV GL divided the CZs into these two major regions that share common geographic characteristics. The coastal CZs are 1, 3, 5, 6, and 7, while the inland region CZs are 2, 3, 4, and 8-16. Using this system, we found no notable trends in permitting. Inland zones have some additional compliance requirements that do not apply to coastal zones; particularly in the 2008 Standards. These requirements additionally could be perceived as deterrents to permitting a project however, that was not supported by the data. The phase one HVAC6 sample contained 34installations in the coastal region and 65 in the inland region. In the next phase of our reporting we will present permit counts at the climate zone level for the 2014 calendar year.

Figure 6. Permit status by climate region



4 REQUIREMENT-LEVEL COMPLIANCE RESULTS

Sections 3 and 4of this memo present the preliminary results of the two metrics developed for this study. This section presents the results of comparing permit status for ten of the 11 compliance requirements in the Standards. The installation requirement can apply to all changeouts (mandatory measures) or only to changeouts undergoing certain types of modifications (prescriptive measures).

Requirement-level compliance rates are presented in one table per requirement along with a summary table containing a row for each requirement showing the sample size and any compliance rate. The final requirement-level compliance rates ranged from 0% to 100% for each requirement, but there is no overall compliance rate across requirements. See Appendix D for additional data on specific requirements that require performance testing. If there was any uncertainty in which requirements were applicable the study team generally tested for all requirements. Therefore, the study has collected additional data that may be informative for energy efficiency program planning and future workpapers that is outside the scope of code compliance.

Table 3 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.

Table 3. Minimum efficiency requirement by permit status

	Permit Status	Met Requirement?		Total
		Yes	No	
Minimum Efficiency	No permit	63	-	**63**
	Open permit	9	-	**9**
	Permit	27	-	**27**
	Total	**99**	-	**99**

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

Table 4 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.

Table 4. Programmable thermostat requirement by permit status

	Permit Status	Met Requirement?		Total
		Yes	No	
Programmable Thermostat	No permit	54	8	**62**
	Open permit	8	1	**9**
	Permit	25	2	**27**

	Total	**87**	**11**	**98**

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

Table 5 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.

Table 5. Duct insulation requirement by permit status

	Permit Status	Meet Requirement?		Total
		Yes	No	
Duct Insulation	No permit	38	5	**43**
	Open permit	14	0	**14**
	Permit	4	3	**7**
	Total	**56**	**8**	**64**

Mandatory, All Climate Zones, threshold R-4.2

Packaged units and heat-only systems are exempt from this requirement; hence this requirement is applicable to a total of 40 units.

Table 6 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; hence this requirement is applicable to a total of 40 units.

Table 6. Refrigerant-line insulation requirement by permit status

	Permit Status	Met Requirement?		Total
		Yes	No	
Refrigerant-Line Insulation	No permit	25	1	**26**
	Open permit	3	-	**3**
	Permit	11	-	**11**
	Total	**39**	**1**	**40**

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

Table 7 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 that is 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 a charge indicator display. HERS verification of refrigerant charge is required only in CZ 2 and CZs 8-15. The measurement protocols have a prerequisite airflow requirement of 300 CFM or greater.

Table 7. Refrigerant charge requirement by permit status

	Permit Status	Met Requirement?		Total
		Yes	No	
Refrigerant Charge	No permit	12	7	**19**
	Open permit	3	-	**3**
	Permit	3	8	**11**
	Total	**18**	**15**	**33**

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

Table 8 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 now mandatory under the 2013 code for completely new systems and new ducted systems in all climate zones.

Table 8. Airflow requirement by permit status

	Permit Status	Met Requirement?		Total
		Yes	No	
Airflow	No permit	1	1	**2**
	Open permit	1	-	**1**
	Permit	3	-	**3**
	Total	**5**	**1**	**6**

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

Table 9 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 watt draw 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. This 2008 prescriptive requirement is a now mandatory under the 2013 code. The compliance rate is somewhat higher in the permitted changeouts (89%) than in the no-permit/open permit changeouts (69%).

Table 9. Fan watt-draw requirement by permit status

	Permit Status	Met Requirement?		Total
		Yes	No	
Fan Watt Draw	No permit	1	1	**1**

	Open permit	1	-	**1**
	Permit	3	-	**3**
	Total	**5**	**1**	**6**

Prescriptive, CZs 10-15, <0.58 W per CFM

Table 10 details the presence of TMAH and PSPP access measurements, 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. All changeouts, where applicable, met this compliance requirement.

Table 10. Measurement access requirement by permit status

	Permit Status	Met Requirement?		Total
		Yes	No	
Measurement Access	No permit	2	-	**2**
	Open permit	1	-	**1**
	Permit	3	-	**3**
	Total	**6**	-	**6**

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

Table 11 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 the results. All ducts in *unconditioned* space must be insulated to at least R-4.2, and depending on the CZ, more insulation may be required up to a maximum of R-8.0 in more extreme environments. As shown, the majority of changeouts did not meet the additional duct installation requirement regardless of the permit status.

Table 11. Additional duct insulation requirement by permit status

	Permit Status	Met Requirement?		Total
		Yes	No	
Additional Duct Insulation	No permit	14	16	**30**
	Open permit	1	1	**2**
	Permit	3	9	**12**
	Total	**18**	**26**	**44**

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

Table 12 compares how often changeouts met the duct-leakage requirements by permit status. 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 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% of nominal airflow total leakage, or 10% of nominal airflow leakage to outside the conditioned space, or 60% measured improvement, or compliance using smoke test and sealing all accessible leaks. The duct sealing requirement applies in CZs 2 and 9-16. When duct sealing is required, under the 2013 Standards, the requirement extends to all CZs. Additionally; the 60% 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% 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 test for 60% leakage reduction, and smoke tests were beyond the scope of the project. As a result, only total-leakage rate and leakage-to-outside rate were considered in determining compliance. While Table 12 shows poor compliance across all permitting groups, it is possible that in some cases the duct sealing requirement was met through either a 60% reduction in leakage or a smoke test. The evaluation team did not attempt to obtain compliance documentation that would identify what duct sealing option was used.

Table 12. Duct leakage requirement by permit status

	Permit Status	Met Requirement?		Total
		Yes	No	
Duct Leakage	No permit	23	24	**47**
	Open permit	5	3	**8**
	Permit	7	10	**17**
	Total	**35**	**37**	**72**

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

The average compliance rate for each requirement is shown in **Error! Reference source not found.** In the table some values and percentages are presented in red italic font these are displayed as such because the sample sizes are less than 20. With small sample sizes the reliability of the results are low and likely too small to draw conclusions or apply to a larger population. The table shows that the mandatory requirements had higher compliance rates than the prescriptive measures that vary by climate zone.

Table 13: Summary of requirement level compliance results by permit status

Requirement	Applicability	Threshold	No Permit		Permit		Open Permit		Overall Status
			Sample Size (n)	Requirement Compliance	Sample Size (n)	Requirement Compliance	Sample Size (n)	Requirement Compliance	
Minimum Efficiency	Mandatory, All Climate Zones	SEER 13, AFUE 80, HSPF 7.7	63	63	27	27	9	9	99 of 99
Programmable Thermostat	Mandatory, All Climate Zones	Yes/No	62	54	27	25	9	8	87 of 98
Load Calculations	Mandatory, All Climate Zones	Yes/No (no sizing requirement based on load calculations in 2008 code)	63	0	27	27	9	9	36 of 99
Duct insulation	Mandatory, All Climate Zones	R-4.2	43	38	7	4	14	14	56 of 64
Refrigerant Line Insulation	Mandatory, All Climate Zones	Insulation thickness based on pipe diameter	26	25	11	11	3	3	39 of 40
Refrigerant Charge	Prescriptive, CZ 2, and CZ's 8-15 for changeouts or altered condensers and refrigerant components	Diagnostic within tolerance of target	19	12	11	3	3	3	18 of 33
Airflow	Prescriptive, CZ 10-15 for completely new systems	350 CFM/ton	2	1	3	3	1	1	5 of 6

Requirement	Applicability	Threshold	No Permit		Permit		Open Permit		Overall Status
Fan Watt Draw	Prescriptive, CZ 10-15 for completely new systems	<0.58 W per CFM	2	1	3	3	1	1	5 of 6
Measurement Access	Prescriptive, CZ 10-15, Temperature and Pressure	Yes/No	2	2	3	3	1	1	6 of 6
Additional Duct insulation	Prescriptive, Varies by CZ from 4.2 to 8.0	R-value from 4.2 to 8.0	30	14	12	3	2	1	18 of 44
Duck Leakage	Adjusted for Code Cycles	15% leakage (changeout) or 6% leakage (entirely new system)	47	23	17	7	8	5	35 of 72

5 HVAC INSTALLATION EFFICACY RESULTS

The small sample sizes that were studied in this evaluation along with the significant potential for self-selection bias cause the reliability of the preliminary results to be limited which tends to constrain the ability to draw conclusions or apply to a larger population. Even so, the research plan outlined this interim deliverable to take the developed analysis metrics and apply them to the data set that was obtained. These should not be perceived as valid for drawing conclusions or applying to any larger population. Exercising the full analysis at this stage allows for feedback and refinement.

The HVAC installation efficacy (HIE) provides a metric that accounts for different requirements that have different energy impacts. When reporting compliance for the permited versus non-permitted changeouts, we report the weighted average HIE for each group. Comparisons of HIE by climate region (groups of CZs) are also reported. The energy savings estimates used as weights in the HIE metric are fully described in Appendix A.

The next series of tables and figures provide results for sample points collected for this study and sample points borrowed from the 2014 PG&E HVAC Permit study. The combined samples contain similar characteristics and provide additional data points for the evaluation. However, it should be noted that although the PG&E study samples are similar, they are not identical because they did not include assessment of all code requirements, but they did focus on most of the requirements that have significant energy weights in the HIE metric. To correct for this limitation we reduced the maximum score of the PG&E sample. For the same scope of changeout, particularly for the inland region, the total compliance score is lower as there were fewer requirements assessed during the onsite inspections. All of the reporting is presented with and without the added sample points to ensure the added data are not biasing the results.

The PG&E study included AC changeouts and focused more in Southern California, while HVAC6 had some heating only changeouts from the entire coast that appear to have higher electric HIE scores. We primarily want to compare permitted and non-permitted and given our lack of statistical significance for certain analysis groups we moved forward with looking at combined samples.

It is important to keep in mind the “energy scores” are effectively performance index ratings and do not represent quantified energy saving values. Each installation site has a maximum possible score based on the climate zone and project scope for the replacement type, and the maximum potential score for any site is 900. For example, a full system changeout in the hottest inland climate zone (15) has the maximum potential score of 900. Conversely, a component-only changeout in the cooler coastal climate zone (3) has the minimum potential score of 30.

The index scores were developed using estimates of how much annual electric energy is saved in the changeouts based on the energy code requirements with variation by CZ. These estimates come from multiple sources and were chosen to show the relative energy impacts of different measures in different CZs.[9] In addition, sites that replace full systems during the changeout (e.g., replace furnace, AC, and ducts) or that are in hotter climates have a higher potential score.

[9] Estimates come from DEER and Case reports with adjustments to normalize between the different software and assumptions used. The current values are the best available estimate and when the CPUC and CEC have better estimates in the future those estimates should replace those used in this analysis.

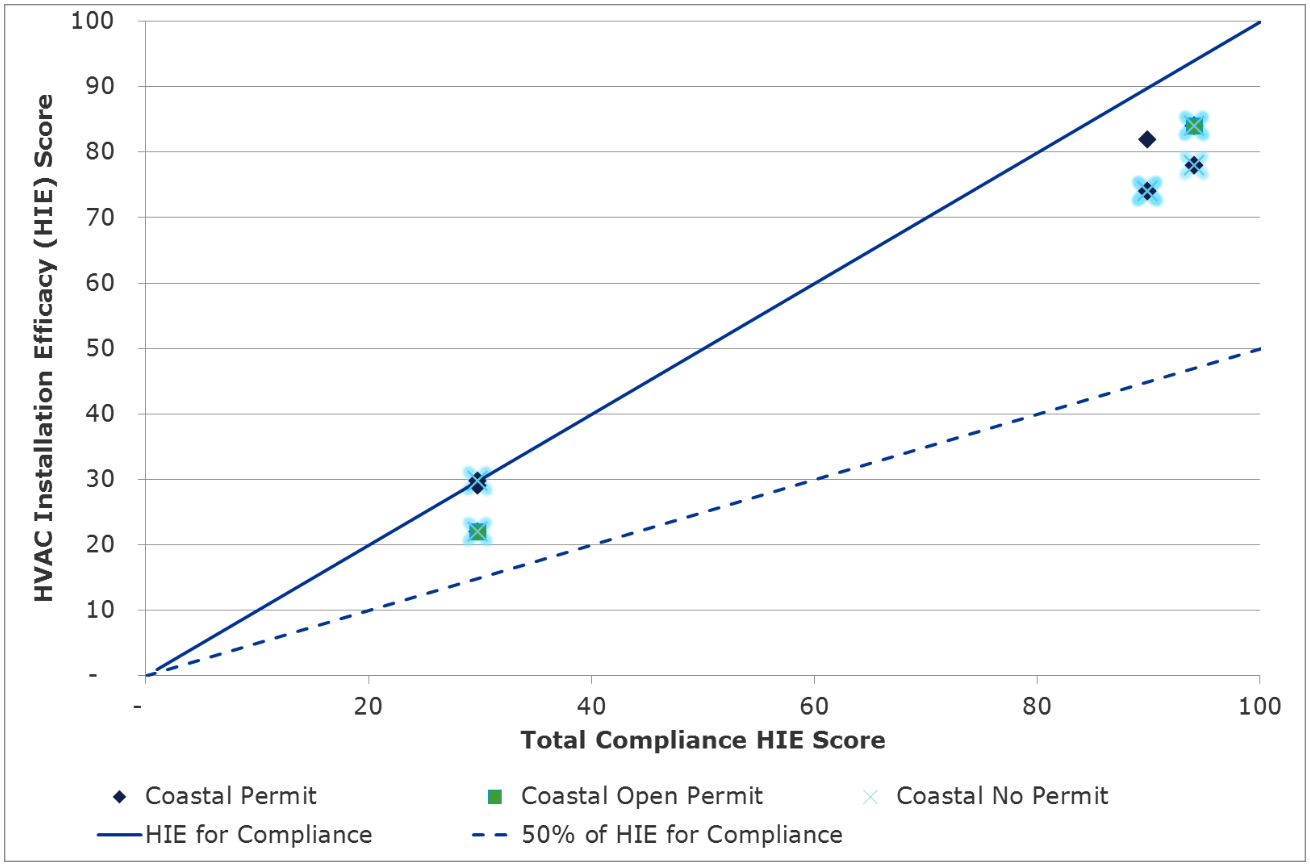
The figures display one data point per changeout, with different colors and symbols distinguishing permitted and non-permitted. These figures also show open permits that are treated as a unique category given they may have initiated permits, but may not have completed HERS verification testing and thus compliance rates may differ from that of completed permits.

If a site partially meets the requirements, then they are some number below a perfect energy score. If a changeout is 100% compliant, that sample point would fall directly on the "Total Compliance" line (the blue line in the figures below). By applying this method, we have an estimate of the level of compliance (how far below 100% compliance the sample is) and effectively we have a relative estimate of how much savings is being lost (or energy wasted) by failing to meet code requirements. The figures also include a dashed line indicating 50% compliance for reference. See the methodology memo in Appendix A for discussion on how these underlying scores were developed and their limitations.

Given the wide variance for the total compliance scores by region, we present the results by climate regions. Figure 7 shows the coastal region (CPUC sample) HIE score. We do not present a figure for coastal compliance scores for both CPUC and PG&E due to the limited PG&E samples (approximately five), and the results overlapped making it difficult to distinguish the results for the two sample sets.

As the figure below shows, most of the coastal sites for the CPUC changeout only are well above 50% compliance and most are near the 100% line, but only a few are totally compliant. There is not a strong pattern between permitted and non-permitted groups.

Figure 7. Electric HVAC installation efficacy (HIE) scores for the coastal CPUC changeout sample



For the inland region, we present two figures. Figure 8 shows the installation efficacy score distribution of CPUC changeouts without the PG&E study sample points added.

Figure 9 shows the same compliance score distribution with the PG&E study sample, which had approximately 40 additional changeouts. As the figures show, there are many sites between 50% and 100% compliance with a few at 100% and a few below 50%. There is no distinct pattern based on permit status. The permitted changeouts appear to be above the non-permitted for some cases, but not others. It is clear the sample size for non-permitted changeouts is much larger than permitted and open permit changeouts.

Figure 8. Electric HVAC installation efficacy (HIE) scores for the inland CPUC changeout sample

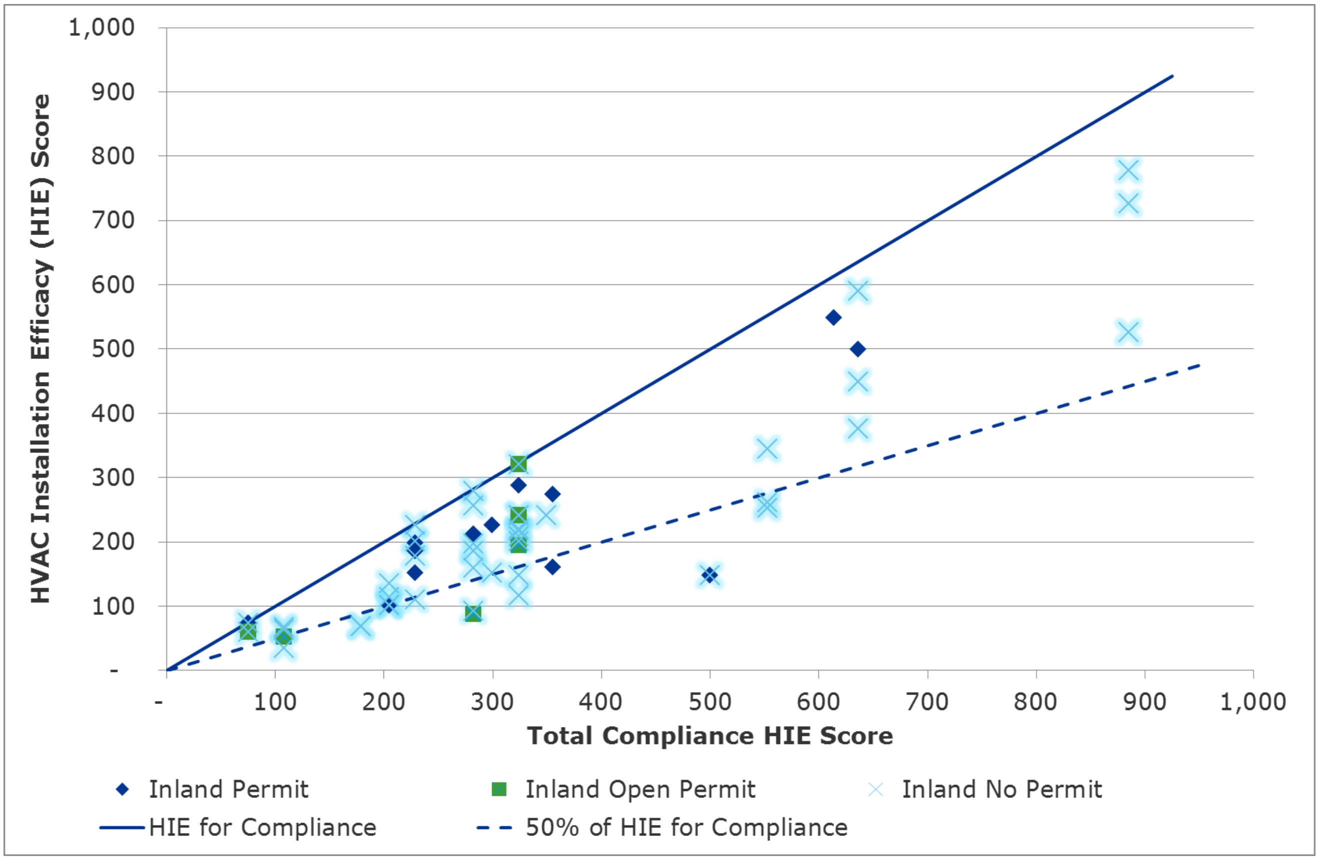


Figure 9. Electric HVAC installation efficacy (HIE) scores for the inland CPUC changeout and PG&E sample

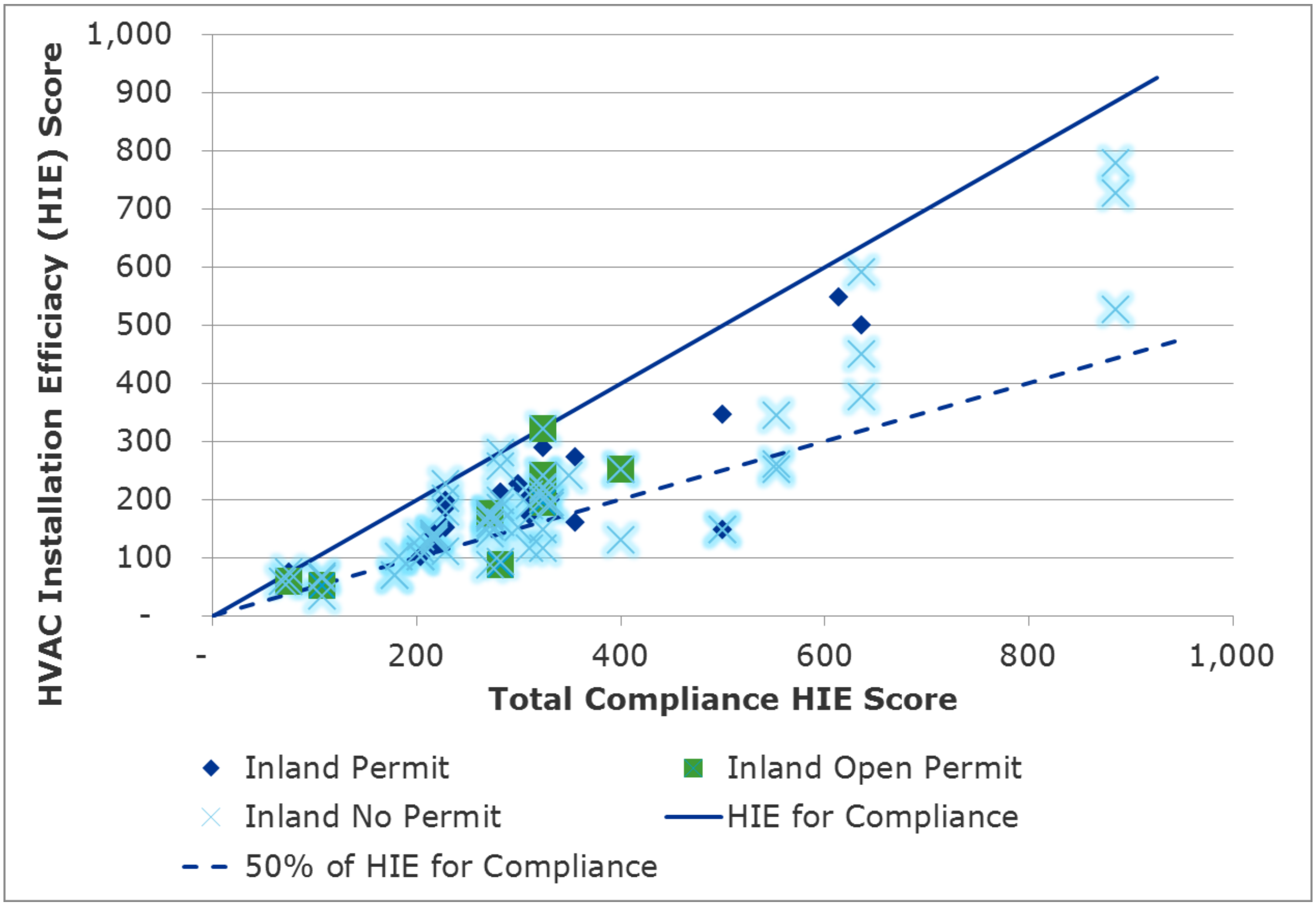
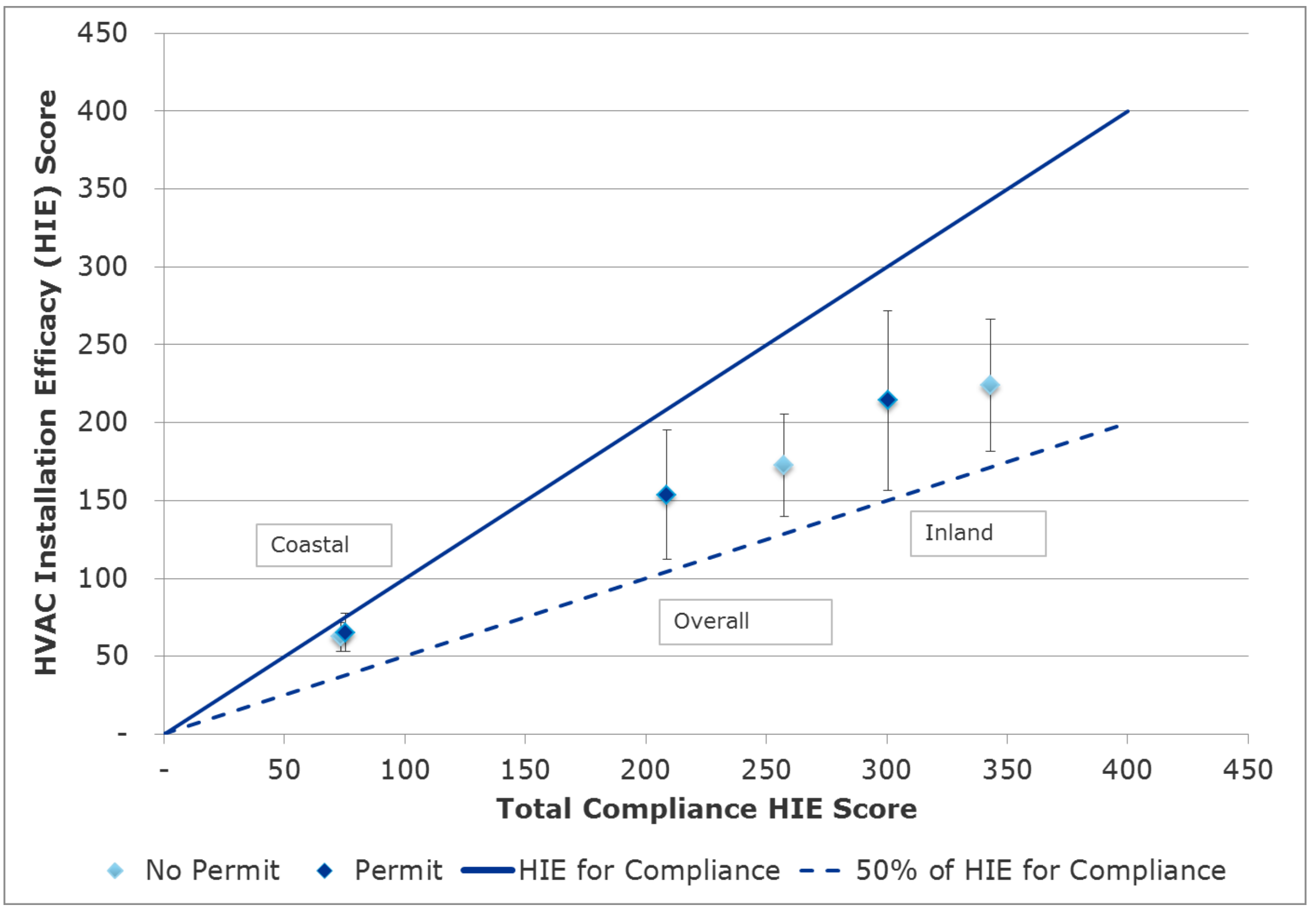


Figure 10 displays a plot with average compliance for permitted and non-permitted changeouts by region as well as overall. The bars display the error bounds of the estimated compliance rate across changeouts for each group. For inland changeouts and overall there was a significant margin between the estimated compliance and 100% compliance. Clearly inland changeouts are not meeting requirements, but there is not a statistically significant difference between permitted and non-permitted. The much larger sample for non-permitted included more changeouts in the hottest inland climate zones as well as more system changeouts as opposed to component changeouts. This led to the average total compliance energy score being different for the two groups. Note the non-permitted averages are consistently to the right of the permitted averages. The previous Table 14 shows the compliance percentage that normalizes this difference.

Figure 10. Average values for HVAC installation efficacy (HIE) scores with error bounds



Given the PG&E permit study focused on air conditioner changeouts (and not total system changeouts); there were several additional inland sample points available. We looked at all of the same results including the PG&E results as points. We do acknowledge a lack of information on some compliance measures, but the ones with greatest impact were measured, and thus results seem valid enough to review both in comparison and in aggregate. We primarily want to compare permitted and non-permitted and given our lack of statistical significance for certain analysis groups we moved forward with looking at combined samples.

Comparing Figure 10 (with PG&E sample points) shows a minimal difference for inland, but shows less compliance for the coastal region in both permitted and non-permitted sites. The PG&E study included AC changeouts and focused more in Southern California, while HVAC6 had some heating only changeouts from the entire coast that appear to be more compliant for electric scores.

Figure 11. Combined HVAC6 and PG&E average HVAC installation efficacy (HIE) score with error bounds

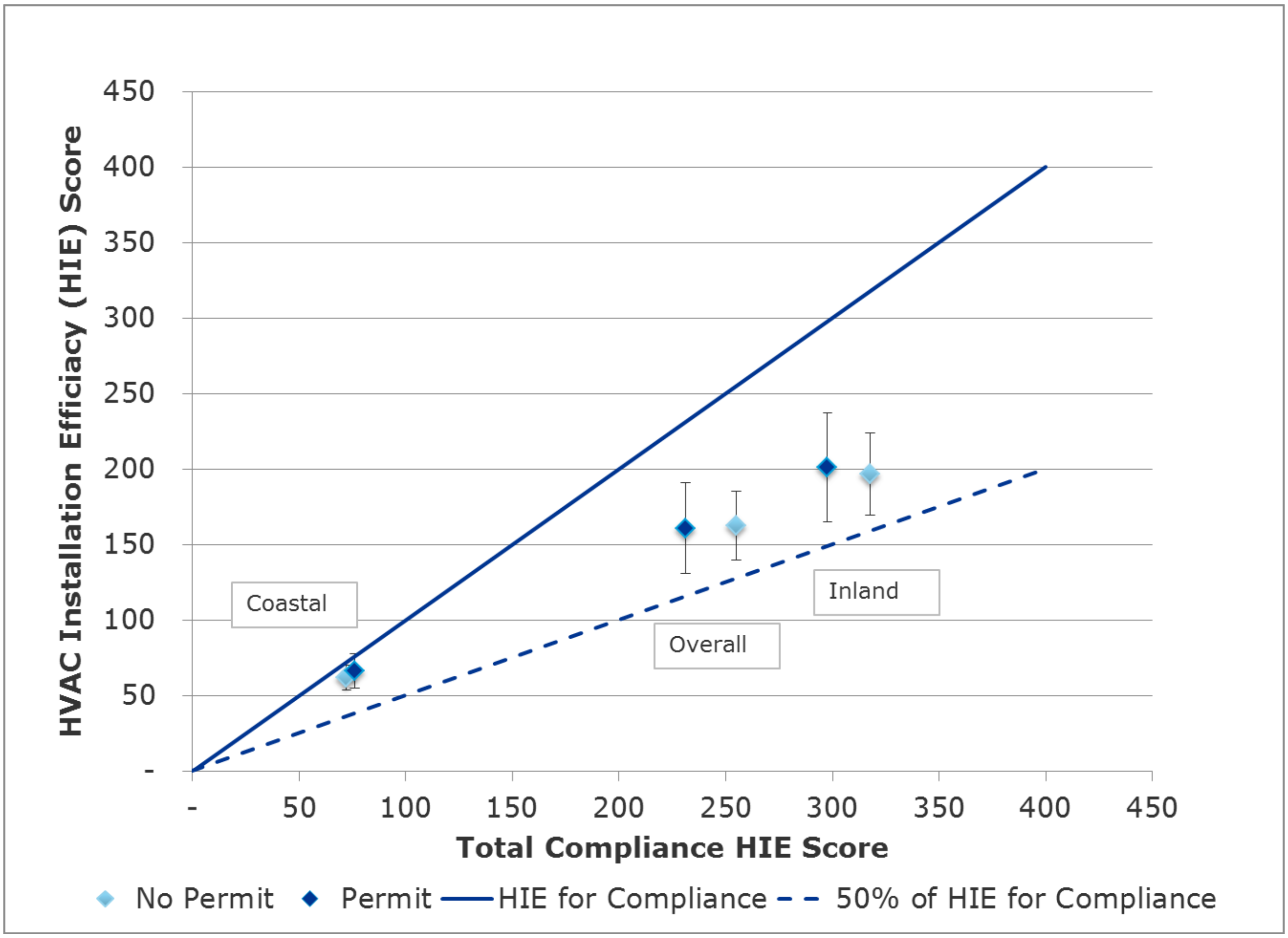


Table 14 provides a summary of the electric energy compliance results with estimates, error bounds, and a test of statistical significance between permitted and non-permitted installation efficacy. The trends are similar to measure compliance with a larger difference for inland than coastal. However the lower bound for permitted estimate overlaps the upper bound for the non-permitted estimate and therefore there is not a statistically significant difference.

Table 14. Electric HVAC installation efficacy (HIE) rates and significance testing for CPUC sample

Region	Group	Sample Size	Electric HIE Rate	Error Bound (90% CI)	Significant Difference
Coastal	Permit	9	87%	+-4%	**No**
	No permit	21	85%	+-3%	
Inland	Permit	17	71%	+-8%	**No**
	No permit	43	65%	+-5%	
Total	**Permit**	**26**	**74%**	**+-6%**	**No**
	No permit	**64**	**67%**	**+-4%**	

Table 15 shows a minimal difference in installation efficacy rates and error bounds. The results still do not achieve statistically significant differences statewide or for the coastal region, but a difference is detected for inland changeouts. The difference remains much lower for installation efficacy with requirement weights than for measure compliance without requirement weights as described in Section 4. Overall precisions are improved. A statistically significant difference was achieved by adding the PG&E sample. The difference in compliance for permitted and non-permitted changeouts in the inland region remains small and not statistically significant.

Table 15. Electric HVAC installation efficacy (HIE) rates with PG&E study sample added and significance testing

Region	Group	Sample Size	Electric HIE Rate	Error Bound (90% CI)	Significant Difference
Coastal	Permit	12	87%	+-3%	**No**
	No permit	24	86%	+-3%	
Inland	Permit	28	68%	+-5%	**No**
	No permit	70	62%	+-3%	
Total	**Permit**	**40**	**70%**	**+-4%**	**No**
	No permit	**94**	**64%**	**+-3%**	

Table 16provides a summary of the gas installation efficacy results with estimates, error bounds, and a test of statistical significance between permitted and non-permitted changeouts. The compliance rates initially appear to be much different than measure level or for electric, but also note the error bounds are larger in all cases primarily because fewer measures have gas savings. We chose not to plot the gas results given the relatively larger error bounds making for difficult comparisons between permitted and non-permitted changeouts. Essentially for gas there were more extreme cases of high and low installation efficacy. So for the same sample size as electric requirements the error bounds are two to six times larger. A much larger sample may be needed to determine the true average gas compliance if further study produces similar findings.

Table 16. Gas HVAC installation efficacy (HIE) rates and significance testing for CPUC sample

Region	Group	Sample Size	Gas HIE Rate	Error Bound (90% CI)	Significant Difference
Coastal	Permit	9	55%	+-31%	**No**
	No permit	21	52%	+-21%	
Inland	Permit	17	79%	+-18%	**No**
	No permit	43	62%	+-12%	
Total	**Permit**	**26**	**77%**	**+-17%**	**No**
	No permit	**64**	**62%**	**+-10%**	

Comparing Table 16 (without PG&E study sample points) with Table 17below shows more substantial difference in installation efficacy rates by adding the PG&E study sample and some reduction to error bounds. The estimates and error bounds changed but the results still do not achieve statistically significant differences. Gas installation efficacy results remain much more variable and uncertain than electric installation efficacy results.

Table 17. Gas HVAC installation efficacy (HIE) rates with PG&E study sample added and significance testing

Region	Group	Sample Size	gas HIE Rate	Error Bound (90% CI)	Significant Difference
Coastal	Permit	12	55%	+-18%	**No**
	No permit	24	55%	+-13%	
Inland	Permit	28	85%	+-8%	**No**
	No permit	70	71%	+-7%	
Total	**Permit**	**40**	**84%**	**+-9%**	**No**
	No permit	**94**	**70%**	**+-6%**	

6 PRELIMINARY FINDINGS

This memo provides initial findings using two distinct metrics. The initial takeaways based on each metric are as follows:

1. **Requirement-level compliance:** Mandatory requirements (Title 24 mandatory measures) have high compliance rates across permit status, installation types, and regions. Increasing the permit rate will not likely amount to a major change in compliance since non-permitted changeouts have a high compliance rate for mandatory requirements. For prescriptive measures, which are dependent on climate zones, compliance rates are lower for both permitted and non-permitted changeouts. Sample sizes for some requirements are small as expected in the research planning. Also, due to the low permitting rate, the small samples for the permitted cases are currently not large enough to achieve good statistical precision. DNV GL will address this gap, balancing the samples of permit to non-permit sample points and in phase two of the research we will sample permitted cases from building department permit data and HERS certificate data.
2. HVAC installation efficacy**:** The same findings regarding sample sizes for permitted holds true for this metric as well. Also holding true with the fact that mandatory requirements are being met, there is relatively high compliance for coastal region changeouts for both permitted and non-permitted groups. Based on the partial results there is not a statically significant difference in installation efficacy between inland region permitted and non-permitted changeouts. That is the average score for non-permitted changeouts are closer to average score for permitted than expected. The additional phase two samples should provide enough sample to reduce the error bounds of the permitted scores which is the smaller, but more measureable population. The study is also adding analyses to assess the extent of bias in the non-permitted sample and added case studies that may be useful to gain additional insights into the un-sampled subpopulation. .

Ultimately, conclusions cannot be drawn from these partial results. There are two broad indications the current estimates may be pointing toward:

- First, most changeouts are not being permitted and are meeting some, but not all of the compliance requirements. For permitted changeouts there may be an opportunity to improve compliance for prescriptive requirements applicable to inland climate zones and installation efficacy scores. For both inland and coastal climate regions, there is an opportunity to improve compliance with certain requirements and improve overall installation efficacy scores.
- Second, based on HVAC installation efficacy there is less of a distinction in between permitted and non-permitted changeouts than generally assumed in the absence of field data. While there is some difference in for inland region changeouts, there is not yet enough samples to show a significant difference for installation efficacy.

The study indirectly provides additional information on permitting, but larger efforts in this study are being used to develop a more rigorous estimate of the permitting rate as described in the research plan.[10] The bottom-up and top-down permit rate estimates are still being developed.

The number of permitted changeouts was compared across several subgroups, (climate region, code cycle, utility, and system type). Thus far, there is little indication of meaningful variation across the subgroups evaluated. Given the permitted changeout sample sizes in this evaluation, it is unlikely the differences are statistically significant. These metrics will continue to be tracked as the Phase two effort adds additional sample, especially of permitted changeouts.

Since this is an interim findings memo we have not developed strong recommendations based on findings as they are subject to change.

[10] http://www.energydataweb.com/cpucFiles/pdaDocs/1239/HVAC%20WO6%20Final%20MAPC%20Research%20Plan_25Feb2015.pdf

APPENDIX A: Proposed Methodology for Measuring Partial Compliance with Residential HVAC Changeout Code

Memo to:
CPUC Energy Division Staff and Advisors

Memo No.: 1
From: HVAC 6 Team at DNV GL
Date: 7/31/2015

Copied to:
Stakeholders

Subject: A Proposed Methodology for Measuring Partial Compliance with Residential HVAC Changeout Code

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.[11]

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[12].

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

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

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 changeouts based on the onsite inspections as described in the research plan[13]. 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.

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

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[14]. As described by the U.S. D.O.E., Building Energy Codes Program, compliance approach options are a: (a) 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.

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

Table 18 and Table 19 show the measures and metrics for prescriptive-level compliance. Table 18 applies to complete system changeouts and Table 19 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.

Table 18 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*

Requirement	Applicability	Threshold	DEER/CASE Energy Impact
Refrigerant Charge	Prescriptive, CZ 2, and CZ's 8-15.	Diagnostic within tolerance of target	Yes
Airflow	Prescriptive, CZ 10-15	350 CFM per ton	Yes
Fan Watt Draw	Prescriptive, CZ 10-15	<0.58 W per CFM	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.

Table 19: 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 Table 18 and Table 19 —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:

1. **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.
2. **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:

1. **The DEER (Database for Energy Efficient Resources[15])**: 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.
2. **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.
3. **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.

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

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.

Table 20 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 table 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.

Table 20: Comparison of DEER and CASE Savings for Duct Sealing to Inform Adjustment

	Electric Savings, kWh			Gas Savings, therms		
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, therms**		**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. After the example, tables are shown that expand those draft tables to show weights that will be used for changeouts in different climate zones.

This example table 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 watt draw is more limited. We have not set all thresholds in this memo since the focus was on the weights.

Table 21: 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 Watt Draw (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%**

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.

Table 22 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. Table 23 shows the partial compliance weights for single-family residential furnace changeouts. The format is the same as Table 18. The primary difference is the weights are in therms, not kWh.

Table 22: 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 Watt Draw	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**	**10**	**30**	**76**	**24**	**90**	**94**	**205**	**32**	**355**	**476**	**300**	**553**	**614**	**885**	**179**

		8							4							

Table 23: Gas Furnace Replacement Partial Compliance Weights for Single Family Residences

Requirement	Source	CZ 1	CZ2	CZ 3	CZ 4	CZ 5	CZ 6	CZ 7	CZ 8	CZ 9	CZ1 0	CZ1 1	CZ1 2	CZ1 3	CZ1 4	CZ1 5	CZ1 6
Minimum Efficiency	**DEER 2011**	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Load Calculations	**No Direct Savings**	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Programmabl e 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 Estimat e**	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Fan Watt Draw	**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		**1.1**	**15.**	**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**

Requirements		**7**														
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. The overall sample also includes case-weights based on the size of the population of air conditioners or furnaces in a climate zone. Some of the climate zones with lower potential savings on a site basis may be in highly populated areas which would mean they have larger case-weights. Nominal compliance will use the same case-weights to expand from site-level sample to the population. As constructed, reporting these two 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.

1. **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%
2. **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.
3. **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.

Table 24: 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	Requirement-level Compliance Relative Precision at 90% Confidence Interval
Load Calculations (M)	200	X%	+/- y%
Measurement Access (P)	120	X%	+/- y%
Minimum Efficiency (M)	200	X%	+/- y%
Programmable Thermostat (M)	200	X%	+/- y%
Duct Insulation (M)	200	X%	+/- y%
Refrigerant Charge (P)	100	X%	+/- y%
Airflow (P)	80	X%	+/- y%
Fan Watt Draw (P)	80	X%	+/- y%
Additional Duct Insulation (P)	80	X%	+/- y%
Duct Sealing (P)	90	X%	+/- y%
Measure Compliance = Average Requirement Level Compliance	200	**X%**	+/- y%
Energy Savings Compliance = Sum of Score / Sum of Weights	200	**X%**	+/- y%

A mock-up of the additional types of where energy potential compliance is used is shown below.

Table 25: 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%
Central Valley	60	X%	+/- y%
Desert/Mountain	20	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.

References

Title of Document	Web Link	Res/Non-Res	Measure Details
Residential Ducts – Duct Sealing, Cooling Coil Airflow, Fan Watt Draw, 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 Watt Draw 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
"Revisions to the Residential ACM Calculations," presented by Bruce	http://www.energy.ca.gov/title24/2008standards/prerulemaking/documents/2007-06-13-	Res	Residential ACM

Wilcox, 2007-06-15	15 workshop/presentations/Wilcox070615b1.pdf		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
"Furnace Fan Watt Draw and Airflow in Cooling Mode," and "Air Conditioner Airflow, Refrigerant	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 Watt Draw and

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			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
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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 Watt Draw 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 Watt Draw and Airflow in Cooling and Air Distribution Modes
Measure Information Template – "Air Conditioner Airflow, Refrigerant Charge and TXVS – Multi-Zone	http://www.energy.ca.gov/title24/2008standards/prerulemaking/documents/2006-07-12_workshop/reviewdocs/MULTI-ZONE_AIRFLOW_OVERVIEW.PDF	Res	Air Conditioner Airflow, Refrigerant

Airflow Overview," based on field tests by Chitwood Energy Management and Robert Morris and Associates, 2005-09-21			Charge and TXVS
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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
"Revision to the Residential ACM Calculation for Furnace Fan	http://www.energy.ca.gov/title24/2008standards/prerulemaking/documents/2006-03-28_workshop/2006-03-28_FURNACE_FAN.PDF	Res	Residential ACM

Modeling," presentation by Ken Nittler and Bruce Wilcox, 2006-03-28			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
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"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
"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 B. ONSITE DATA COLLECTION INTRUMENT

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 replaced?	Yes No
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.	$n = \dfrac{\ln\left(\frac{Q_{50}}{Q_{25}}\right)}{\ln\left(\frac{P_{50}}{P_{25}}\right)}$
Notes:		

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. <u>Total wall area to ambient (all four orientations; exclude wall to garage)</u>
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 C. ONSITE TESTING PROTOCOL

6.1 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.

6.2 Airflow Testing Protocol

6.2.1 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).

6.2.2 True Flow Test Procedure

Perform the True Flow test as follows:

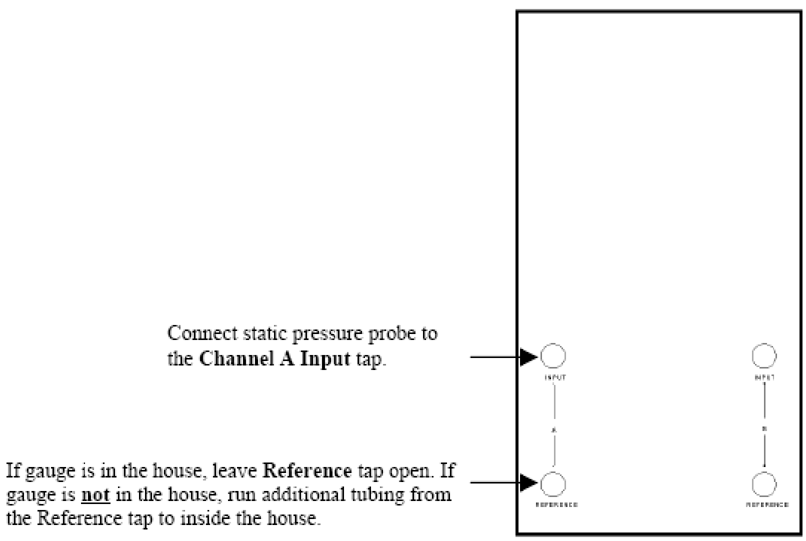
1. Record External Static Pressure (static pressure across unit):
    a. Turn the system on and let it run for fifteen minutes to reach equilibrium (fifteen minutes should yield a wet evaporator coil).
    b. Once the system has reached equilibrium, record the static pressure. With the system running, 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.

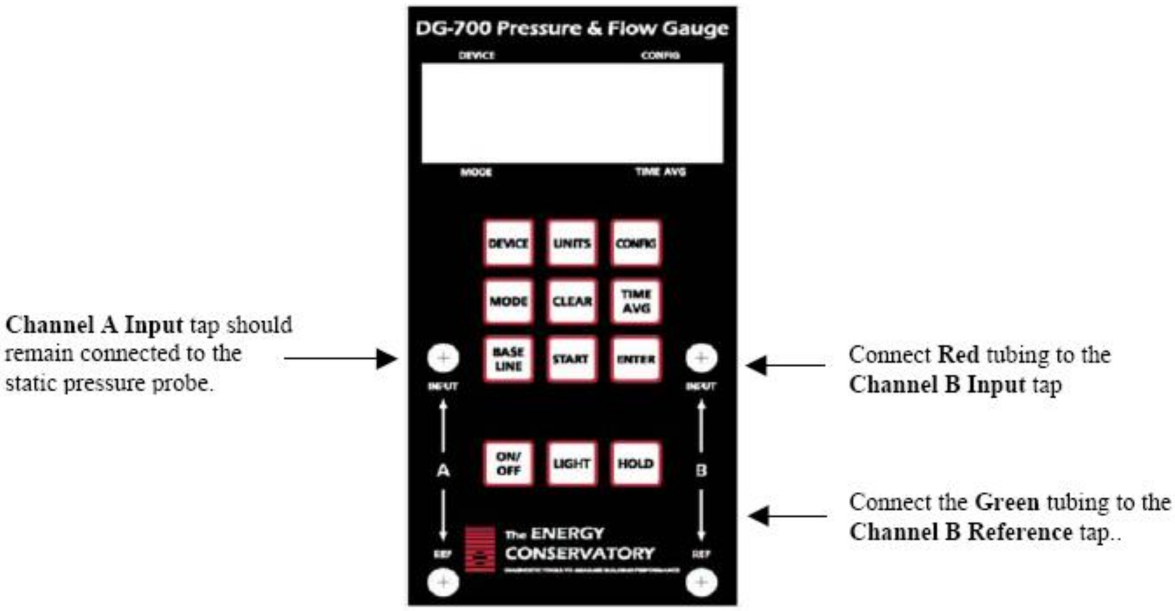
The NSOP value is now stored in the gauge. On Channel B, ADJ should appear in the window. In the next test the gauge will calculate the Adjusted CFM for you. **DO NOT wait until the system is turned off to press enter. Note that if unable to run a tube from the second pressure tab into the building, 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.

6.3 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.

6.3.1 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.

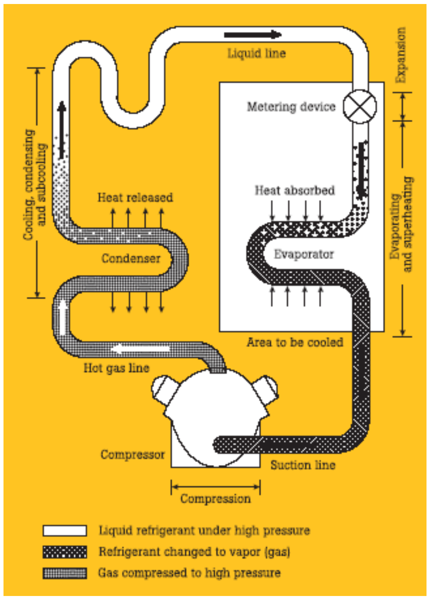
5. Photograph condenser coils, unit location, Schrader valves. Note any damage. For split systems, measure and record the diameter of the suction line and the thickness of insulation on the suction line between condensing unit and structure. Also make a note if there is no insulation or if the insulation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

6.4 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.

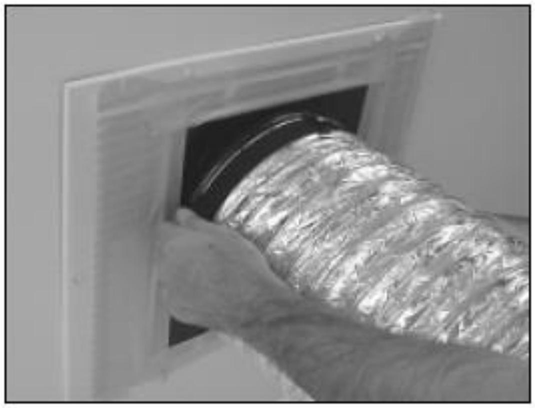
8. Remove the Micro Station logger from the return plenum or register.

6.4.1 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.

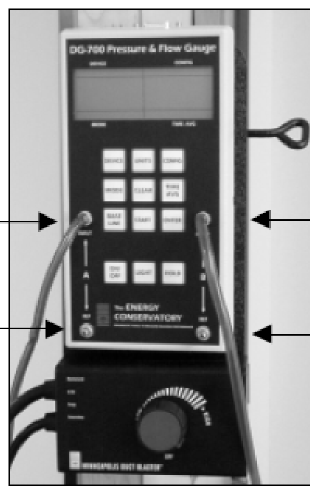
3. Install the duct blaster at the duct system at the central return or air handler cabinet (the return will be the most common installation). In the case of multiple returns, seal off the smallest returns and use the largest return for the test.



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. **Connec**t 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.

6.5 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 6.7 (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.

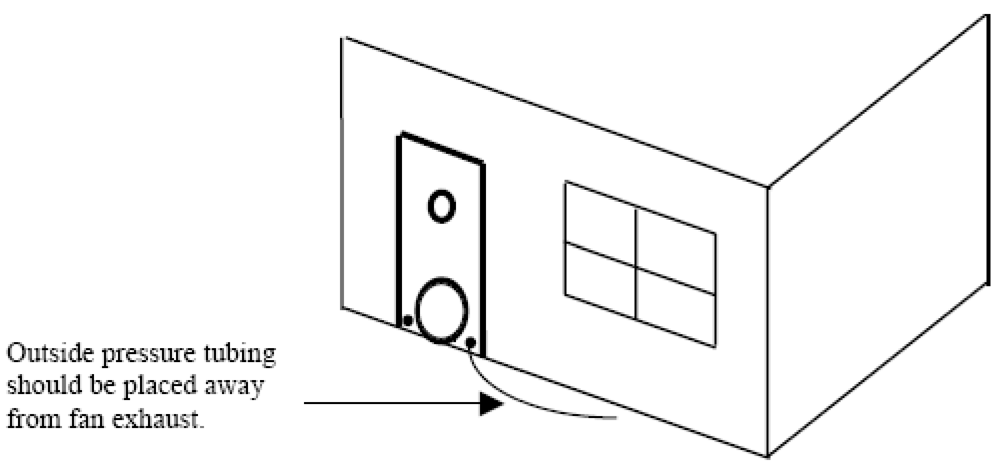
While good judgment is expected, the leakage-to-outside test is not optional. It’s merely unnecessary if the outcome of the test appears clear to the team leader. If you have any doubt about whether to run the leakage-to-outside test, run it.

6.6 Infiltration and Duct Leakage-To-Outside Testing Protocol

6.6.1 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

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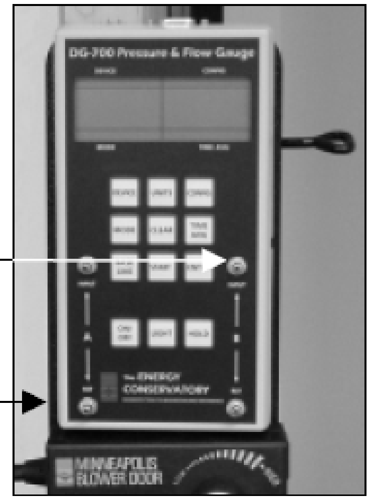
18. Connect the Red pressure tubing to the Channel B Input Tap and connect the other end to the pressure tap located on the blower door fan.

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.***

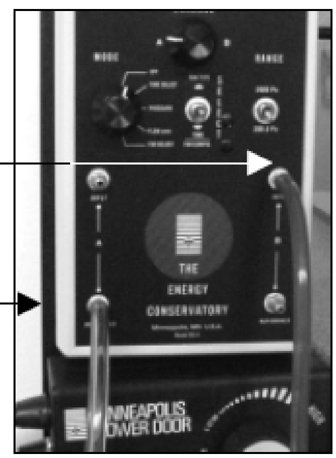
Connect the **Green** tubing to the Channel A Reference tap. ***Channel A is used to measure building pressure with reference to outside.***



3.5.b DG-3 Gauge:

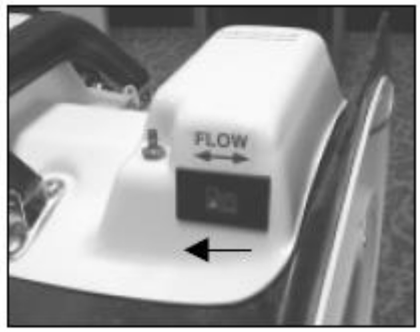
Connect the **Red** tubing to the Channel B Input tap. ***Channel B is used to measure Fan pressure and flow.***

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.



6.6.2 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.)

6.6.3 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 ∆P you measure when checking the flow exponent. For example, if the house gets to –48 Pa for the high ∆P, use this as the P50 in the equation. If the flow exponent is not between 0.50 and 0.75, repeat the test.

6.7 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.

6.7.1 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

6.7.2 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

APPEMDIX D: ONSITE TESTING RESULTS

The small sample sizes that were studied in this evaluation along with the significant potential for self-selection bias cause the reliability of the results to be low, which likely precludes the validity to draw conclusions or apply to a larger population. Even so, the evaluators determined measure compliance rates for the data set that was obtained. These should not be perceived as valid for drawing conclusions or applying to any larger population.

This section focuses on the results for the key measured parameters of refrigerant charge, airflow, fan watt draw, duct insulation, and duct leakage. Table D-1**Error! Reference source not found.** reflects the results of onsite testing for refrigerant charge. The deviation between the measured value and superheat or sub cooling target were used to develop a scale that applies to all units tested. The first phase completed relatively small sample sizes for refrigerant charge and the finding that non-permitted passed more tests for the small samples cannot be generally applied. Note there were two changeouts with open permits that both passed the refrigerant charge test.[16]

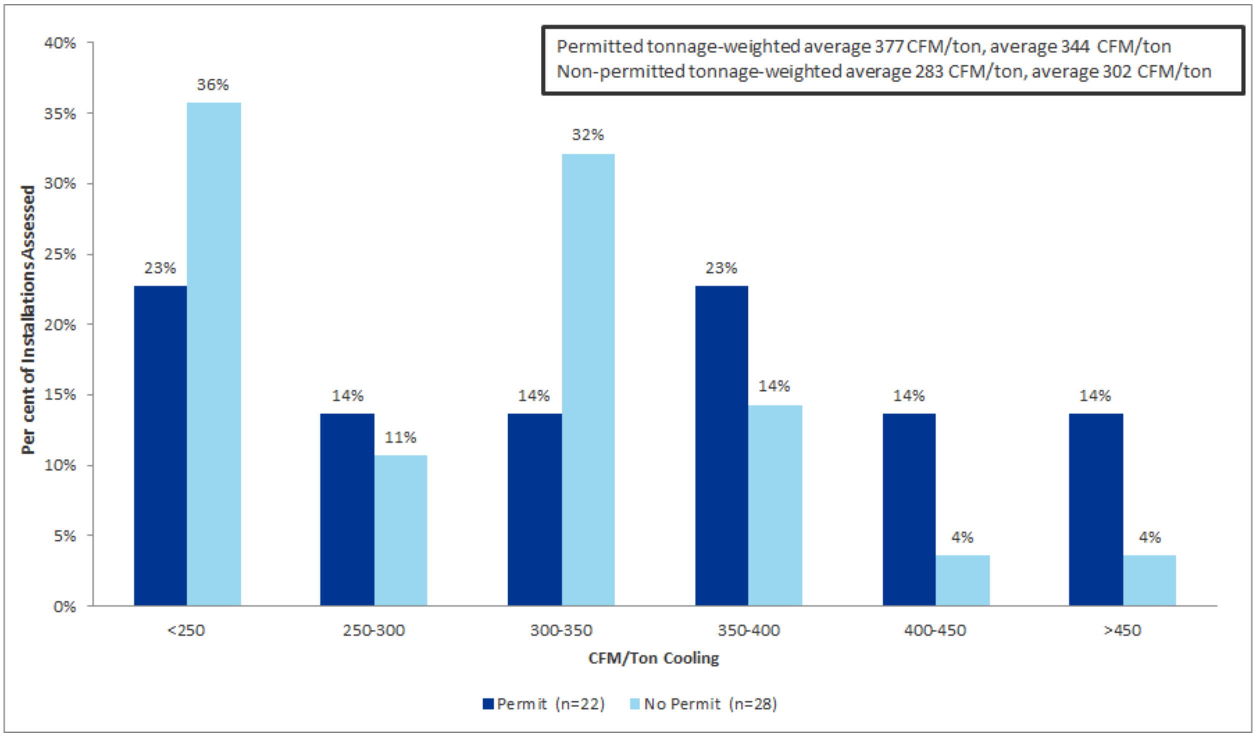
Table D-1. Refrigerant charge diagnostic deviation

Charge Disposition	Permit	No Permit	Total
Pass (+/- 5^{o}F)	4	12	**16**
Fail (+/- 5-10^{o}F)	6	2	**8**
Fail (> +/- 10^{o}F)	5	3	**8**
Total	**15**	**17**	**32**

For airflow measurements, Table 8 shows results for complete system replacements where this measure is applicable. Data were collected on many more sites which are presented in Figure D-1**Error! Reference source not found.**, which shows airflow results for permitted vs. non-permitted changeouts. The distributions illustrate that non-permitted changeouts tend toward lower airflow than do permitted changeouts. Half of the permitted systems (11 out of 22) had airflow greater than the required 350 CFM/ton, while only about one-quarter of the non-permitted systems met this compliance threshold.

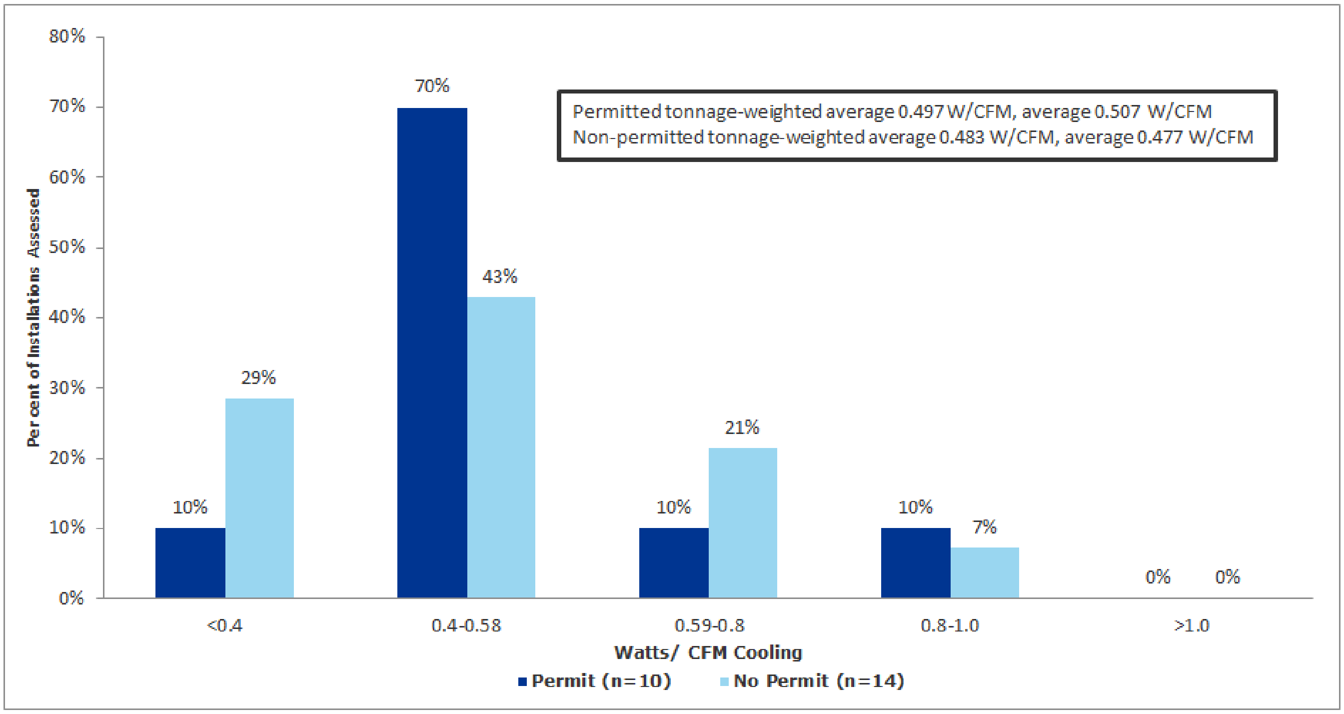
[16] Approaches to refrigerant charge testing, pg. 31
http://www.energydataweb.com/cpucFiles/pdaDocs/1239/HVAC%20WO6%20Final%20MAPC%20Research%20Plan_25Feb2015.pdf

Figure D-1. Distribution of airflow-per-ton by permit status



For fan power measurements, Table 9 shows results for complete system replacements where this measure is applicable. Data were collected on many more sites which are presented in Figure D-2. This figure**Error! Reference source not found.** shows the distribution of fan power results for permitted vs. non-permitted changeouts. Permitted changeouts had a higher pass rate than non-permitted changeouts relative to meeting the criteria of fan watt-draw less than 0.58 W/CFM.

Figure D-2. Distribution of fan watt-draw per CFM by permit status



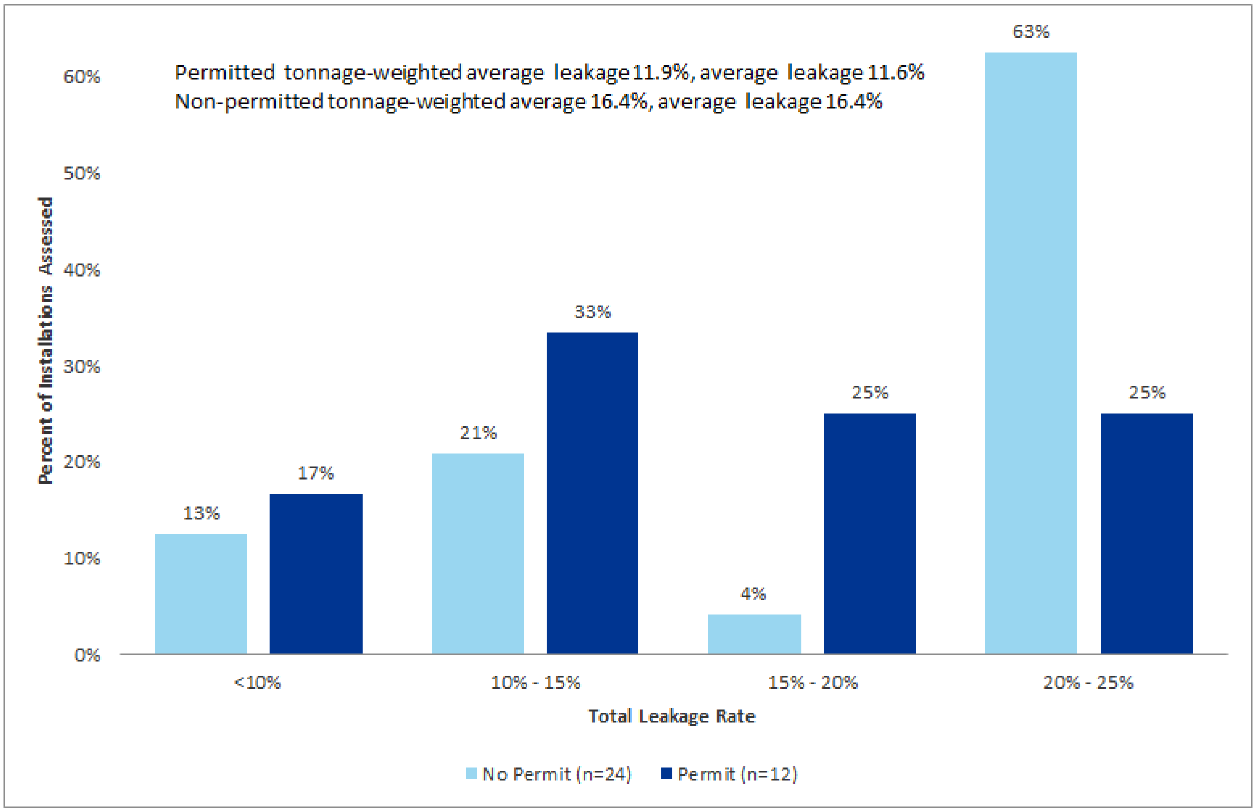
The mandatory measure for duct insulation is only reported under requirement level compliance, but some climate zones require additional duct insulation for system changeouts. Additional duct insulation means that more than R-4.2 is required. The requirement is R-6 in many climate zones and R-8 in the most extreme hot and cold climates. Table D-2**Error! Reference source not found.** compares the frequency of units that met or partially met the additional duct insulation requirements.

Table D-2. Additional duct insulation

Duct Insulation	Permit	No Permit	Total
Pass (R-6 to 8)	5	13	**18**
Fail (Some Additional)	6	12	**18**
Fail (No Additional)	3	3	**6**
Total	**14**	**28**	**42**

Figure D-3**Error! Reference source not found.** illustrates the distribution of total duct leakage in intervals of 5% from <10% leakage to >20% leakage. The data reflects the applicable Title 24 code cycle, units subject to the 2013 code in all climate zones are included, but only units in CZs 2 and 9-15 are presented for the 2008 code.

Figure D-3. Total duct leakage rate



APPENDIX E. DIRECT RESPONSES TO PUBLIC COMMENTS

Direct Responses to Public Comments

Comment from Mark Meyers

Comment: "This study seams terribly flawed based on my experiences as a building official. Last year we found lots of systems replaced without permits of those not a single one was installed to the minimum code standards with out of date equipment not meeting minimum efficiencies to extremely poor quality installation that would have exceeded 20 % leakage. There were cases that were so egregious that we turned them over to CSLB and they did a great job of going after these licensed contractors that had performed the work. All were installed by CSLB contractors but because of the City's "kinder gentler" building department policy only the most egregious of the offenders were turned over to the CSLB. I'll close by saying if the results of this survey are correct then the local building department adds nothing to the compliance of HVAC installation and that all of the corrections written on system installed with a permits must be incorrect or unnecessary, and the unpermitted system were a waste of the local jurisdiction time in perusing, and that the consumer who is a very unsophisticated buyer in this market should be left to the market and they will get what they get".

Response: This comment did not provide the specific flaws other than the results do not agree with the commenter's past experience. We appreciate the information and have several follow-up questions that may inform our study. First, we note, our results did identify non-permitted installations with duct leakage greater than 20% (as did Mr. Meyers). These are *partial* results and there are other supporting tasks of this study and therefore we have not drawn *final* conclusions and request our commenters to do the same. The primary follow-up questions are:

- What is the rate of complaints and CSLB turnovers for the building department in question?
- Are complaints and turn-over to CSLB tracked such that they can be analyzed? These may represent one extreme of the market and final permits are the other extreme with many of the non-permitted in our study falling in the middle.

Comment from CalCERTS, Inc.

Comment1:

Thank you for the opportunity to comment on DNV-GL's Results of HVAC6 Phase One Market Assessment of Residential Permitting and Partial-Compliance (HVAC Assessment) supported by the California Public Utility Commission Energy Division's Evaluation, Measurement, and Verification work. As the Chief Executive Officer of CalCERTS, Inc., a Home Energy Rating Service (HERS) Provider, I am able to offer a unique perspective on DNVGL's HVAC Assessment.

CalCERTS applauds this important effort to assess the value and necessity of obtaining a building permit for the hundreds of thousands of HVAC units that are changed out each year in California. The importance of this study cannot be understated since it affects consumers on health and safety issues (inspected by building departments), and system performance issues (the Building Energy Efficiency Standards are *performance* standards) which are inspected and verified by HERS Raters. This market assessment must be done correctly and accurately to preserve the value of the $1.4 million study cost, and to provide helpful guidance to policy makers going forward. A biased and flawed assessment cannot inform our industry and does not serve the interests of California's ratepayers.

Response1: No response

Comment2:

CalCERTS is an approved HERS Provider for the 2005, 2008, and 2013, California

Building Energy Efficiency Standards, codified under Title 24 of the California Code of Regulations (Title 24). We are dedicated to working with stakeholders in the HVAC industry to improve and promote compliance with Title 24, and all building codes. Each day our *Field Support Team* answers calls and emails from contractors, installers, designers, builders, energy analysts, raters, and homeowners, all striving to comply with Title 24. Our team helps members of the industry work through the complicated nuances that arise when verifying compliance which in turn ensures energy efficiency for new and existing buildings. In addition, our *Quality Assurance Team* has conducted thousands of field reviews to verify the accuracy of our raters, who in turn verify compliance with Title 24. Through our involvement with the industry, we know firsthand that requiring permits and supporting enforcement leads to improved compliance with Title 24. Our experience in the field and on the phone conflicts with the preliminary conclusions espoused by DNV-GL.

Response2:

In Phase 1 only 9 of the 26 permitted cases were identified in the CalCERTS registry. So over half of the permitted and all of the Non-permitted cases would not be a part of the CalCERTS ratings or QA team review. We plan to do a separate analysis of the HERS verified installations from for additional comparison, but we do not expect CalCERTS experience will align with Non-permitted or permitted jobs not in the registry which were 90 of the 99 cases in phase1.

Comment3:

As Title 24 has evolved, HERS Raters have become the experts on compliance. With each code change, HERS Raters learn the new compliance rules and are certified or recertified by an approved HERS Provider. Through this process, we have found that raters are, to a large extent, the ones educating California's builders, contractors, installers, and building officials on the changes to Title 24. Permits facilitate this process and are integral to ensuring that the health and safety, as well as the energy efficiency benefits of Title 24 are realized by California's homeowners. Unpermitted jobs do not benefit from the use of a HERS Rater or Building Inspector. Energy efficiency assessments, health and safety inspections, verification of licensed contractors and installers, and the compilation of information and data to inform energy savings, rebate programs, quality installation, are *all* direct benefits of permitting.

Response3:

The scope of this study is limited and does not include all permitting benefits as energy efficiency is the focus of the CPUC.

Comment4:

Regarding this specific study, there are significant deficiencies within the *HVAC Assessment* and some perceived biases. In DNV-GL's initial proposed study 2) DNV-GL set out to test what it categorized as an "assumption" that permitted HVAC systems are more compliant with Title 24 than non-permitted systems.3) DNV-GL's "rigorous test" of this assumption included no more than 27 permitted units throughout the entire state of California, spanning multiple code cycles. Despite this limitation, in its preliminary conclusions, DNV-GL claims that there is little difference between permitted and non-permitted systems with respect to compliance with Title 24. At best, the preliminary conclusions are questionable and not supported by industry experience. DNV-GL should be asked to detail its methodology for verifying compliance and should address the perceived bias within its study.

Response4:

Phase two is oversampling permitted cases. We are also addressing self-selection bias in the overall study. Conclusions are not drawn from these interim findings. The methodology to evaluate savings was distributed as a separate document (July 2015) that was shared with stakeholders and was included as an Appendices to the phase one memo results. The field data collection methods and calculations are all shown in Appendices in the memo.

Comment5:

DNV-GL approached CalCERTS numerous times, for data to support its study. The requests were ever-changing, inconsistent, and revealed a significant lack of understanding of how compliance with Title 24 is verified. Through the evolution of its requests, DNV-GL appeared to be searching for a methodology to execute its study, rather than seeking data to conduct its study. CalCERTS offered to advise DNV-GL on how compliance forms are processed and verified; however, DNV-GL declined our offer. DNV-GL has not demonstrated the industry specific expertise needed to conduct this study. DNV-GL should be directed to further invite the HVAC industry to comment on DNV-GL's initial research plan and the *HVAC Assessment* so that it can gain the expertise needed to complete its work.

Response5:

Generally the way data requests are full filled to support a study, is we scope what we need to fulfill the evaluation requirements. We contact the supplier and explain our data needs; based on the discussion we refine the request. Once the data is provided we review the data and we may find further data needs arise. We then go back to the supplier and explain the additional needs and the purpose they serve. The approach with the CALCERTS is no different then what we do with any data request. The data requests followed directly from the research plan. CalCERTS was approached numerous times because initial requests were denied. Any changes to the requests were direct reactions to what CalCERTS was willing to provide. CalCERTS was compensated for all data supplied to the study. The offer for further assistance was too limiting to fulfill the study needs. Additional recent data requests have been declined by CalCERTS with no explanation as to why.

In this statement we are specifically asking for additional industry comment.

Comment6 (Footnotes): In support of the above, our raters tell us that most HVAC contractors like to have the rater present at completion of the initial installation. This allows the rater to test the system and tell the contractor what is not in compliance so the contractor can make the appropriate adjustments to bring the system into compliance before leaving the job.

DNV-GL must not be allowed to blame the lack of industry related comments on its proposed study for its poor execution of the *HVAC Assessment*. DNV-GL was ostensibly awarded this contract based on its purported expertise and qualifications and/or its ability to secure the expertise needed to conduct the study.

Response6: Interviews with HERS rater confirm they work closely with contractors and that working too closely with contractors can create conflicts of interest.

From the sample frame we also identified many permitted cases with no HERS verification.

We are not blaming lack of industry comments for study results. We do think questioning methods based on disagreement with results is an issue when the methods were in the public domain for so long. We specifically reached out to the industry via the WHPA over the last year and a half to allow them amble opportunity to scrutinize our approach.

Comment7:

Towards this effort, last week DNV-GL presented the *HVAC Assessment* to the *Western HVAC Performance Alliance* (WHPA) and received tremendous feedback from industry players. This feedback should be considered to advise next steps. Industry expertise is needed to ensure that the findings are accurate, fairly target all relevant practices, and are scientifically defensible. Key terminology and concepts should be vetted and data sources should be identified.

Response7: DNV GL has presented the research plan and a methods memo in the year and a half to the WHPA preceding the release of this memo. All terminology is provided but we did not receive any comments from parties other than the CEC. This memo was available for comment for four weeks to the public.

Comment8:

DNV-GL should not be allowed to forge ahead with this study simply to meet project deadlines since the work being conducted is flawed and will result in erroneous conclusions. CalCERTS recommends that the CPUC direct DNV GL to address the statistical and methodological deficiencies of the *HVAC Assessment* before moving on to Phase Two of the study. We also recommend that the comment period on the *HVAC Assessment* be extended so that stakeholders in the HVAC industry can have time to review the *HVAC Assessment* and have time to provide meaningful comments. The CPUC Energy Division's Evaluation, Measurement, and Verification work is very important to consumers, state energy goals, and the energy efficiency industry. It is imperative that the information gathered to inform future program and policy decisions be correct and complete. We appreciate the opportunity to help ensure that the Energy Division's efforts generate accurate data that is supportable by commonly acceptable scientific principles. Overall, DNV GL's study seems predestined to come to the conclusion that pulling a permit for HVAC installation will not lead to more energy efficiency. Yet having a permit, which triggers a HERS Rater, generates compliance forms that include *exactly* the information needed by the Energy Division to determine the energy savings being achieved through compliant installations for California homeowners.

Response8:

This memo was available from April 11 to May 20 for comment which was already a granted timeline extension. The study is moving forward. What are the flaws? We're unable to address statistical and methodological deficiencies that are not explicitly stated. We have worked with the CEC to outline and address several concerns regarding the presentation of the data.

The information on installations outside of permitting are essential to determine energy savings. Our early findings are that there may be permitted jobs outside of the HERS process. After Phase 2 we will have a much larger sample of permitted installs. The information collected through HERS is valuable, but we met numerous challenges when requesting the data. Ideally we could use the population of HERS data to conduct analysis, but these data were held as being business intelligence and could not be shared. Access to the registry data would allow all stakeholders to improve this study and future studies.